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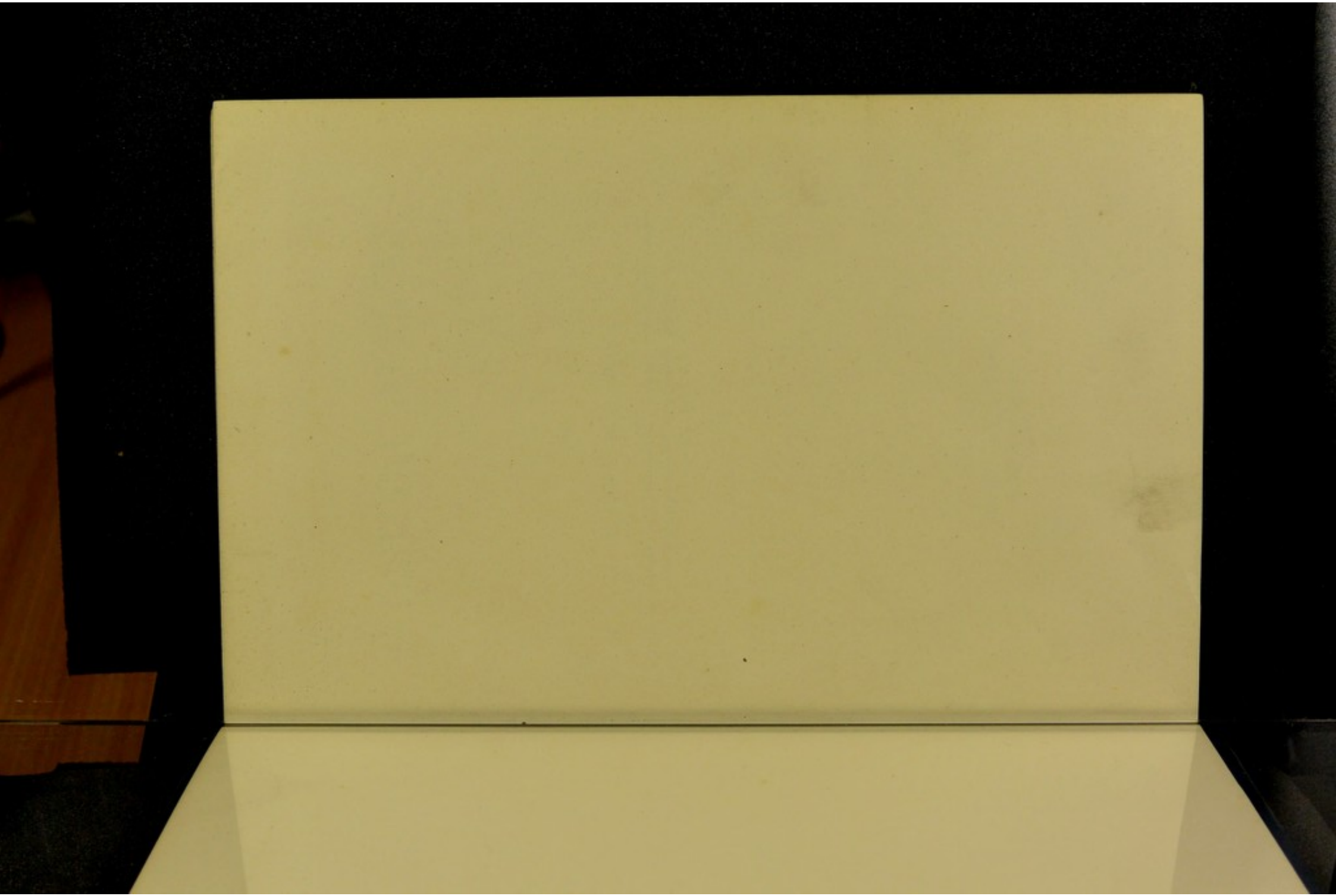

# INTESTINAL SURGERY.

BY

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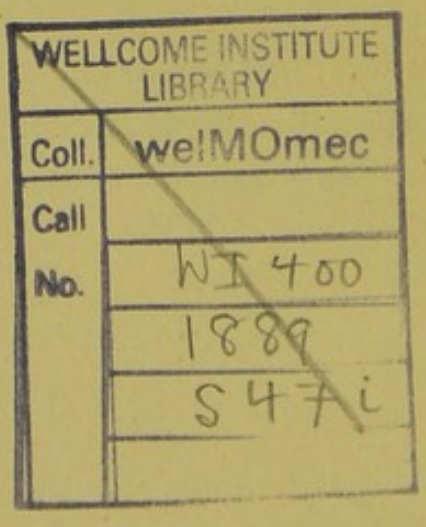

# PREFACE.

There are few subjects in practical surgery on which opinion is more unsettled than on the best method of treating intestinal obstruction and injuries of the gastro-intestinal canal. While the following pages are not intended to serve the purpose of a complete textbook on Intestinal Surgery, still the author hopes that they contain some new facts and suggestions which will prove useful to those who practice this branch of surgery.

The first part of the book contains a résumé of the best literature on the surgical treatment of intestinal obstruction, which has been arranged in a systematic manner for ready reference. The advice given to the surgeon who is confronted by certain anatomico-pathological conditions, is based on clinical experience and the results obtained by experimental investigation.

The second part represents the author's own original work, made with special reference to the surgical treatment of intestinal obstruction, and the diagnosis of perforation of the gastro-intestinal canal; to which is added the report of three cases of gunshot wound of the abdomen, in which inflation with hydrogen gas proved a positive test in making a correct diagnosis, before the abdomen was opened.

One of the principal objects in publishing these papers in book form is a desire to stimulate the young men in our profession to enter the field of original investigation, as the author is firmly convinced that experimental research constitutes the shortest and safest route to the perfection of the principles and practice of intestinal surgery.

N. Senn.

Milwaukee, *December, 1888.*

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# INTESTINAL SURGERY.

## THE SURGICAL TREATMENT OF INTESTINAL OBSTRUCTION.

The operative treatment of intestinal obstruction is in its infancy. Since laparotomy for other indications has become an established and frequently practiced procedure, a number of the bolder and more aggressive surgeons have resorted to direct measures for the relief of intestinal obstruction, but like all serious operations for otherwise incurable and fatal affections its general application has met with strong opposition not only by the laity, but also by the profession. The appalling mortality which has attended the operations in the hands of even the most competent surgeons has been a sufficiently strong argument for non-operative interference.

In this regard the history of laparotomy for intestinal obstruction is only a repetition of the history of ovariotomy. During the early part of the latter, the mortality was so great that the operation was condemned and denounced as a deliberate murder by some of the ablest and most influential surgeons. Yet in spite of all opposition the good work progressed until by an improved technique, and more especially the introduction of antiseptic surgery, ovariotomy in the hands of experts has become one of the safest operations in surgery. To accomplish this hundreds of lives were sacrificed that thousands might be saved. The early ovariotomists operated only on patients worn out by the disease and often the subjects of additional serious visceral lesions caused by the prolonged intra-abdominal pressure, the reason for this being the great mortality which attended the operation. To-day the danger incident to opening the abdominal cavity under proper antiseptic precautions is so slight that patients suffering from ovarian tumors are encouraged to have them removed as soon as their presence can be diagnosticated, at a time when the

general health remains unimpaired, a change of practice which has still further reduced the mortality of ovariotomy. The mortality of laparotomy for acute intestinal obstruction will be reduced to that of other intraperitoneal operations as soon as surgeons will recognize the importance of operating early, before the patient's strength has been wasted by the disease, and before the parts involved in the operation have undergone irreparable textural changes. The mortality of abdominal section in the treatment of the different forms of intestinal obstruction will always be great, because the conditions which have caused the obstruction are often an intrinsic source of danger. In others, the removal of the obstruction necessitates an intestinal resection which in itself is a vastly more serious operation than the removal of an ovarian tumor. Intestinal obstruction, irrespective of its cause, is always followed by a series of consecutive pathological changes which independently of the partial, or complete interruption of the passage of intestinal contents tend to destroy life.

The dilatation of the intestinal tube on the proximal side of the seat of obstruction may give rise to such a degree of abdominal distention as to destroy life from suspension of important functions by mechanical pressure. In acute obstruction, the violent peristalsis on the proximal side of the occlusion causes an increased afflux of blood to the portion of bowel the seat of exaggerated physiological function, which after cessation of peristaltic action remains as an intense venous and capillary engorgement. During the paretic stage the blood vessels in the intestinal wall have lost their extra vascular support, hence transudation and exudation readily take place into the paravascular tissues, which, combined with the capillary stasis attending this stage of the inflammatory process, often results in gangrene. The intestinal wall, in a state of inflammation, becomes permeable to pathogenic micro-organisms which are always present in the intestinal canal, and which after passing through the entire thickness of its walls enter the peritoneal cavity and induce septic peritonitis,—a frequent immediate cause of death. These facts are cogent reasons for adopting surgical measures in all cases of intestinal obstruction due to mechanical causes as soon as a probable diagnosis can be made. If this were done, the two greatest sources of immediate danger attending and following laparotomy, shock and septic peritonitis, if not entirely avoided, at

least would be less likely to occur, and the tissues the seat of operation would be in a favorable condition for direct treatment and repair. An abdominal section in the treatment of intestinal obstruction is always necessarily attended by some shock, and it is therefore of the utmost importance to perform the operation at a time when the organs of circulation and the nervous system are still in a condition to successfully resist the immediate effects of the operation. Death from septic causes can only be avoided by operating at a time when the intestinal canal at the seat of obstruction and on its proximal side is still in a condition capable of resisting infection and of undergoing a satisfactory process of repair in case it becomes necessary to incise, or resect during the operation. The statistics of operations for intestinal obstruction will improve as soon as we shall be able by improved methods of diagnosis to make an early positive diagnosis and to adopt in the treatment positive surgical measures before the prospects of a recovery have been rendered improbable, if not impossible, by days and weeks of useless, and worse than useless, internal medication. True intestinal obstruction, whatever its cause may be, is as strictly a surgical affection as strangulated hernia and remediable only by the same kind of surgical treatment. Physicians should recognize this fact and should call into counsel a surgeon as soon as a probable diagnosis of intestinal obstruction can be made. To let a patient die of the consequences of a removable cause of obstruction without an operation is a reflection upon the advances of modern aggressive surgery.

The difficulties which surround the diagnosis and the present imperfect technique of the operative procedures in cases of intestinal obstruction are not only responsible for the heretofore late operations, but also to a great extent for the many failures. Ways and means for more accurate diagnosis will have to be devised by more careful clinical observations and by experimental research, while new and improved methods of operation must be devised and their merits and safety tested by experiments on animals. I am convinced that accurate experimental work of this kind will render essential information in the diagnosis of the obscure causes of obstruction, and will point out more clearly the indications for operative treatment, while improved methods of operation will have to be studied exclusively in this manner. The obstacles which the surgeon encounters in the diagnosis and treatment of many cases of

intestinal obstruction often appear insurmountable, but they will be greatly diminished in the future by facts which will be revealed by the results of experimental investigation. Abdominal surgery was founded and developed on American soil, and in the part which refers to the treatment of intestinal obstruction, ample scope is left for the exercise of the genius and perseverance of the younger members of the profession in this country, who would do honor to the memory of our McDowell, our Sims, and our Gross by honest, faithful, unselfish, original work.

## I. Definition of Intestinal Obstruction.

Intestinal obstruction, occlusion and strangulation have been used as synonymous terms. Some authors wish to draw a line of distinction between cases of intestinal obstruction and intestinal strangulation, including under the former term all cases where the obstruction is caused by a tumor, enterolith, or intussusception, while internal hernia, volvolus, and constriction by a band are included under the head of strangulation. For practical purposes such a distinction is superfluous, as any cause which mechanically interferes with the passage of intestinal contents produces intestinal obstruction, and if it cannot be removed by ordinary means should be treated by abdominal section. The classification into true and false obstruction, from a surgical standpoint, should also be abandoned, as operative interference is only indicated in cases of obstruction due to the presence of mechanical obstacles, such as foreign bodies, tumors, or intussusceptum in the lumen of the bowel, or to compression of the lumen by tumors, flexion, twisting, and bands of constriction. Inflammation of the tunics of the bowel and diffuse peritonitis may give rise to symptoms resembling obstruction, but in such cases the obstruction follows as a sequence of an antecedent or accompanying inflammatory lesion, and is due to dynamic disturbances and not to mechanical occlusion, and the indications for treatment are to combat the inflammation and to restore peristaltic action, combined with mechanical means to relieve the abdominal distention. A more important classification remains to be mentioned by which all cases of true intestinal obstruction are divided into acute and chronic. This distinction must be maintained for many reasons. In chronic obstruction the symptoms usually develop very slowly as the occlusion becomes more complete. During the early

part of the affection the intestinal walls above the seat of obstruction undergo compensatory hypertrophy, dilatation taking place very slowly unless the chronic suddenly merges into the acute form, an event which is always announced by a complexus of symptoms characteristic of acute or subacute obstruction. Chronic obstruction is more frequently met with in persons advanced in years, and the seat of obstruction is usually located in some part of the large intestines. The acute form is caused by some pathological conditions which suddenly narrow, or obliterate the lumen of some portion of the intestine, usually above the ileo-cæcal valve, and often without any premonitory symptoms gives rise to a complexus of acute symptoms almost pathognomonic of this affection. The sudden interruption of the passage of intestinal contents is followed by violent peristaltic action of the bowel above the seat of obstruction in a vain attempt to clear the intestinal tract, which from muscular exhaustion and the distention from the accumulation of intestinal contents finally gives rise to paresis and the textural changes previously alluded to. In the treatment of such acute cases prompt action constitutes an essential element of success, as in a few hours, or days, the patient becomes utterly prostrated, and the bowel at and above the seat of obstruction has undergone irreparable pathological changes. These are the cases that demand early surgical treatment, and that now claim our special attention.

## II. Frequency of Intestinal Obstruction.

An examination of the statistics of Leichtenstern[1] shows that, external herniæ and malignant tumors being excluded, one death from intestinal obstruction takes place in every three to five hundred deaths from all causes in hospital practice. This statement is based upon the records of the late Dr. Brinton, of London, and a number of large hospitals on the European continent.

Hilton Fagge[2] has shown from an examination of the records of four thousand autopsies in Guy's Hospital, from 1854 to 1868, that fifty-four, or about one-fourth per cent., were cases of intestinal obstruction.

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[1] Ziemssen's Cyclopædia of the Practice of Medicine, American Translation, Vol. VIII.

[2] Guy's Hospital Reports, 1869.

Heusner[1] from his own investigations regarding the frequency of intestinal obstruction maintains that annually out of every one-hundred thousand individuals, from five to ten suffer from this affection, and that one to every three to five hundred deaths is attributable to this cause. These statistics show the importance of intestinal obstruction in its medical and surgical relations, and it is hoped that by their aid new light may be shed upon a class of affections which heretofore, only too often, have baffled the skill of both physician and surgeon.

## III. Surgical Resources in the Treatment of Intestinal Obstruction.

### 1. Irrigation of Stomach.

The accumulation of intestinal contents above the seat of obstruction acts deleteriously in several ways: 1. It causes violent peristaltic action of the intestine above the seat of obstruction. 2. It exhausts the patient's strength by causing persistent retching and vomiting. 3. It is one of the causes which produces distention of the intestine. 4. It favors fermentative and putrefactive changes in the intestine by the fluid serving the purpose of a nutrient medium for pathogenic micro-organisms. In my experiments on animals where I made complete obstruction I never witnessed such persistent vomiting as in man. I attributed this difference to the fact that animals thus treated refuse, as a rule, both food and drink, and that the intestinal canal in proportion to the size of the abdominal cavity is much shorter than in man. Patients suffering from acute intestinal obstruction should abstain from taking either food or drink, as digestion and absorption are almost, if not completely, suspended, and the accumulation of fluids cannot fail in aggravating the symptoms.

Kussmaul[2] has introduced a new and exceedingly valuable therapeutic measure in the treatment of intestinal obstruction in the use of the elastic stomach-tube. By the siphon action of the tube, gas and the fluid contents of the stomach and upper portion of the intestinal canal are evacuated, and thus abdominal distention is relieved and the hydrostatic pressure in the intestine above the

[1] Deutsche Med. Wochenschrift, 1887.

[2] Berl. Klin. Wochenschrift, Nos. 42, 43, 1884.

obstruction diminished. He claims for this measure the following advantages: 1. Intra-abdominal tension is diminished and thus the first condition secured for the correction of the mechanical difficulties which have caused the obstruction. 2. It relieves the distention of the bowel above the seat of obstruction and consequently also the pressure of the intestines against each other, a condition which cannot fail to impair peristaltic action. 3. Finally, what is most important, by evacuating the accumulated contents it diminishes the violent peristalsis. He reports the case of an adult where an intestinal obstruction due to an invagination had lasted twenty-three days and which yielded to daily irrigations of the stomach. A portion of the intussusceptum sloughed and was found in the stool. The patient died later of peritonitis which may have started from the seat of invagination.

Bardeleben[1] in a paper on the treatment of acute intestinal obstruction, praises the utility of irrigation of the stomach as a palliative means, but speaks at the same time of the danger incident to the employment of such a temporizing measure, as too much valuable time may be lost before a curative treatment is adopted. He reports a case in which irrigation afforded such absolute relief that the operation was postponed until it could be no longer of any avail. Kuester expects from irrigation of the stomach prompt palliative effects, but warns not to persist with it in cases where the seat and cause of the obstruction can be ascertained. Hahn looks upon it as a curative agent only in cases where the obstruction is due to koprostasis in the large intestines, and he claims that in such cases irrigation of the rectum would lead more promptly to the desired result.

Schlegtendal[2] claims that lavage of the stomach in the treatment of intestinal obstruction fulfills a threefold therapeutic indication: 1. It prevents distressing symptoms; 2. alleviates them when they are present; and in some cases 3. cures the disease.

Rehn[3] maintains that irrigation of the stomach, as devised by Kussmaul, in the treatment of intestinal obstruction not only empties the stomach of its contents, but it also evacuates a certain portion of the intestinal canal above the seat of obstruction. In two cases

[1] Ueber Ileus. Berl. Klin. Wochenschrift, Nos. 25, 26, 1885.

[2] Frauenarzt, 1887.

[3] Fortschritte der Medicin, 1887.

of intestinal obstruction, where this expedient was resorted to after the abdominal cavity was opened, he observed that a considerable portion of the dilated intestine was emptied of its contents.

Heusner states that by this means many litres of intestinal contents can be removed, pain is relieved, eructation and vomiting controlled, peristalsis quieted, the function of the stomach restored, suitable nourishment can be taken and assimilated, thus maintaining strength and life until the cause of obstruction is removed spontaneously, or through the intervention of surgery. Madelung has called attention to the necessity of resorting to irrigation of the stomach prior to the administration of an anæsthetic in operations for intestinal obstruction, as without such precaution there is danger during the attacks of vomiting which are almost sure to be provoked by the anæsthetic, of fluid entering the trachea, causing suffocation, or later, pneumonia. As an aid in the treatment of intestinal obstruction due to mechanical causes, irrigation of the stomach should always be systematically practiced every four to six hours, but as a curative measure it should never be relied upon. In my own practice I have always combined emptying of the stomach with irrigation, using large quantities of warm water rendered antiseptic by the addition of salicylated soda, or hypophosphite of soda. The washing out of the stomach with a harmless and efficient antiseptic solution, has a decided beneficial effect in preventing fermentative and putrefactive changes in the intestinal contents above the seat of obstruction.

## 2. Distention of Colon with Fluids.

Evacuation of the colon by copious rectal injections is resorted to almost instinctively in every case of intestinal obstruction. This procedure has also been employed with the intention of utilizing the hydrostatic pressure as a means for the correction of the mechanical difficulties which have given rise to the obstruction. This method of treatment has given rise to the much discussed question as to the permeability of the ileo-cæcal valve to rectal injections of fluids, or to the insufflation of air or gases. The majority of those who have studied this subject clinically or by experiment make the positive assertion that the ileo-cæcal valve is perfectly competent and effectually guards the ileum against the entrance of both fluids and gases forced into the rectum, while others insist that it is

permeable only in exceptional cases, and only a few claim that its resistance can be overcome by a moderate degree of pressure.

Heschl[1] made a number of experiments on the cadaver and satisfied himself that the ileo-cæcal valve serves as a safe and perfect barrier against the entrance of fluids from below. In testing the resisting capacity of the coats of the intestine he found that the serous coat of the colon gave way first to over-distention, while the remaining tunics yielded subsequently to a somewhat slighter pressure. The small intestine of a child on being subjected to over-distention ruptured first on the mesenteric side, the place where acquired diverticula are found.

Bull[2] has found that in the adult one litre of water injected by the rectum will reach the cæcum, but that the entire capacity of the large intestine is from 4 to 5 litres. He is of the opinion that in the living body fluid cannot be forced beyond the ileo-cæcal valve, although ancient and modern experimenters claim to have succeeded in the cadaver. He affirms that when the rectum is distended by air the ileo-cæcal valve is rendered incompetent and the air passes into the small intestines. Cantani[3] is a firm believer in the permeability of the ileo-cæcal valve to fluid rectal injections. In one instance he treated a case of coprostasis by an injection of a litre and a half of oil per rectum, and an hour later a part of the oil was ejected by vomiting. He advises that the intestinal tract above the ileo-cæcal valve should be utilized as an absorbing surface in cases requiring rectal alimentation, and when in a diseased condition should be treated by topical applications.

Behrens[4] concluded from his experiments that it required the insufflation per rectum of one and one-eighth litres of air to reach the ileum through the ileo-cæcal valve. In his experiments he had no difficulty in overcoming the competency of the ileo-cæcal valve by rectal insufflation of air.

Debierré[5] made numerous experiments on the cadaver to test

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[1] Zur Mechanik der Diastaltischen Darmperforationen, Wiener Med. Wochenscrift, No. 1, 1881.

[2] Virchow u. Hirsch's Jahresbericht, B. 2, 1870, p. 180.

[3] Virchow u. Hirsch's Jahresbericht, B. 2, 1879, p. 180.

[4] Ueber den Werth der künstlichen Auftreibung des Dickdarmes mit Gasen u. Flüssigkeiten. Dissertation. Göttingen, 1886.

[5] La valvule de Bauhin consideré comme barriere des apothecaires. Lyon Médicale, No. 45, 1885.

the permeability of the ileo-cæcal valve to rectal injections of fluids or insufflation of air. The results which he obtained were not constant. In some subjects the valve proved only permeable to air; in others, to both air and water; while in some no air nor fluids could be forced into the ileum by any degree of force. When the intestine was left *in situ* the valve was found less permeable than when the intestine had been removed from the body. He attributes the different degrees of competency of the valve to variations in the anatomical construction of the valve. If both lips of the valve are equal in length, or if the lower lip is longer, the valve was found impermeable. It proved permeable in cases where the lower lip was shorter, contracted, and smaller than the upper. In the last instance, the advancing volume of fluid or air lifted the upper valve, while in the former structure of the valve, the margins of the lips of the valve were approximated, perfectly shutting off all communication between the colon and the ileum.

Mr. Lucas[1] enumerates the following objections against forcible rectal injections of water as a means to reduce an invagination:

1. Owing to its weight it exerts much too strong lateral pressure for the intestine safely to bear, and he has found it easy to rupture the bowel after death by forcing in water.

2. Should reduction have been accomplished the contact of a large quantity of water with the large bowel is apt to increase the tendency to diarrhœa. He claims, very properly, that gas, on the other hand, is a natural occupant of the intestinal canal, and whilst its pressure is of the gentlest, its presence excites no unnatural peristaltic action. He administers an anæsthetic to the point of relaxation before the inflation is attempted.

Dawson[2] made a number of experiments on the cadaver and came to the conclusion that when the ileo-cæcal valve is in a normal condition, it effectually guards the small intestine against the ingress of fluids from below.

Illoway[3] devised a force-pump which he strongly recommends for the purpose of forcing water beyond the ileo-cæcal valve in case the seat of an intestinal obstruction is located above that point. He

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[1] On Inversion with Inflation in the Cure of Intussusception. The Lancet, Jan. 16, 1886.

[2] Lancet and Clinic, Feb. 21, 1885.

[3] American Journal of Medical Sciences, Vol. 41, page 168.

reports four cases of intestinal obstruction treated by this method, three of which recovered.

Battey[1] asserts the permeability of the entire alimentary canal by enema, and verifies his statement by the recital of his own clinical experience and experiments upon the cadaver. Ziemssen recommends inflation of the rectum for diagnostic and therapeutic purposes, and proceeds as follows: A rectal tube about six inches long is carried into the anus and fixed by pressing together the nates, the patient lying on the back. A funnel is then connected with the rectal tube by means of rubber tubing. For complete inflation of the large intestine 3 drachms of bicarbonate of soda, and 4½ drachms of tartaric acid are separately dissolved in water and portions of either solution alternately added. To prevent sudden over-distention of the bowel it is advised to add the solutions at intervals of several minutes. A very important use of this method is to diagnosticate the position of the contractions, strictures, or occlusion of the intestine in cases in which it is desirable to operate, and also as showing the position of peritoneal adhesions. The result of his observations has led him to believe that, as a rule, the small intestine is completely closed to the entrance of substances from the colon by the ileo-cæcal valve. Under the influence of deep chloroform narcosis, however, this resistance is lessened, and fluids can be thrown into the small intestine.

Insufflation of air per rectum in the treatment of intestinal obstruction has been known since the time of Hippocrates. Gorham[2] was the first to resort to this method of treatment in England. In comparing the effect of enemata to air insufflation, he says: "But the effect is totally different, when air is used; its freedom from all irritating qualities, its elasticity and expansibility give it a decided preference over enemata."

In my paper read at the last meeting of the International Medical Congress[3] I detailed the results of a number of experiments which I made on dogs, to determine to my own satisfaction the extent to which the ileo-cæcal valve is permeable to fluids forced

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[1] Transactions of the American Medical Association, 1878.

[2] Observations on Intussusception as it occurs in Infants. Guy's Hospital Reports, Vol. III, p. 330.

[3] An Experimental Contribution to Intestinal Surgery, with Special Reference to the Treatment of Intestinal Obstruction.

from below. In three cases where fluid was forced beyond the ileo-cæcal valve, the post-mortem revealed in two of them, multiple lacerations of the peritoneal coat of the large intestine, while the third animal sickened immediately after the experiment was made, and died from the effects of the injuries inflicted, eight days later. These experiments combined with clinical experience leave no further doubt that, practically, the ileo-cæcal valve is impermeable to fluids from below, and that for diagnostic and therapeutic purposes it is unsafe and unjustifiable to attempt to force fluids beyond the ileo-cæcal valve. In two cases of ileo-colic invagination, in children less than two years of age, I succeeded in reducing the bowel by steady hydrostatic pressure, while the little patients were under the influence of an anæsthetic and held in the inverted position. In both instances the invagination had existed for two or three days. We should, *a priori*, expect that air and gases, on account of their lesser weight and greater elasticity than water, could be forced along the intestinal canal with less force, and for that reason alone, if for no other, should be preferred to water in cases where it appears desirable to distend the intestine below or above the ileo-cæcal valve for diagnostic or therapeutic purposes. I shall, therefore, call your attention briefly to :

### 3. Rectal Insufflation of Hydrogen Gas.

Hydrogen gas is the lightest of all known gases.[1] I have demonstrated by my experiments that this gas is non-toxic, non-irritant when injected into the connective tissue and into the large serous cavities, and is rapidly removed by absorption. Distention of the entire gastro-intestinal canal with this gas by rectal insufflation, both in man and animals, was never followed by any immediate or remote ill effects. Accurate experiments to determine the force requisite to render the ileo-cæcal valve incompetent by insufflation of air or gas, had previously not been made, and as it is exceedingly important to obtain accurate information on this subject, I made a number of inflations in animals and man, estimating at the same time the pressure under which it was made, either with a mercury gauge or a manometer such as is used by gas-fitters and plumbers. The gas was

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[1] Rectal Insufflation of Hydrogen Gas an Infallible Test in the Diagnosis of Visceral Injury of the Gastro-Intestinal Canal in Penetrating Wounds of the Abdomen. Jour. Amer. Med. Association, June 23, 30, 1888.

collected in a four-gallon rubber balloon and the inflation made by compressing the balloon. The manometer, or mercury gauge was connected by means of rubber tubing with the rectal tube on one side and the rubber balloon on the other. Numerous experiments showed that when the gas was forced through the opening of a stop-cock, the lumen of which was about the size of a knitting-needle, compression equal to two hundred pounds (ninety kilogr.) would never register more than two and a half to three pounds of pressure to the square inch. In the living subject the escape of gas from the rectum was prevented by an assistant pressing the margins of the anus firmly against the rectal tube. A number of experiments made for the special purpose of measuring the resisting capacity of the ileo-cæcal valve to the entrance of gas from the cæcum into the ileum, showed that in a normal condition the valve in a healthy adult person is overcome by rectal inflation under a pressure varying from one and a half to two and one-fourth pounds (.6 to 1.2 kilo.). This amount of pressure is not sufficient to injure any of the coats of a healthy intestine in any part of its course. As the result of numerous observations on man and animals, I can state that when the inflation is made slowly and continuously there is less danger of inflicting injury than when it is done rapidly or interruptedly. When the patient is placed fully under the influence of an anæsthetic, the ileo-cæcal valve yields to a lower pressure than when the abdominal muscles are in a state of rigidity, as this interferes with the requisite degree of distention of the cæcum which is necessary to effect the separation of the margins of the valve. A rubber balloon holding from two to four gallons (ten to twenty litres) is the simplest, safest and most efficient instrument for making rectal insufflation both for diagnostic and curative purposes.

Another series of experiments on dogs I made in order to determine the degree of pressure which is required to force hydrogen gas from anus to mouth, the whole length of the gastro-intestinal canal. In all of the experiments the pressure fell rapidly after the ileo-cæcal valve had been opened, but had again to be increased before the gas reached the stomach and escaped through the stomach tube. It usually required one-half to one pound more pressure to force gas through the entire length of the alimentary canal than when it had to be forced only through the ileo-cæcal valve. Whenever it becomes necessary to conduct the hydrogen gas a considerable distance along

the intestines, or through the entire alimentary canal, it is exceedingly important to proceed slowly with the inflation, as under slow gradual distention, half a pound (.2 kilogr.) of pressure to the square inch of surface will accomplish in time a great deal more without doing harm, than four times this amount of pressure if the force is applied quickly and only for a short time. In the dog, rectal insufflation of hydrogen gas made under a pressure of one-quarter of a pound, if made very slowly and uninterruptedly, the abdominal walls being completely relaxed by an anæsthetic, will not only overcome the resistance offered by the ileo-cæcal valve, but will prove sufficient to force the gas through the whole length of the alimentary canal.

Experiments made on different portions of the gastro-intestinal canal when in a healthy condition and removed soon after death, proved that laceration did not take place under a pressure of less than eight pounds, and often it had to be increased to twelve pounds. It was found that the resisting power of the intestinal wall is nearly the same throughout the entire length of the canal, and in a normal condition yielded to a diastaltic force of from eight to twelve pounds of pressure. When rupture took place, it either occurred as a longitudinal laceration of the peritoneum on the convex surface of the bowel, or as multiple ruptures from within outwards, at the mesenteric attachment. The former result followed rapid, and the latter slow, inflation. The superiority of hydrogen gas inflation over injections of liquids in the mechanical treatment of intestinal obstruction is apparent. Liquid injections cannot safely be forced beyond the ileo-cæcal valve, and even in distending the entire colon by liquids a great deal more force is required than by insufflation with hydrogen gas. Insufflation of hydrogen gas is a valuable means of diagnosis in locating the seat of obstruction before tympanites has set in and therefore best adapted at a time when most needed—during the early stage of intestinal obstruction. If the colon dilates uniformly from the sigmoid flexure to the cæcum, the obstruction must be sought for higher up in the intestinal canal. The passage of gas through the ileo-cæcal valve, rendered incompetent by the distention of the cæcum, is always attended by a characteristic gurgling or blowing sound which is heard distinctly by applying the ear or stethoscope over the ileo-cæcal region. Not infrequently the sounds are so loud and distinct that they can be

heard at a distance of several feet. If the gas passes the ileo-cæcal valve under a pressure not in excess of that required to overcome it in a state of health, and, if after inflation a thorough examination of the ileo-cæcal region by inspection, palpation and percussion reveals nothing abnormal, the search for the obstruction is continued by inflating the small intestines slowly and making frequent examinations of the abdomen to ascertain the height to which inflation has been made and to study the relative position of the different abdominal organs. Inflation is also a useful diagnostic resource in locating the obstruction during laparotomy for intestinal obstruction. The intestine below the seat of obstruction is always empty, collapsed and anæmic as compared with the portion above the obstruction. When the obstruction is located high up in the intestinal canal and the tympanites is extensive, the empty portion of the small intestines has, by compression, become displaced and is often not readily found. In such cases the distention of the bowel from below will indicate to the surgeon at once the location and length of the intestine below the seat of obstruction, and will enable him to search for the obstruction from below upwards. The manipulation of the healthy intact portion of the intestinal canal in the search for the obstruction is by far a less hazardous procedure than the handling of the distended portion above the obstruction, rendered paretic, exceedingly vascular, and much softened by the obstruction. In cases where we suspect the presence of a perforation, inflation with hydrogen gas will demonstrate not only its existence, but also its location. Invagination is rare above the ileo-cæcal valve, and its location can be determined by inflation with hydrogen gas, and if resorted to early, it may prove the means of effecting reduction. In ileo-cæcal and colonic invagination slow and persistent distention of the colon with hydrogen gas, with the patients completely under the influence of chloroform, is the safest and most efficient means of effecting reduction and should always be resorted to whenever these conditions are recognized or even suspected. Rectal inflation as ordinarily practiced, by forcing air into the rectum with bellows, or a Davidson's syringe is not devoid of danger, as the force employed cannot be accurately regulated or estimated.

Bryant[1] has collected twenty cases of invagination treated by inflation, in three of which it produced rupture of the bowel below the invaginated portion, while in a fourth the child died in collapse shortly after the inflation. He does not look upon inflation as a proper and safe method of treatment in cases of acute invagination, and in the subacute form, it should only be resorted to within the first three days, because later on changes in the bowel are almost certain to have taken place, which would render this measure fruitless, and probably dangerous.

Knaggs[2] reports the particulars of eight cases of invagination where forcible distention of the bowel by air or water was the cause of rupture or other serious injury to the bowel. These cases show that this method of treatment is attended by great risk in children less than one year of age, as six of the eight cases in which harm resulted were children less than eight months old. In Symond's case the abdomen was opened at once after rupture had taken place, and the rupture was sutured. The child, however, was too exhausted to rally from the operation, but at the necropsy the sutured bowel was able to resist successfully very considerable distention with water.

Greig[3] reports five cases of invagination treated by insufflation of air, in four of which it proved successful. In some of the cases the insufflation had to be repeated. Insufflation of hydrogen gas from a rubber balloon is applicable in all cases of subacute and chronic invagination and during the early stage of acute invagination, that is, before the passive hyperæmia in the invaginated portion has rendered reduction by this method impossible. Should perforation take place, the accident is at once recognized by a uniform distention of the abdomen, from the entrance of the hydrogen gas into the peritoneal cavity, as well as by a sudden diminution of pressure readily felt by the person who makes compression of the balloon. The entrance of hydrogen gas into the peritoneal cavity is in itself a harmless occurrence, as the gas is non-irritant and

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[1] Harveian Lectures on the Mode of Death from Acute Intestinal Strangulation and Chronic Intestinal Obstruction. British Medical Journal, 1884, Nov. 22.

[2] Resection of an Irreducible and Gangrenous Intussusception, etc. The Lancet, 1887, June 4, 11.

[3] On Insufflation of Air as a Remedy in Intussusception. Edinburgh Medical Journal, October, 1864.

perfectly aseptic. In such cases the insufflation must be followed at once by abdominal section and the necessary operative treatment of the invagination.

## 4. Tubage of Colon.

Even a few years ago it was as much a mooted point in reference to how far fluids could be forced beyond the rectum, as the permeability of the ileo-cæcal valve is at the present time.

Von Trautvetter[1] made numerous experiments on the cadaver to determine how far up into the bowel fluids could be injected per rectum. He injected either with an ordinary syringe or through a rectal tube. The fluid used was a solution of ferrocyanide of potassium, and after the injection chloride of iron was applied to different parts of the intestine to test for the presence of the fluid injected. Ordinary injections did not pass beyond the lower portion of the descending colon, while injections made through a long elastic tube reached the cæcum. These experiments are only alluded to as an illustration of the ideas which were entertained in reference to the permeability of the colon to rectal injections, at the time O'Bierne first advocated the use of the elastic rectal tube in cases where it was deemed necessary to make high injections. Some authors suggest the introduction of a rectal tube, in the treatment of intestinal obstruction as first practiced by O'Bierne, and claim that with it they have reached the cæcum; but Treves assures us that he has made numerous experiments on the cadaver and has never succeeded in passing it farther than the sigmoid flexure.

Cadge[2] states that even O'Bierne never claimed that the elastic rectal tube could be inserted farther than the sigmoid flexure. Cadge made numerous attempts on the cadaver and was never able to reach the descending colon. In cases where the tube was introduced to a depth of twenty to thirty inches, he found that the tip of the instrument remained in contact with the intestinal wall; and that this portion of the bowel is pushed forward when the end of the instrument can be felt through the abdominal wall at a higher point. In the administration of ordinary injections, the

[1] Wie weit können Flüssigkeiten in den Darmkanal per anum hinauf gespritzt werden? Deutsches Archiv. f. Klinische Medicin, B. IV., p. 476.

[2] Case of Intestinal Obstruction, with Remarks. British Medical Journal, 1888.

introduction of a rectal tube is superfluons, as in Hegar's knee-chest position the fluid from an ordinary fountain syringe will follow the course of the colon and advance as far as the cæcum.

Hegar[1] seldom found it necessary to elevate the funnel more than one foot, a column of water corresponding to this elevation being found sufficient to force the fluid as far as the cæcum and as he believes sometimes beyond the ileo-cæcal valve. The legitimate indications for tubage of the colon are the following:

1. Detection and location of obstruction below the sigmoid flexure.
2. To relieve gaseous distention of the colon.
3. To administer high nutrient enemata in cases where it becomes necessary to maintain the strength of the patient by this method of alimentation.

## 5. Manual Exploration by the Rectum.

The introduction of the whole hand into the rectum as a means of diagnosis was devised and first practiced by Simon. This method of exploration is applicable only in the adult. Simon and his numerous followers claim that the hand can be introduced sufficiently far to enable the surgeon to palpate most of the abdominal organs. Nussbaum assures us that he has felt more than once the tip of the sternum with the hand employed in the manual exploration by the rectum.

Wagstaff[2] in his paper "On Intestinal Obstruction" places great stress on the importance of manual exploration by the rectum as a diagnostic measure, as appears from one of his conclusions: "That the causes of obstruction can generally be determined by the history of present and past illnesses and by thorough external and internal examination, and that manual exploration by the rectum is certainly the greatest advance in our means of diagnosis." The glowing accounts of the value of this method of exploration were soon followed by accounts of disastrous consequences such as rupture of the gut and permanent loss of function of the sphincter muscles. Manual exploration by the rectum should only be undertaken by surgeons with small slender hands, and the examination should

[1] Ueber Einführing von Flüssigkeiten in Harnblase und Darm. Deutsche Klinik, No. 8, 1873.

[2] St. Thomas' Hospital Reports. New Series, Vol. IV., 1873.

always be made with the patient fully under the influence of an anæsthetic, and always with the utmost care and gentleness. This method of examination will enable the surgeon to ascertain the location and nature of obstructions below the sigmoid flexure, the existence of volvolus at the sigmoid flexure, and to determine the presence of pathological conditions in the pelvis which might have caused the obstruction. As a therapeutic measure this procedure can be employed in the removal of foreign bodies or an enterolith within reach of the hand, and in the reduction of some cases of intussusception where the invaginated portion of the bowel has passed beyond the sigmoid flexure.

## 6. Taxis and Massage.

Hutchinson decidedly opposes early operative interference in cases of intestinal obstruction, and expects little from it in those which have been some time in existence. He advocates what he terms *abdominal taxis*, under an anæsthetic. By abdominal taxis he means a thorough kneading of the abdomen, with inversion of the patient, shaking him, tossing him in a blanket, and a variety of rough performances, the object being to dislodge the bowel, or untwist the volvolus. At the same time he advises large enemata and cathartics. If these means do not lead to the desired result, he waits and keeps the patient on a low diet, and administers opium or belladonna internally, and subsequently repeats the abdominal taxis. He reports a number of cases successfully treated by this method. It is doubtful if any surgeon at the present time could be found who would be willing to subject his patients to such primitive treatment as advised by Hutchinson. In most forms of intestinal obstruction such treatment is not only unscientific and useless, but attended by great risk to life, as the violent movements would not only aggravate the mechanical difficulties which have caused the obstruction, but might produce rupture of the distended intestine, and could not fail in causing exacerbation of the vascular disturbances. Taxis and massage, scientifically practiced, have a limited range of application in the treatment of intestinal obstruction, as they are applicable only to cases where the obstruction is due to the presence of a foreign body, a fæcal accumulation or an enterolith, and should only be resorted to before these causes have developed inflammatory changes at the seat of impaction. A

number of such cases are on record where this treatment proved successful.

Streubel[1] succeeded, in a boy eleven years of age suffering from intestinal obstruction due to the impaction of a mass of cherry stones above the ileo-cæcal valve, in removing the cause of obstruction by submitting the swelling to gentle massage frequently repeated.

Marrotte[2] gives an account of a case of acute intestinal obstruction which had lasted for some days when fæcal vomiting set in, and in which the usual internal treatment with opiates and chloroform afforded no relief, which was promptly cured by palpation of the abdomen made for the purpose of locating the seat of obstruction. The patient experienced a sensation at the time as though the obstruction had given way, and soon afterwards had a number of evacuations in which a gall-stone the size of a walnut was found. The author refers to five cases of intestinal obstruction caused by the presence of gall-stones, collected by Fauconneau-Dufresne. One of these cases came under the observation of Mayo. In this case the gall-stone was also dislodged by palpation, followed by cessation of the symptoms of obstruction and recovery of the patient. The remaining four patients died. In cases of fæcal accumulation in any portion of the large intestine from the cæcum to the sigmoid flexure, unattended by inflammation and giving rise to symptoms of obstruction, and not amenable to irrigation of the colon, massage and taxis should be made while the patient is under the influence of an anæsthetic, so as to enable the operator to break up the mass and to force it onwards in the interior of the bowel to a point where peristaltic action is more active.

## 7. Puncture of Intestine.

Advanced cases of intestinal obstruction are always attended by great distention of the bowel on the proximal side of the obstruction, a condition which causes increased intra-abdominal pressure. The tympanitic distention of the abdomen may be so great as to destroy life by the suspension of important functions from mechanical pressure. The diaphragm is pushed upwards so

[1] Ueber Erkennung und Behandlung der inneren Darmeinklemmung. Prager Vierteljahrsschrift. B. XV, 1858.

[2] Einklemmung eines Gallen-steines im Darme. Heilung Durch Palpation dee Bauches. Schmidt's Jahrbücher. B. 93, p. 189.

far that death may ensue from asphyxia, or the circulation is so far impeded by compression of the heart as to cause death from syncope. Great distention of the intestines on the proximal side of the obstruction also aggravates the mechanical difficulties which have caused the obstruction, as the distended bowel under such circumstances forms numerous flexions which interfere with the free passage of its contents as far as the obstruction; at the same time the distended coils may render the bowel less permeable at the seat of obstruction by compression. The anxiety with which surgeons look upon extensive tympanites following the course of intestinal obstruction is universal, hence it is only natural that for a long time it has been customary to make attempts in affording relief, by puncturing the distended bowel through the abdominal wall. A small trocar was usually employed for this purpose, but since the introduction of the hypodermic needle and the aspirator, a hollow needle of one of these instruments has been used. Cases have been reported where repeated punctures not only afforded relief, but finally led to a permanent cure. In some instances the cannula of a trocar, after puncture, was allowed to remain until a fæcal fistula had been established. An intestine distended to the extent of giving rise to distressing and dangerous intra-abdominal pressure is always in a paretic condition, unable to expel its contents, and whatever escapes through a needle or the cannula of a trocar is expelled by the contraction of the abdominal wall. This applies not only to the liquid, but also to the gaseous contents. I have repeatedly satisfied myself during operations on the living subject and in animals where the obstruction was caused artificially, that mere puncture empties only a limited space not more than six to eight inches on each side of the puncture. If aspiration is practiced at the same time the effect is doubled; further evacuation is arrested by flexions among the distended coils and valvular closure of the collapsed segment, at the terminus of the evacuated area.

The recorded results of puncture of the intestine represent largely only the successful cases, while the numerous failures seldom find their way into literature. Puncture of a healthy intestine with a needle of moderate size is never followed by extravasation, as the irritation incident to the puncture always produces muscular contractions which start from the point of puncture and at once obliterate the canal made by the needle. Puncture of a paretic intestine is

always attended by great risk of extravasation, as the muscular coat has lost its tonicity, and the track of the needle or trocar is slower in closing, or remains permanently patent. Numerous cases have been reported where a needle puncture gave rise to escape of fæcal contents into the peritoneal cavity. As the removal of the tympanites is the means, only in exceptional cases, of removing the cause of obstruction, and as the puncture of a distended paretic intestine is never devoid of risk of causing fæcal extravasation, the legitimate indications for puncture of the intestine are extremely limited. If employed at all, this procedure is only applicable to cases where no mechanical obstruction is present, and where the rapid distention of the abdomen, in itself, constitutes an imminent source of danger. Puncture should never be resorted to with a view of removing liquid contents; its use should be limited to the evacuation of gases. For this purpose one of the smaller needles of an aspirator should be used. The point of the needle should be sharp so that it can be readily passed through the intestinal wall. The needle should always be thoroughly disinfected by heating it in the flame of an alcohol lamp. The point of puncture should always be made at the most prominent point and the instrument pushed boldly forwards until all resistance is overcome. As soon as gas escapes, the intra-abdominal pressure should be increased by gentle and uniform compression of the abdominal walls. As soon as gas ceases to escape, aspiration should be made and continued as long as anything can be evacuated, and until the needle is withdrawn, but not at the time it is withdrawn. Should it be possible to ascertain the location and direction of the part of the intestine to be punctured, it is advisable to make the puncture obliquely in the long axis of the bowel so as to guard more effectually against extravasation.

## 8. Uniform and Uninterrupted Compression of the Abdomen.

In all cases of intestinal obstruction, but more particularly in the chronic form, uniform firm support of the abdomen affords relief to the patient and is one of the best means in preventing rapid distention of the intestine above the seat of obstruction. Fixation and equable compression are resorted to in other parts of the body as the best known means in controlling muscular spasm. It is

only reasonable to expect that the same measures should prove useful in retarding, if not in preventing, the violent peristalsis in cases of intestinal obstruction, and especially in preventing over-distention of the intestine. Equable compression of the abdomen should be made before great distention has occurred. Uniform compression of the abdomen is best secured by padding the iliac regions with absorbent cotton and then enveloping the body from the pubes to the tip of the sternum with broad strips of adhesive plaster which should be made to overlap each other.

## 9. Enterotomy.

In 1840 Nélaton made the first enterotomy for intestinal obstruction. He conceived the propriety of such an operation from Mannoury, who in his thesis in 1819 first called attention to the formation of a preternatural anus in cases of intestinal obstruction. Nélaton taught that by opening the abdomen in the right inguinal region and seizing the first distended coil that might present, the surgeon almost without exception would establish the artificial opening in the bowel near the ileo-cæcal region. The mortality of enterotomy has been nearly as great as that of laparotomy with removal of the cause of obstruction, and on this score alone its further application should be limited to exceptional cases, cases where a radical operation is inadmissible on account of the nature of the obstruction or the enfeebled condition of the patient. No one who under the pressure of circumstances has been forced to establish a preternatural anus, has left his patient with a feeling of satisfaction, as he must have been sadly impressed with the fact, that, at best, he has only succeeded in relieving the urgent symptoms of the obstruction, while he has failed in removing the cause, and consequently also in restoring the continuity of the intestinal canal.

A patient with an artificial anus is indeed an object of pity, as experience has sufficiently demonstrated how difficult it is in many instances to close the abnormal opening, even after the cause of obstruction is subsequently removed or corrected spontaneously, without exposing him a second time to the risk of life incident to another abdominal section. If the causes which have led to the obstruction are of a permanent character, all attempts at closing the fistulous opening will, of course, prove worse than useless, and the patient is condemned to suffer from this loathsome condition the

balance of his lifetime, without a hope of ultimate relief. I believe I can safely make the statement without fear of contradiction, that most of these unfortunate patients would prefer death itself to such a life of misery. In performing enterotomy the surgeon has no means of selecting the most desirable place in the intestine for making the opening. The only rule laid down by the text-books, and the only one applicable in such a case, is to secure in the wound and open, the first distended loop which presents itself. It not infrequently happens that the opening is made far above the seat of the obstruction, an occurrence which is attended by two immediate sources of danger: 1. Physiological exclusion of a large portion of the intestinal canal, which in the event the patient recovers from the operation and the cause of obstruction remains permanent, is followed by marasmus, which in itself may prove the cause of a subsequent fatal issue. 2. The portion of intestine between the artificial opening and the seat of obstruction being the part which has suffered the most from the effects of the obstruction remains distended and continues to exert the same deleterious effect as before the operation. Many able surgeons, even at the present time, prefer enterotomy to laparotomy and mention as principal arguments in its favor, that it requires less time in its execution and can therefore be resorted to in patients where a radical operation for this reason alone would be inadmissible; again, it is claimed that the intestine above the seat of obstruction, is not in a condition for direct operative measures which have in view the restoration of the continuity of the intestinal canal. It must, however, not be forgotten that in quite a number of cases the second objection to a radical operation does not apply, as the removal of the cause of obstruction is accomplished without interrupting the continuity of the intestinal canal and, as I shall show further on, in the remaining cases, where the cause of obstruction cannot be removed, the continuity of the intestinal canal can be restored by making an intestinal anastomosis, which can be done without greater immediate or remote risk to life than attends enterotomy. As the technique of radical operations for intestinal obstruction will be improved, the indications for enterotomy will diminish. As long as the patient's strength warrants a radical operation, enterotomy should never be performed. In patients so enfeebled that the administration of an anæsthetic would be attended by imminent danger to life, an enter-

otomy can be made without anæsthesia and under such circumstances will occasionally save a life which otherwise would be lost.

The operation is performed by making an incision not more than two and a half inches in length in the right iliac region, above and parallel to the outer half of Poupart's ligament. The tissues should be recognized as they are divided, without, however, using a director until the subperitoneal fat is reached. This layer is divided with a blunt instrument, and pushed aside when the peritoneum comes into view. This membrane is seized with a toothed forceps or lifted up with a sharp hook, and carefully incised and divided upon a grooved director. The peritoneum is united all around with the skin by a continued suture. Almost without exception, a distended knuckle of intestine, readily recognized by its size and color, presents itself in the wound, and is united with the external wound; and after it is securely fastened, an incision large enough to admit the tip of the index finger is made in the bowel, and the margins of the visceral wound sutured separately to the external wound by a single suture on each side, so as to secure patency of the opening. On incising the bowel the surgeon is often disappointed at the small amount of gas and fluid which escapes, and it is frequently several hours before a free escape takes place and the abdominal distention begins to diminish. The escape of intestinal contents is expedited by the introduction of a large-sized Nélaton's catheter.

## 10. Colotomy.

Colotomy will always retain its place in operative surgery as a palliative and life-prolonging procedure in the treatment of carcinomatous stenosis of the lower portion of the colon, and in cases of inoperable carcinoma of the rectum. The recent advances in abdominal surgery have rendered the old-fashioned lumbar or extra-peritoneal operation obsolete. The modern operation is made by opening the peritoneal cavity in the right or left groin, according to the indications which are to be fulfilled, and one of its principal objects is to terminate the intestinal canal at the artificial anus so as to provide absolute physiological rest for the portion of bowel below it. The obvious disadvantages of colotomy, as usually performed, are cited by Maydl[1] as the reasons which induced him

[1] Centralblatt f. Chirurgie, No. 24, 1888.

to devise the operation which he has described. He opens the peritoneal cavity by Littré's incision, and draws a loop of intestine forward until its mesenteric attachment is on a level with the external incision. Through a slit in the mesentery close to the gut is inserted a hard rubber cylinder wrapped in iodoform gauze. A goose-quill will answer the same purpose. This device holds the intestine in the wound and prevents its return into the abdominal cavity. By means of a row of sutures placed on each side of the prolapsed gut, including the serous and muscular coats, the two limbs of the flexure, in so far as they lie in the abdominal wound, are stitched together beneath the rubber support. If the intestine is to be opened immediately, it is stitched to the parietal peritoneum of the abdominal incision and the latter protected by iodoform collodium. If the bowel is to be incised later, the latter is not stitched to the peritoneum, but surrounded by iodoform gauze packed in beneath the rubber support, the incision of the bowel being made four or six days later, after the peritoneal cavity has been excluded by firm adhesions. If the artificial anus is made for lesions incapable of a subsequent removal, a transverse opening, including one-third of the periphery of the bowel, is made by the thermo-cautery, drainage tubes are inserted into the two lumina, and the intestine is carefully washed out. If the progress of the case is satisfactory the bowel is cut through completely in two or three weeks, the rubber support serving a useful purpose as a guide in making this incision. A few sutures will serve to secure the cut end to the skin. If the direction of the muscular fibres has been respected in making the abdominal incision, the patient is provided with such an efficient sphincter that a large drainage tube is required to keep the opening patulous. Should the artificial anus only be a temporary one, the incision in the intestine is made in a longitudinal direction. When it has become desirable to close the artificial opening, the rubber support is removed, after which the bowel retracts and the opening often closes without any further treatment. If the adhesions are too firm for this they are removed and the bowel is sutured and returned into the peritoneal cavity. Lauenstein accomplishes the same object by suturing first the peritoneum to the skin, thus lining the external incision by peritoneum, then drawing out a loop of intestine and closing the parietal wound by sutures passing through the meso-colon of the prolapsed portion of intestine which is thus

fastened in the abdominal incision; next the serosa of each limb of the prolapsed loop is stitched through its entire circumference to the parietal peritoneum.

An interesting discussion has arisen lately in Germany in regard to a step in the operation of colotomy which was described by Knie.[1] So far the operation has been only done on dogs. It consists in opening the abdomen transversely in the region of the transverse colon, stitching the peritoneum to the edges of the wound, drawing out the colon, making a slit in the meso-colon near the gut with a blunt instrument and closing the abdominal wound with two or three sutures, which are passed through the slit in the meso-colon. The object of this is to secure a loop of the colon outside of the abdominal cavity. This loop is to be carefully stitched at each side to the edge of the (now) two abdominal openings, after which it is to be opened by an incision, or if the symptoms are not urgent, the incision is postponed for a few days until the peritoneal cavity has been shut off by adhesions. As a general thing Lauenstein's operation will be found simplest, and should receive the preference in ordinary cases. The modern operation of colotomy is indicated in cases of congenital atresia of the rectum when the bowel cannot be readily reached from below; also in cases of carcinoma of the sigmoid flexure and the rectum not amenable to a radical operation. Finally, the operation might become necessary in irreducible colonic invagination in which, for anatomical reasons, resection or anastomosis cannot be done.

## 11. Abdominal Section.

A radical operation in the treatment of intestinal obstruction embraces the fulfillment of two principal indications: 1. The removal or rendering harmless of the cause of obstruction. 2. The immediate restoration of the continuity of the intestinal canal. To meet the first indication the cause of obstruction must be found, its nature determined, and whenever advisable or practicable, removed, a step in the operation which may be very easy, or may demand a most formidable and serious undertaking, more especially in cases where the pathological conditions which have given rise to the obstruction are of such a nature as to constitute in themselves an imminent or remote source of danger, as, for instance, malignant

[1] Centralblatt f. Chirurgie, May 5, 1888.

disease or gangrêne of the bowel from constriction. Abdominal section in the treatment of intestinal obstruction has so far been attended by a fearful mortality, owing to the fact that most operations were performed when the patients were in collapse, or when the parts involved in the obstruction had undergone advanced and often irreparable pathological changes.

Ashhurst[1] tabulated fifty-seven cases of laparotomy for acute intestinal obstruction from other causes than intussusception, from which it will be seen that only eighteen terminated favorably, so that at that time the mortality of laparotomy in cases of intestinal obstruction other than intussusception, was over 68 per cent. Most of these operations were performed without antiseptic precautions.

Schramm has collected one hundred and ninety cases of intestinal strangulation treated by laparotomy, including three cases observed by himself in the practice of Mikulicz. He alludes to the difficulties encountered in the diagnosis of these cases and pleads in favor of early operative interference. Of this number 64.2 per cent. died, the mortality before the antiseptic treatment of wounds being 73 per cent., and since that time 58 per cent. The cause of strangulation and mortality attending each kind may be gleaned from the following table:

| | | | | | | |
|---|---|---|---|---|---|---|
| 27 | times, | Invagination, | 8 | cured, | 19 | died. |
| 49 | " | Bands, or intestinal diverticula, | 13 | " | 36 | " |
| 16 | " | Adhesions, | 7 | " | 9 | " |
| 11 | " | Reduction *en masse*, | 6 | " | 5 | " |
| 10 | " | Torsions, | 1 | " | 9 | " |
| 12 | " | Knotting of bowel, | 4 | " | 8 | " |
| 12 | " | Internal strangulation, | 4 | " | 8 | " |
| 7 | " | Foreign bodies, | 4 | " | 3 | " |
| 38 | " | Neoplasms, | 16 | " | 22 | " |
| 8 | " | Unknown causes, | 5 | " | 3 | " |

Curtis[2] has collected the cases of intestinal obstruction treated by abdominal section since the year 1873, consequently since the antiseptic treatment of wounds was introduced. Table I. shows a total of 328 cases with 102 recoveries and 226 deaths, the percentage of mortality being 68.9—a higher percentage than that of

[1] Amer. Jour. Med. Sciences, July, 1874.

[2] The Results of Laparotomy in Acute Intestinal Obstruction. Annals of Surgery, May, 1888.

Schramm's collection. Table III. shows that in 101 cases, the failure of the operation was due directly to the unfavorable condition of the patient, who was in a dying condition in 8 cases. In the majority of the cases with complications, 41 in all, the fatal result was also really due to the condition of the patient, for the existence of peritonitis or gangrene of the bowel at the time of operation shows that there had been too much delay in resorting to operative measures, and most of these cases died a few hours after operation. In 28 cases the cause of obstruction was not found, or could not be removed, and in 11 the reports are so defective that the cause of death cannot be ascertained from them. Of the remaining 45 fatal cases, 13 died of shock, in 3 cases the unusual length of the operation was probably the direct cause of death, and in 17 cases, sepsis, probably due to the operation, was the cause of death. In 12 cases the cause could not be definitely learned, but as death followed in most of them within 24 hours after the operation, it was probably shock and exhaustion. In 247 cases where the cause of obstruction was removed, the mortality was only 62.7 per cent.; while in 74 in which it was not done, the mortality was 86.4 per cent. In 41 cases where the obstruction consisted of invagination, volvolus, adhesions, bands and internal incarceration, in which the obstruction was not removed, not a single one recovered, although in 16 an artificial anus was made. The greatest mortality attended cases where from any cause suturing of the bowel was made, attaining the extreme point of 86.6 per cent. in 45 cases. The necessity for a short operation is well shown by the cases collected by Curtis, which give a mortality of 57 per cent. in 190 cases in which the operative interference was limited to relieving the obstruction, without wounding the bowel, while it rose to 73 per cent. in 15 cases in which it became necessary to establish an artificial anus after the obstruction had been removed, and to 83 per cent. in 48 cases in which the gut had to be sutured. In all these cases the true danger lay in the length of the operation, for death resulted from the immediate effects of the operation in most of the cases.

These statistics show the value and importance of early operation, as sometimes delay of only a few hours will bring complications which not only necessitate more time in their removal, but will at the same time necessitate a resection or an anastomosis, which, had the operation been done at an earlier date, might have been obviated.

The older text-books on surgery always cautioned the practitioner to postpone the operative treatment of a strangulated hernia for a certain length of time which was often consumed in vain attempts at reduction, consequently the old statistics of herniotomy present a high mortality when contrasted with recent operations. This striking contrast was brought about not solely by an improved technique, or by the introduction of antiseptic surgery, but it is largely owing to the modern teaching that it is dangerous to delay an operation, if the strangulation is not relieved by gentle taxis persisted in not for hours and days, but only for fifteen minutes, and at the utmost for half an hour. Modern surgery recognizes the safety of an early operation for strangulated hernia, and the results which have been obtained have demonstrated the wisdom of the change in practice. Vain and prolonged attempts at reduction of a strangulated hernia aggravate the causes which have produced the strangulation, and hasten the pathological changes in the strangulated intestinal loop which arise from the strangulation. If delay is dangerous in a case of strangulated hernia, what can we expect of a laparotomy for intestinal obstruction when postponed until the patient has been exhausted, or the local conditions necessitate complicated operative measures? In strangulated hernia the destructive changes in the constricted intestinal loop, affect by continuity and contiguity primarily only a limited peritioneal surface, while in intestinal obstruction the seat of obstruction is in direct communication with the entire peritoneal cavity, which becomes the seat of a rapidly fatal, septic inflammation if gangrene or perforation have caused the inflammation. A recent intestinal obstruction due to a change of visceral relations, such as flexion, volvolus, and invagination, if subjected to operative treatment before consecutive pathological changes have occurred, would offer but little difficulty to mechanical correction of the displacement, and as in such cases the intestinal tube would be in a healthy intact condition, the danger of the operation would not be greater than that of an ordinary ovariotomy.

I think enough has been said in favor of early operation in all cases where the signs and symptoms indicate the existence of an obstruction which does not yield to milder measures. Cases of intestinal obstruction are surgical lesions in every sense of the word, and should be treated from the very beginning upon common sense surgical principles. To temporize with such cases by the adminis-

tration of uncertain drugs must be looked upon as evidence of ignorance or a relic of barbarism. The treatment of a case of intestinal obstruction upon the expectant plan until gangrene or perforation has taken place, which, if submitted in time to proper surgical treatment, might have been cured by one stroke of the scissors should be considered as gross negligence for which the modern aggressive physician and surgeon can offer no justification or apology. The future progress of abdominal surgery will conquer the difficulties which now surround the diagnosis and treatment of intestinal obstruction. Experimental research and more careful and accurate clinical observation will solve the difficult problems which now surround us in this as yet unexplored field of surgical labor.

Laparotomy for intestinal obstruction should not be undertaken by every tyro in surgery. He who undertakes it should be master of the situation, familiar with every detail of the technique of the different operative procedures and fully conversant with the manifold complications with which he may be confronted. Every possible contingency must be fully considered before the abdomen is opened, as this is an operation where unnecessary hesitation and loss of time weigh heavily in the balance on the side of failure. Like other abdominal operations laparotomy cannot be mastered in the lecture room or even under the tuition of experienced surgeons. Those who expect to perform this operation must, in the first place, have a perfect knowledge of the structure and relations of all the abdominal organs in conditions of health and disease, and must acquire the necessary operative skill on the cadaver, and then, what is still more important, should make the more important operations on the living animal. It is not necessary or even desirable that every physician should become a laparotomist, but in every section of the country, distant from the medical centers, some one should interest himself in this branch of surgery and prepare himself to meet such emergencies. Unlike a patient suffering from an ovarian tumor, a patient affected with acute intestinal obstruction cannot be transported great distances, and as loss of time leads to disastrous consequences, it is not always possible to secure the services of a surgeon versed in abdominal surgery, from a distance. For such contingencies I should recommend that at least one member of every county or district medical society should familiarize himself sufficiently with the details of intestinal surgery so that patients in his

neighborhood may reap the advantages of modern aggressive surgery at the proper time and at their own homes.

### a. Preparations for the Operation.

The most careful and perfect preparations should be made for the operation. The presence of at least three reliable and intelligent assistants is an absolute necessity. As an exventration may become necessary and exposure of the intestines to a cool atmosphere is productive of shock, an equable temperature of from 80° to 85° Fahr. should be maintained in the operating room from the beginning to the end of the operation. Opinions among operators may still differ as to the wisdom or even propriety of using antiseptics in a healthy peritoneal cavity, but no one at the present day would have the courage to oppose the use of *strictest antiseptic precautions in securing an aseptic condition for everything that will come in contact with the wound or the peritoneal surfaces.* The operating room must be cleared of everything, except the bare walls and windows, and the whole of its interior surface washed with a strong solution of sublimate or carbolic acid. The table and stands are disinfected in a similar manner. The blankets if not perfectly aseptic can be covered with clean linen sheets. Heat is the most reliable, safest and cheapest sterilizer, and can be used for the disinfection of towels, napkins, instruments and wash-basins. *The operator must satisfy himself of the aseptic nature of everything which is used inside of the peritoneal cavity.* The abdomen of the patient and the operator's and assistants' hands are rendered aseptic by washing with potash soap and warm water, and afterwards with a 1-1000 solution of corrosive sublimate. The water used for solutions and sponges is sterilized by boiling. For the protection of prolapsed intestine compresses of aseptic gauze or napkins are better than sponges, and the temperature of the parts is maintained, not by pouring warm water on the compresses, but by removing them and applying new ones wrung out of warm water.

The danger of using corrosive sublimate solution within the peritoneal cavity is well shown by Kümmell's experience.[1] He made nine laparotomies, using for the sponges a 1-5000 solution of sublimate, and all the patients recovered without an unpleasant

[1] Ueber Sublimat-intoxication bei Laparatomien. Centrallblatt f. Chirurgie, No. 22, 1886.

symptom. Then he met with two cases of sublimate intoxication in succession, having used a solution of the same strength. One of the patients died on the fourth day and the post-mortem revealed intestinal lesions characteristic of acute mercurial poisoning. The other patient recovered after a lingering illness during which the symptoms of mercurial intoxication were well marked. He cautions against the use of sublimate in debilitated, anæmic individuals, or in patients suffering from renal disease. In cases where the peritoneal cavity is in a healthy aseptic condition the use of any of the stronger antiseptics is contra-indicated. For the cases where septic peritonitis, suppuration, gangrene or perforation exists, a two per cent. solution of boracic acid, or a saturated solution of salicylic acid (0.3 per cent.) should be kept in readiness for flushing the abdominal cavity. Bands of rubber or fine rubber tubing should always be on hand, as well as a good assortment of aseptic silk, well prepared catgut, glass drains, decalcified perforated bone plates, and a good assortment of needles and forceps. Stimulants and means to make auto-transfusion must never be absent, as prompt interference when symptoms of shock make their appearance, may prove the means of restoring the force of the circulation until reaction can be established by other measures.

Weir[1] suggests the administration of a hypodermic injection of 1-100 to 1-80 of a grain of atropia and a large rectal enema of brandy before the anæsthesia, for the purpose of increasing the force of the heart's action. During the operation the peripheral circulation is best kept up by placing the patient on a rubber bed, filled with hot water, and in the absence of such a contrivance by applying to the extremities rubber bags or bottles filled with hot water.

### b. Anæsthesia.

A number of American surgeons have recently expressed a preference for chloroform to ether as an anæsthetic in abdominal operations, as it is less likely to produce vomiting before, during, and after the operation. Another serious objection to the use of ether, especially in persons advanced in years, is the frequency with which bronchitis is produced when this anæsthetic is exclusively used. The use of chloroform, however, is also not free from objec-

[1] On the Technique of the Operations for the Relief of Intestinal Obstruction. The Medical Record, Feb. 2, 1888.

tion. The depressing effect of this anæsthetic on the action of the heart is well known, and as the force of the circulation is almost without exception seriously impaired in these cases, its prolonged use might result in dangerous consequences. The best course to pursue is to follow the use of chloroform by ether. The retching and bronchorrhœa are prevented by placing the patient first under the influence of chloroform and the deleterious effects of the prolonged use of this agent are avoided by keeping up the narcosis during the operation with ether. From the time the first incision is made until the abdominal wound is closed, the patient must be kept profoundly under the influence of the anæsthetic, inasmuch as any interruption will cause an unnecessary delay in the operation and may result in complications which are not easily remedied. Irrigation of the stomach should always precede the administration of the anæsthetic, as evacuation of the stomach by preventing vomiting, will guard against the entrance of foreign material into the larynx and trachea, which might produce asphyxia during the narcosis, or pneumonia later.

### c. Incision.

Differences of opinion still exist among surgeons as to the size and location of the abdominal incision. The advocates of exventration argue in favor of a long incision through the median line. Kümmell advises that it should be carried from the ensiform cartilage to the pubis for the purpose of affording free access to every part of the abdominal cavity. On the other hand, a number of distinguished surgeons, among them Madelung, Czerny, and Obalinski, are in favor of a small incision. Polaillon[1] is strongly in favor of a lateral incision in opening the abdomen for the relief of intestinal obstruction in all cases where the seat of obstruction can be reached more directly by such incision. He also claims that in cases where extensive meteorismus is present, the distended intestines are more prone to prolapse and are more difficult to return through a median than a lateral incision. He thinks that this is due to a lesser degree of intra-abdominal pressure in the iliac than in the middle abdominal region, and that in the former the muscular fibres keep the margins of the wound in contact. He opens the abdomen in the ilio-inguinal region by an incision parallel with the fibres of the external oblique muscle, and if occasion requires, this can be made

[1] Gazette Médicale de Paris. April 25, 1885.

sufficiently large to permit exploration of the abdomen by the introduction of the whole hand. In lateral laparotomy exploration is less easy, but this operation is indicated in all cases of localized obstruction, circumscribed adhesion, or when any symptoms render it probable that the obstruction exists in one or the other side of the abdominal cavity. In case a distinct swelling, the probable cause of the obstruction, can be detected in the ileo-cæcal region, the ascending or descending colon, as will probably be the case in ileo-cæcal and colic invagination, volvolus of the sigmoid flexure, tumors of the cæcum and colon, the incision should be made over the most prominent part of the swelling, as such a course affords the most ready access to the seat of obstruction and greatly facilitates the operative procedures which may become necessary. In reference to these points J. Greig Smith regards it as only less than a surgical calamity to perform median laparotomy for obstruction in the colon, since in the majority of cases it must, he says, be supplemented by a transverse or lumbar incision.

In all other forms of intestinal obstruction, and in all cases where it is found impossible to ascertain the nature and location of the obstruction, the incision should be made through the median line. Not much time should be consumed in making the external incision. With successive strokes of a sharp scalpel the tissues are rapidly divided until the subperitoneal layer of fat is reached. This is picked up and nipped between two toothed forceps; when the peritoneum comes into view it is seized and divided in a similar manner. The incision is then enlarged as circumstances may require by introducing the left index and middle finger into the peritoneal cavity and dividing the tissues between them with a blunt-pointed bistoury or scalpel. Hæmorrhage is arrested as it occurs by applying hæmostatic forceps to the bleeding points; this in most instances obviates the application of ligatures. In reference to the size of the incision, this will vary in accordance with the difficulties which are encountered in locating the seat of obstruction and in removing the cause or causes which have produced the occlusion. With few if any exceptions it must be large enough to admit the introduction of the whole hand. As a rule it may be stated that the ease in diagnosis increases with the size of the incision, and the danger which attends searching in the dark for the seat of obstruction more than overbalances the slight increase of risk incident to a

large incision. Intra-abdominal manual exploration through a small incision is, in most instances, an unreliable diagnostic measure, as the cause of obstruction may be of such a character as entirely to elude such method of examination. It is a well known fact that the location of the seat of obstruction, even in the post-mortem room after a full abdominal section, has sometimes been found a difficult task. A large incision shortens the operation by facilitating the intra-abdominal examination and the operative treatment of the obstruction, and the immediate risks of the operation are diminished in proportion to the shortening of the time required in its performance.

### d. Intra-Abdominal Examination.

The first and most important object of the external incision is to enable the surgeon to make a satisfactory intra-abdominal examination. Unless a positive diagnosis has been made beforehand the first incision is an exploratory one. Exploration of the abdomen for the purpose of locating the obstruction and ascertaining its nature is a more difficult procedure than in cases of abdominal tumors, and on this account the first or exploratory incision must be made at least large enough to enable the surgeon to combine ocular inspection with manual exploration.

Smith[1] says: "The best guide to the seat of operation is not manual exploration, but visual examination, assisted, if necessary, by extrusion of bowel."

The surgeon must bear in mind that in nine out of ten cases of intestinal obstruction the cause is located in the lower portion of the abdominal cavity, below the umbilicus, and that in the great majority of these cases it will be found either in the right or left inguinal region.

Bryant lays down the rule that in all abdominal operations for intestinal obstruction, when the seat of obstruction cannot be readily found, the surgeon should find the cæcum, since it is from it that he will obtain his best guide. If this be distended, he will at once know that the cause of obstruction is below; if it be found collapsed, or not tense, the obstruction must be higher up. The naked eye appearances of the intestine that presents itself in the incision, will serve a useful purpose in deciding whether it belongs to the part of intestine above or below the seat of obstruction. In all cases of

[1] The British Medical Journal, Aug. 29, 1885.

intestinal obstruction the bowel above the seat of obstruction is dilated and congested, while below the obstruction it is empty, pale and contracted. The contents of the presenting loop, if distended, will also indicate whether it is near or distant from the obstruction; if near, it will probably contain fluid fæces and gas; if distant, only gas. If the obstruction is located in the lower portion of the small intestine, or in any portion of the colon, without exception a distended loop above the obstruction presents itself in the wound.

Fowler[1] has called attention to the fact that in all forms of intestinal obstruction the empty contracted portion of the intestine, corresponding to the part below the obstruction is always found in the pelvis, and that it may be most easily reached towards the right side. He explains this on the supposition that during the violent and continued peristalsis and gradual distention of the bowel above the obstruction, the smaller and less active portion of bowel below, after expelling its contents, is forced downwards into the pelvis, whilst the distended, and therefore specifically lighter portions rise to the surface. The pelvis also is too small to hold a distended loop. If the seat of obstruction cannot be readily found by manual exploration of the regions where it occurs most frequently, two methods of further examination present themselves. The presenting bowel is drawn forward into the wound and systematically examined step by step, as it glides through the fingers of the surgeon who replaces the loops as they are examined. This method of examination is only safe and practicable where the distention of the intestines is moderate, and the intra-abdominal pressure not excessive, so that loop after loop can be drawn forward, examined and returned without injury to the intestine. If this method of examination is selected it would be advisable to secure the portion of intestine first examined near the wound by passing a strip of gauze through its mesentery, so that in case the obstruction is not found in one direction the examination in the opposite direction can be made without passing the portion already examined again through the operator's hands. Mikulicz attains the same object by an assistant holding the first knuckle that appears against one of the angles of the wound while the operator examines and returns immediately coil after coil until the obstruction is found. During the examination prolapse of the intestines is pre-

[1] The Lancet, June 30, 1883.

vented by an assistant who guards the opening with an antiseptic compress, and thus as inspection is progressing unnecessary exposure of the intestines is prevented.

For the purpose of avoiding exventration and its evil consequences in cases of intestinal obstruction with great distention of the abdomen, Madelung[1] has recently described a new method of dealing with the distended intestines. He makes a comparatively small incision through the median line and brings the first distended knuckle of intestine that presents itself into the wound and by passing two fixation ligatures through the mesentery near the gut and making traction upon them, draws it forward until both limbs of the loop can be ligated with a strip of antiseptic gauze at a point corresponding to the external surface of the wound. The patient is now placed on his side and the prolapsed loop is incised over the convex surface and its contents evacuated. The gauze ligature is slowly loosened so as to prevent flooding of the wound with intestinal contents by too forcible escape of the fluid contents. When the spontaneous escape ceases a Nélaton's catheter is introduced into the incised bowel for the purpose of facilitating the escape of intestinal contents. Fifteen minutes are spent in efforts aimed at evacuation of the distended paretic intestine, during which time anæsthesia is suspended in order to effect still further evacuation of the bowel above the seat of obstruction by the contraction of the abdominal muscles. After all discharge has ceased the visceral wound is cleansed and sutured and the ligatures on each side of the wound are tied so as to prevent undue tension upon the sutures after the gut has been replaced. The ligatures are left hanging out of the wound to serve as guides to the incised part of the gut after the completion of the intra-abdominal examination. The abdominal incision is now enlarged and the intestine drawn forward and careful search made for the obstruction. If this is not found the incised loop of bowel is brought into the wound, the sutures of the visceral wound and the two ligatures removed, and an artificial anus established by stitching the intestinal wound to the margins of the external wound, and the portion which is not required for this purpose is also sutured.

While Madelung's procedure cannot fail in facilitating exploration of the abdomen by diminishing intra-abdominal pressure

[1] Zur Frage der operativen Behandlung der inneren Darmeinklemmungen. Archiv. f. Klin. Chirurgie, B. XXXVI, p. 283.

it is questionable if the room thus gained is a sufficient recompense for the time lost and the additional risks incident to an intestinal wound in a place where it is not required. If a laparotomy is decided upon in the treatment of an intestinal obstruction, it is made for the distinct purpose of finding and removing the obstruction; hence if the patient's strength is such as to warrant this treatment at all, the surgeon should not close the abdomen with the principal object of the operation unaccomplished. How difficult it is to find the obstruction in some cases is well shown by Madelung, who in several cases where the seat of obstruction could not be located during life, requested the pathologist when he made the post-mortems to locate the obstruction by introducing his hand through an incision, allowing him from ten to twenty minutes for the exploration; in every instance he failed to find or locate the obstruction within the specified time. Where the ordinary methods of examination through an incision large enough to permit the introduction of the hand prove themselves inadequate in locating the obstruction, after a search of from ten to twenty minutes, it is useless and unwise to persist in pursuing the same course. Such cases should be dealt with by resorting to exventration. This method of exploration was first suggested by Harber, in 1872, and practiced by Kümmell[1] in 1885. The large incision which he advocates is necessarily followed by prolapse of the distended intestines and enables the surgeon to examine rapidly and accurately every portion of the intestinal canal with a view of locating the obstruction, with little or no risk of inflicting injury during the examination. The greatest objection that has been urged against it is that it is sometimes exceedingly difficult to replace the intestines even after the cause of obstruction has been removed, as the paretic intestines are slow in regaining their normal peristaltic action, and that during the attempts at replacement the intestines are often injured.

The proper way to effect replacement is to follow Kümmell's advice and instead of making direct compression, to resort to protection of the intestines by covering the whole mass with a warm, moist, aseptic compress, the margins of which are tucked in under the abdominal incision. In this way the bowels are protected against

[1] Ueber Laparotomie bei innerer Darmeinklemmung. Deutsche Med. Wochenschrift, No. 12, 1886.

the injurious effects of irregular direct pressure an are guided back into the abdominal cavity as the wound is closed, by tying the sutures, already in place, from above downwards. If uniform, diffuse, gentle pressure fails in replacing the intestines, then the margins of the abdominal incision should be lifted with blunt hooks, an expedient which renders material aid in effecting replacement. Should the obstacles be so great as to frustrate all attempts at replacement it is better to resort to incision and evacuation of the most distended portion of the prolapsed bowel, which can be done with greater safety and more marked effect than by the plan devised by Madelung. This is well illustrated by a case that recently came under my observation, which I will report in brief.

The patient was a woman forty-eight years of age, the mother of eight children, the last being an infant ten months old. She stated that she had suffered during the last year from constipation, but had always been promptly relieved by cathartics. Ten days before her admission into the Milwaukee hospital, April 18, 1888, symptoms of acute intestinal obstruction appeared, which increased in intensity until fæcal vomiting supervened the day before she came under my observation. She had been treated by high injections and irrigation of the stomach, the former without any effect, the latter affording great relief. The patient was well nourished and her general appearance gave rise to no suspicion of malignant disease in any of the organs. She had passed nothing per viam naturalis since she was taken ill, and the retching and vomiting were persistent. The abdomen was uniformly and enormously distended; upon the surface of the abdominal wall the outlines of some distended coils of intestine could be distinctly seen. The tympanitic distention of the abdomen interfered with respiration, the respiratory movements being shallow and rapid, lips cyanosed and extremities cold. Examination per vaginam and rectum revealed nothing as to the seat and nature of the obstruction. Percussion and palpation of the abdomen yielded the same negative results.

Laparotomy was performed under the most careful antiseptic precautions. The stomach was irrigated and chloroform used as an anæsthetic. The operation was performed with the patient upon a rubber bed filled with hot water. The first incision was made half way between the umbilicus and pubes and large enough to permit the introduction of the hand. As soon as the peritoneal cavity was

opened a loop of small intestine, distended to three times its natural size and intensely congested, presented itself. This was pushed aside and similar loops made their appearance. I now introduced my hand and found that the cæcum and entire colon were also enormously distended, which satisfied me that the obstruction must be located low down in the colon, or the upper portion of the rectum; but the most careful attempts by manual exploration failed in furnishing any clue as to the location or nature of the obstruction. The incision was enlarged upwards an inch above the umbilicus and downwards to the pubes for the purpose of effecting complete exventration. Two assistants caught the intestines as they prolapsed in warm, moist aseptic compresses, and as the abdominal cavity was nearly empty I could explore with ease the sigmoid flexure, which I had reason to believe was the seat of the obstruction; as this part of the colon was only greatly distended, I had to proceed lower down with my exploration and finally found a circular carcinoma below the sigmoid flexure in the pelvic cavity near the junction of the colon with the rectum.

As resection in this locality was impossible, and as for the same anatomical reasons an anastomosis could likewise not be made, I was forced to establish an artificial anus. In examining the colon with the view of the best locality for making a colostomy, I found that the enormous dilatation of this part of the intestine had resulted in such an elongation as to force the transverse colon in a downward direction nearly as far as the brim of the pelvis. I made an incision in the left inguinal region above Poupart's ligament, two inches in length and sutured the parietal peritoneum to the skin. Into this incision a loop of the displaced transverse colon was pushed by the hand within the abdomen and fixed by a number of sutures. When this was done I attempted to replace the intestines, but after trying all the ordinary devices I had to abandon the attempt. The patient was now placed on her side, and one of the most distended loops was grasped, held over a basin, and punctured with a large trocar, while the remaining intestines remained covered with the warm compresses. As the escape of gas and fluid fæces through the cannula was very slow, an incision an inch and a half in length was made in the gut. As the intestine did not contract, the escape of contents was very slow, and I had to resort to pouring out of the contents, as it were, by seizing the gut several feet above and below the incision

and elevating it; a large quantity of fluid fæces was literally poured out. When no further evacuation could be effected the visceral wound was closed by the continued suture, and after thoroughly disinfecting the loop, the bowels were returned without difficulty.

The abdominal incision was closed in the usual way, only that I added two tension sutures as a matter of precaution. After the abdominal wound was closed and dressed, the colon that had been stitched into the inguinal wound was incised and the margins of the incision separately stitched to the sides of the external wound. A considerable quantity of gas and fluid fæces escaped. The vomiting ceased after the operation and the patient rallied under the effects of stimulants. The abdominal distention had diminished greatly the next day, and disappeared almost completely on the second day. The patient's general condition continued to improve until the tenth day after the operation, when symptoms of collapse set in which persisted until she died on the following day. The post-mortem showed that the median incision had healed with the exception of the skin, and that the artificial anus had served as a perfect outlet to the intestinal contents. Small intestines restored to nearly normal size, and incision healed, the fine silk suture being completely imbedded. The cause of the recent diffuse septic peritonitis was traced to perforation of a small abscess behind the carcinoma. The constriction caused by the carcinoma had reduced the lumen of the bowel so much that it was only permeable to the tip of the little finger.

I shall refer again to the relation which exists between chronic causes giving rise to acute obstruction. This case also illustrates the importance of establishing the artificial anus, when such a procedure cannot be avoided, not in the laparotomy wound, but in the right or left inguinal region. When exventration is practiced it is essential to furnish the prolapsed and dilated intestine with an artificial covering which shall act as nearly as possible as a substitute for the abdominal parietes. This is best accomplished with warm compresses in the hands of one or two reliable assistants. After the surgeon has found the obstruction it becomes necessary to demonstrate the permeability of the remaining portion of the intestinal canal, as it has happened that after a successful removal of an obstruction, patients have died because a second obstruction was overlooked. Of course in such cases the search for additional

obstructions must be extended below the obstruction which has been found and removed. An infallible test for ascertaining the permeability of the remaining portion of the intestinal canal is furnished by rectal insufflation of hydrogen gas. In cases where after exventration it is not possible to find the obstruction by examination of the distended portion of the intestine, the contracted empty portion below the obstruction can be brought into sight by the same means, and a search for the obstruction made from below upwards by examining the bowel as it becomes inflated, until the seat of obstruction is reached.

### Operative Treatment of the Obstruction.

#### 1. Intestinal Anastomosis.

What shall be done if the obstruction cannot be found after all diagnostic resources have been exhausted? Shall we establish an artificial anus and leave the patient to the inevitable fate of remaining a sufferer from this loathsome condition the balance of his lifetime, should he recover from the operation? Under such circumstances the surgeon assumes a great responsibility in establishing an artificial anus high up in the intestinal canal, even as far as the immediate effects of the operation are concerned. The paretic bowel below the seat of the artificial outlet, unable to empty itself of its contents, constitutes an immediate and remote source of danger, as it leaves that portion of the bowel between the new opening and the obstruction, in the same condition as before the operation, and permanent exclusion of a considerable portion of the intestinal canal alone may subsequently destroy life by progressive marasmus. In such cases I should advise the following plan of treatment: The empty bowel below the seat of obstruction, if not already found, should be inflated with hydrogen gas per rectum, and the highest portion of the inflated bowel drawn forward into the wound, and two rubber bands passed through its mesentery about four inches apart and held in place by an assistant. The surgeon now locates as near as he can the lowest portion of the bowel on the obstructed side, which is also brought forward into the wound and similarly secured. The bowel on the proximal side is incised on the convex surface to the extent of an inch and a half; through this incision the contents are evacuated as far as possible, after which all the four rubber bands are tied and the bowel on the distal side

incised in a similar manner. Into each of these incisions a decalcified perforated bone plate is inserted and, with the lateral suture armed with a round needle, the margin of the wound on each side is transfixed. After the plates and sutures are in place the loops are thoroughly disinfected and the serous surfaces to the extent of the size of the plates are lightly scarified with the point of a needle, when the wounds are placed *vis-a-vis*, and the corresponding four threads tied together with sufficient firmness to secure perfect coaptation of the serous surfaces. The sutures are cut short and their ends buried as deeply as possible by pushing them in between the approximated bowels with a director or blunt scissors. A few superficial stitches of a continued suture will enhance the safety of the operation. In this manner an anastomosis is established with the exclusion of probably only a small portion of the intestinal tract.

After uniting two intestines by approximation plates in the formation of an intestinal anastomosis it appears at first sight as though on the slightest distention of the intestines, leakage of gas or fluid contents would take place between the serous surfaces. That this fear is unfounded I have satisfactorily proved by a number of experiments. The intestines of animals recently killed were used and an anastomosis made between the lower portion of the ileum and the colon. The colon was tied below the new opening and fluid forced into the ileum on the proximal side. The pressure was measured by a mercury gauge. It was found that no leakage occurred under a pressure of two pounds to the square inch, continued for thirty seconds. As even in cases of great intestinal distention the pressure can never reach this degree, leakage from mechanical or physical causes will never take place from the new opening. The margins of the visceral wounds act like valves and when the serous surfaces are kept in contact by the plates, prevent the escape of gas or fluids into the peritoneal cavity. The safety and practicability of this operation I have abundantly demonstrated by my experiments on animals and by a number of operations on the human subject. The operative treatment of the obstruction will depend upon the location and nature of the obstruction. If it is decided not to remove the obstruction, either on account of its intrinsic harmless character, aside from its mechanical effect, or on account of its extent, in which case the removal would be an imminent source of

danger to life, or if after removal a recurrence in the near future appears inevitable, an anastomosis is established between the intestine above and below the obstruction by lateral apposition with decalcified perforated bone plates. By this operation the continuity of the intestinal canal is restored with permanent exclusion of the seat of obstruction.

In cases of cicatricial stenosis as a cause of obstruction, intestinal anastomosis, for instance, would be a vastly more safe operation than resection and circular enterorrhaphy, and would secure equally well restoration of the continuity of the intestinal canal. In cases of carcinoma of the intestine with extensive infiltration of the lymphatic glands a resection followed by circular enterorrhaphy must always constitute a hazardous precedure, and even if it proved successful an early recurrence of the disease would be inevitable. Under such circumstances it is advisable to establish in preference an intestinal anastomosis, which will effectually exclude the cause of obstruction, alleviate suffering and prolong life. The opponents of laparotomy in cases of acute intestinal obstruction have urged as one of the principal reasons for their opposition that the dilated inflamed intestine above the obstruction is not in a condition to undergo reparative processes when the operation demands a solution of continuity in this part of the intestinal tract. Circular enterorrhaphy under such circumstances is a very dangerous procedure for two reasons: 1. It becomes necessary to unite bowel ends of unequal size. 2. The inflamed intestine has undergone textural changes illy adapted for suturing, as the sutures readily cut through the softened tissues. A number of clinical observations have satisfied me that the failures which have attended circular enterorrhaphy in such cases, are not due to a lack of healing capacity on the part of the inflamed end of the bowel, but to the mechanical difficulties which are encountered in the approximation and retention of the bowel ends, and the danger of the cutting through or yielding of the sutures. I believe on the contrary that in case septic peritonitis does not exist, the vascularity of the bowel above the seat of obstruction constitutes a favorable condition for rapid union. To demonstrate the correctness of this assertion, I made the following experiments:

*Experiment 1.* Dog, weight fourteen pounds. The whole abdomen was shaved and thoroughly disinfected, and while the animal was under the influence

of ether a small incision was made in the left iliac region, and a loop of intestine drawn forward and ligated with a band of iodoform gauze, the ligature being tied with sufficient firmness to cause complete occlusion, intestine returned and wound sutured. Seventy-three hours later, the dog was again etherized and median laparotomy performed. Distended vascular loops of the intestine came into the wound, which were pushed aside and the hand introduced, which being passed towards the left inguinal region at once came in contact with the ligated portion which had formed adhesions to the parietal peritoneum and neighboring intestinal loops. The adhesions were separated and the ligated loop drawn out of the wound. Above the ligature the bowel was at least one and a half times larger than immediately below the seat of obstruction, very vascular and contained gas and fluid fæces. The degree of dilatation diminished from below upwards. The seat of obstruction was eight inches above the ileo-cæcal valve, and the gauze ligature was covered with a thick layer of plastic lymph. The obstruction was left and the continuity of the intestinal canal restored by an ileo-colostomy with perforated decalcified bone plates. The animal, which was not vigorous before the experiment was made, appeared much prostrated and died twenty-four hours after the operation. The necropsy showed that the bowel above the constriction had to a great extent recovered its normal size and color. The two intestines where anastomosis had been made were firmly adherent, the groove between them, corresponding to the length of the plates, filled in with plastic lymph. New opening permeable; no leakage at point of operation under hydrostatic pressure. No peritonitis.

*Experiment 2.* Dog, weight twenty-four pounds. Obstruction produced in a similar manner as in preceding experiment. Seventy-five hours later, operative treatment of obstruction by laparotomy. The seat of obstruction was again readily found by manual exploration of the abdomen. Bowel above seat of constriction at least twice the normal size and highly congested. Peristaltic action sluggish, responding very slowly and imperfectly to mechanical irritation. Gauze band buried under a ring of plastic lymph, which bridge-like united the gut below and above the constriction. As the obstruction was located about the middle of the ileum, an ileo-ileostomy by lateral apposition with decalcified perforated bone plates was made, leaving the gauze band undisturbed. The incision into the bowel above the seat of obstruction showed that all the coats were thickened and softened, while below the obstruction, only the mucous membrane was in a state of catarrhal inflammation. About eight inches of the bowel including the seat of constriction were excluded by the operation. The animal showed no signs of suffering or illness after the operation, and when killed after the expiration of twenty-one days was in excellent condition. During this time the appetite was good and fæcal evacuations normal. Gauze band completely encapsuled, and close to it an acute flexion of the bowel; excluded portions adherent along convex surface to each other; bowel above constriction about one-third larger than below. New opening admits the tips of two fingers.

*Experiment 3.* Dog, weight twenty-eight pounds. Laparotomy seven days after complete obstruction had been caused by ligation of small intestine

with gauze band through a small wound in the left inguinal region. Tympanites moderate. Obstruction found sixteen inches above the ileo-cæcal region. Peristaltic action almost suspended in bowel above obstruction, normal below. Intestine above the constriction dilated to twice its normal size, exceedingly vascular, containing solid fæcal masses, fluid fæces and gas; below, empty, contracted and anæmic. Exclusion of six inches of the intestine at seat of obstruction and restoration of continuity of intestinal canal by ileo-ileostomy with decalcified perforated bone plates. After operation function of intestinal canal normal and appetite good. Killed eight days after operation; no peritonitis; adhesion of omentum to line of abdominal incision; gauze band completely covered by a plastic exudation; a number of adhesions between adjacent intestinal loops. Point of operation situated in the center of a horse-shoe shaped loop of intestine, which was found to be the excluded portion. Intestine above obstruction about one-fourth larger in size than below. Excluded portion of bowel empty. At seat of anastomosis a mass of straw and hair had accumulated on proximal side. New opening large enough to admit two fingers.

*Experiment 4.* Dog, weight thirty-four pounds. Complete obstruction of small intestines by ligation with gauze band through a small wound in the left iliac region. Operative treatment by laparotomy one hundred and twenty hours later. This animal vomited several times shortly before the operation. Bowel at seat of obstruction adherent to adjacent intestines. Obstruction readily found and brought into the incision. Intestine above constriction twice its normal size, dark purple in color, tissues swollen and very much softened. Below constriction bowel empty, collapsed, pale, and only the mucous membrane in a state of catarrhal inflammation. The dilated bowel contained gas and fluid fæces. Peristaltic action in this part nearly suspended, the response to mechanical irritation being slow and imperfect. Below the obstruction function of bowel unimpaired. As the occlusion was only four inches above the ileo-cæcal valve, it was found impossible to limit the anastomosis to the ileum, consequently the continuity of the bowel was restored by an ileo-colostomy, uniting the ileum just above the obstruction with the colon above the cæcum, using the perforated approximation plates. The gauze band was left *in situ*. The animal showed no untoward symptoms after the operation, and was killed twenty-one days later. During this time appetite was good and intestinal functions normal. A number of adhesions were found at the site of operation between adjacent intestinal loops. Gauze band completely encysted. Some crude material, as straw, hair and fragments of bone, was found on the proximal side of new opening. Anastomotic opening large enough to admit tips of two fingers; union between approximated portions of intestine so complete that it presented all around the appearance as though their peritoneal surfaces were continuous.

These experiments show conclusively that in acute obstruction even after seven days, the bowel above the obstruction is capable of undergoing a rapid reparative process and that adhesive union takes place as early, if not earlier than in operations upon a normal

intestine. The experiments likewise prove the greater safety of anastomosis by lateral apposition with decalcified perforated bone plates than of circular enterorrhaphy in restoring the continuity of the intestinal canal after resection. Anastomosis, after resection for intestinal obstruction, can be made in the same manner between the proximal and distal part after the resected ends have been closed by invagination and a few stitches of the continued suture, as when the obstruction is not resected but excluded.

In cases of congenital atresia of the small intestines, most frequently met with in the upper portion, anastomosis should always take the place of circular resection, as the operation can be done in less than twenty minutes, an exceedingly important matter as far as the immediate effects of the operation is concerned in infants, at the most only a few days old. In cases where such a congenital defect is suspected the abdomen should be opened in the median line, being careful not to cut through the umbilicus, when the seat of obstruction can be readily and rapidly located by inflation of the stomach and rectum with hydrogen gas. It is necessary to inflate from both directions, as in some cases the atresia is multiple. In cases of cicatricial stenosis of the pylorus a gastro-enterostomy by lateral apposition with approximation plates is a safer operation than resection, or the procedures recommended by Loretta and Mikulicz, while the functional result is equally, if not more, satisfactory. In carcinoma of the pylorus, where resection is contra-indicated on account of the extent of the disease, or its extension to neighboring organs, or because glandular infection has taken place, suffering can be diminished and life prolonged by making a gastro-enterostomy, substituting for the tedious double suturing as advised by Wölfler the perforated approximation plates. During the last year I made four such operations and with such satisfactory results as far as the operation was concerned that I am induced to report them in this connection with the hope that others may give this method of operating a trial in similar cases. I have made it a rule that the patient should abstain from taking food by the stomach for at least twenty-four hours before the operation, and rely for a few days, at least, entirely upon rectal alimentation, allowing only pieces of ice to quench thirst.

The operations were performed as follows: The evening before the operation the stomach was washed out by the syphon

tube and again just before the anæsthetic was administered. For the last irrigation a five per cent. solution of salicylate of soda was used. In all of these cases the incision was made through the median line and extended from near the ensiform cartilage to the umbilicus. The opening in the stomach was made parallel to the long axis of the organ and at least an inch and a half distant from the margin of the tumor. A continued suture of fine silk was applied around the whole circumference of the opening both for the purpose of arresting hæmorrhage and preventing bulging of the mucous membrane. In the intestine the opening was made between two rubber ligatures, so as to prevent any extravasation of intestinal contents and the margins of the wound were sutured in a similar manner. The opening in the intestine was made first and the plate introduced and sutures adjusted and the loop retained in the lower angle of the wound, covered by a warm compress. The large curvature of the stomach near the pyloric orifice was then drawn sufficiently forward into the wound to make the incision and introduce the plate. When everything was ready for adjustment, the parts around the visceral wound were carefully disinfected, dried and the serous surface lightly scarified with an ordinary needle over a surface corresponding to the size of the plate; the new openings (wounds) were then brought opposite each other and a fine silk suture, embracing only the serous and muscular coats, was applied behind the lower middle-plate-suture and tied; the middle lower suture was now tied, while an assistant approximated the two openings; the lateral sutures were next tied, and lastly the anterior middle. The sutures were all cut short and ends buried. During the tying of the sutures, it is necessary to exercise caution that the margins of the visceral wound are well embraced by the plates all around. As in these cases the weight of the intestine exerts considerable tension, I have taken the precaution in my two last cases to apply a superficial continuous suture anteriorly after tying the four sutures, so as to approximate the serous surfaces over the anterior margins of the plates. The necessary preparations being made, with good assistance the operation can be finished in from twenty to thirty minutes. Neither shock nor peritonitis was observed in any of the cases. Usually on the third day small quantities of peptonized milk and beef tea were given at short intervals and solid diet during the second week.

*Case I.* Male, aged sixty-five. Symptoms of pyloric stenosis for one year. Emaciated to a skeleton; œdema of legs; unable to retain food of any kind for more than a few hours. The patient was so anæmic and prostrated that he was only partially anæsthetized. During the operation the pulse became almost imperceptible, and brandy had to be administered subcutaneously, with lowering of head, and hot applications externally. An hour after the operation the pulse was stronger than before it was commenced. Rectal feeding; only slight rise in temperature on second day; no pain. On the third day small quantities of liquid food by the stomach. The heart's action gradually failed and the patient died of marasmus five days after the operation. The post-mortem revealed that the plates were still *in situ*, adhesions firm and opening patent. No peritonitis. In this case the carcinoma was circular and limited to the pylorus. Anastomosis just below the duodenum. The intense suffering had made the patient desperate, and although the nature of the disease and the probable outcome of the operation had been fully explained to him, he begged to have it done, with a perfect understanding that at best it would afford only temporary relief. I am quite confident that the operation did not shorten his life.

*Case II.* Male, aged forty-seven. Duration of disease eighteen months; obstinate vomiting; great emaciation and œdema of legs. Contour of tumor could be readily mapped out by percussion and palpation. Tumor adherent to under surface of liver; enlargement of lymphatic glands. In this case the anastomosis was again made just below the duodenum. No untoward symptoms after operation. At the end of the first week solid food was allowed. No vomiting. At the end of the third week an abscess formed in the upper part of the healed incision, in the contents of which the plate ligatures were found. A gastric fistula formed, through which food escaped almost immediately after it was swallowed. This closed in less than two weeks; after which the patient improved in strength and gained in weight. He retained and digested all kinds of food. Improvement continued so that he was able to walk short distances and to take long drives. At the end of three months after the operation he commenced to fail and died two weeks later of progressive marasmus. Unfortunately no post-mortem could be obtained.

*Case III.* Male, aged thirty-five. Symptoms of pyloric stenosis for six months. Tumor discovered four months ago, rapidly increasing in size. Considerable emaciation and cachectic appearance. Tumor involves nearly one-third of anterior wall of stomach and the entire pylorus. Glands of omentum infiltrated. The first loop of intestine which came within reach was united with the anterior wall of stomach in the usual manner. Sutures of abdominal wound removed on the eighth day. Until this time no untoward symptoms, although the patient had taken liquid food for several days. The day following obstinate vomiting occurred; the plates, very much softened and greatly reduced in size, were ejected. The stomach was repeatedly irrigated, but vomiting continued until the patient died three weeks after the operation. Post-mortem: Abdominal incision united throughout; omentum, stomach and intestines adherent to abdominal incision. Anastomosis perfect

at a point eight feet below pylorus. Intestine between pylorus and artificial opening enormously distended. As the opening was large enough to admit two fingers it was difficult to understand what had caused the obstruction. The pyloric orifice was large enough to admit the tip of index finger. Fluid could not be forced from the stomach into the bowel below the new opening. Injection through the duodenum was made with the same negative result. On close examination it was found that the intestine at the point of anastomosis, probably on account of the great length of the part between the stomach and the new opening, had become flexed at the point where it was attached to the stomach, and the two limbs were adherent to each other for four inches. This bending of the bowel had formed a spur, opposite to the opening in the stomach by the apex of the concave side of the bowel, and this spur acted like a valve, closing the opening in the distal part of the bowel when water was injected into the stomach or duodenum.

This case taught me that it is unsafe to follow the advice given by Luecke and others, to seize the first presenting loop for the anastomosis, as by so doing, it is possible to grasp a loop of intestine which corresponds to the lower portion of the small intestines, as in this case. If this is done we not only exclude permanently too great a portion of the intestinal canal from the processes of digestion and absorption, but a similarly unfortunate mechanical difficulty at the new opening may be created, as has been described above.

Lauenstein recently reported a case of gastro-enterostomy where the post-mortem revealed that the new opening was made near the ileo-cæcal region. In making a gastro-enterostomy it is important for the reasons just cited to follow the advice of Hahn and search for the duodenum, which when found can be readily recognized by its short and fixed attachments, and to make the new opening in the upper part of the jejunum as near as possible to the duodenum.

*Case IV.* Male, aged forty-three. Has complained of stomach difficulties for a year. During the last two months obstinate vomiting an hour or two after meals. Tumor as large as a child's fist; movable. Emaciation and marked anæmia; glandular infection behind the stomach. Anastomosis made just below the duodenum. Very little pain, and no other symptoms until the tenth day, when he vomited several times. Stomach washed out twice, four hours apart, and food by the stomach discontinued. No vomiting after this, and after two days a liquid diet ordered. At the end of the second week could digest all kinds of solid food, which caused no distress. On the thirteenth day fragments of both plates were found in one of the stools. Patient has gained in flesh, and after four weeks presented a great deal better appearance than before the operation.

These cases have satisfied me that gastro-enterostomy in cases of inoperable carcinomatous stenosis of the stomach is a safe and

justifiable operation and should be more frequently resorted to, as it is the only resource which promises substantial relief, prolongs life and infuses new hope in a class of patients otherwise doomed to certain, speedy death.

### 2. Physiological Exclusion by Anastomosis.

In some cases of intestinal obstruction the restoration of the continuity of the intestinal canal by resection and circular enterorrhaphy would necessitate the removal of several feet of the intestine where the cause of obstruction in itself constitutes no intrinsic source of danger, and where recovery would be more likely to take place by the substitution of anastomosis for resection. That resection of a number of feet of the small intestines is not always compatible with health is well illustrated by a case reported by Baum, in which he removed 137 cm. in a woman forty years of age. The patient was suffering from strangulated femoral hernia. Taxis was only partially successful. On opening the sac an offensive fluid escaped, and a portion of the omentum was removed. Peritonitis followed and a swelling formed in the abdomen above the crural ring, which broke and a fæcal fistula formed; rapid emaciation ensued; symptoms of strangulation made a laparotomy necessary. A mass of intestine was found twisted into a bunch which could not be unravelled, and as it was surrounded by an abscess it was resected and the ends united with sutures. Patient recovered from operation and improved for several weeks. Six months later progressive marasmus resulted in death. The autopsy revealed no other cause of death except marasmus from too extensive resection. In such a case I would propose that the twisted adherent intestinal coils, the cause of the obstruction, if they present no evidences of gangrene, should be left and permanently excluded from the fæcal circulation by making an anastomosis with approximation plates between the bowel leading to and from the obstructing mass. A case somewhat similar to Baum's, but under less favorable circumstances, came under my care during the last year where this plan of treatment was adopted.

*Strangulated Hernia; Resection of Gangrenous Portion; Additional Obstruction by a Mass of Adherent Intestinal Loops; Restoration of Continuity of Intestinal Canal by Anastomosis.*—The patient was a brewer, thirty years of age, who had an inguinal hernia for several years, but never wore a truss. On lifting a heavy weight the swelling became suddenly enlarged, followed by

symptoms of acute strangulation. The attending physician overlooked the hernia and treated the patient for gastritis. Eight days after the attack he was admitted into the Milwaukee County Hospital. At this time symptoms of acute diffuse peritonitis were well marked. Pulse rapid and feeble; extremities cold; abdomen tympanitic and excessively tender on pressure. Stercoraceous vomiting. Hernia as large as a child's fist, skin covering it discolored and œdematous. It was plain enough that gangrene had occurred, and that in consequence of this, peritonitis had developed. The patient was given 1–120 of a grain of atropia hypodermically before chloroform was administered. On opening the sac fæcal matter escaped and a large mass of discolored omentum presented itself. The sac was irrigated with a weak solution of sublimate, and the omentum drawn forward and wrapped in a small compress of gauze. The entire loop of intestine was gangrenous and perforated on the convex surface at its highest point. The parts were again irrigated before the inguinal canal was laid open by incision. The omentum was now drawn downward until a healthy portion was reached, when it was ligated in several parts and cut off. The intestine was separated from its attachments to the inguinal canal and the gangrenous part, about eight inches in length, excised, after having previously guarded against fæcal extravasation by applying a rubber ligature on each side. Examination of the abdominal cavity at this time showed recent peritonitis.

In drawing down the proximal end of the gut it was found that it was but little distended, hence search was made for an additional obstruction higher up, which was found in the shape of a mass of intestinal coils twisted in every conceivable shape and so firmly adherent that all attempts at unravelling had to be abandoned. The intestine above this point was enormously distended, showing that the bunch of adherent intestines had caused a second obstruction. Excision of three to four feet of intestines, under these circumstances, was not to be thought of, as the patient would certainly have died on the table. Should I leave the cause of obstruction and establish an artificial anus on the proximal side? I decided to leave the obstruction and establish a communication between the intestine on the distal and proximal sides of the obstruction. Both resected ends were closed by invagination and a few stitches of the continued suture. By lateral apposition with decalcified perforated bone plates an anastomosis was established between the distal collapsed end and the dilated bowel on the proximal side of the obstruction. Before the approximation sutures were tied, the intestinal contents were evacuated as far as possible. The whole peritoneal cavity was flushed with sterilized water, carefully dried, drained, and the wound sutured. The toilette of the peritoneum was made with a sponge wrung out of a 1–2000 solution of sublimate. The hernial sac was excised and the stump fastened in the inguinal canal by the deep sutures used in closing the external wound. Duration of operation less than an hour. The patient rallied from the operation, but succumbed to the peritonitis at the end of twenty four hours. Post-mortem: On removing the sutures the sac walls were found agglutinated by plastic lymph. Drainage tube surrounded by a thick layer of plastic lymph, and coils

of intestine which completely shut out the abdominal cavity. Only about half of the omentum remained. The part of intestine where anastomosis was made was found in the pelvis lying against the concave surface of the sacrum, surrounded by numerous recent adhesions. The new opening was twelve inches above the ileo-cæcal valve; adhesion between the serous surfaces, held in approximation by the plates, was sufficiently firm to prevent leakage under strong hydrostatic pressure. Opening patent.

My experiments on animals related in the paper previously referred to, have demonstrated that physiological exclusion of a certain portion of the intestinal tract is a less dangerous operation than excision. The appearances of the specimens also tend to prove that as long as any of the contents of the intestines reach the excluded portion, the peristaltic or anti-peristaltic action in that part is effective in forcing it back into the active current of the fæcal circulation. If the excluded portion again becomes permeable it resumes its physiological function and again takes an active part in the processes of digestion and absorption; if the obstruction remains permanent it undergoes progressive atrophic changes.

### 3. Laparo-Enterotomy.

Incision of the bowel for the removal of obstruction during laparotomy is indicated when the obstruction is due to the presence of a foreign body, a concretion, an enterolith, or a pedunculated benign polypoid tumor. In the removal of a foreign body, a concretion, or an enterolith, not amenable to removal by submural crushing, or fragmentation with a needle, the incision for extraction should not be made over the seat of impaction, as this part of the intestine has undergone changes unfavorable to the satisfactory healing of the visceral wound. It is much better in such cases to make the incision in a healthy part of the intestine an inch or two below the impaction, and then crush the foreign body by instruments introduced through the incision. The removal of a non-malignant pedunculated polypoid tumor is to be accomplished by making an incision on the convex surface of the bowel large enough to admit of dragging of the tumor through it, after which the base of the pedicle is transfixed by a double ligature and tied, the tumor cut off, and the wound closed in the usual manner.

### 4. Enterectomy.

Enterectomy is indicated when the obstruction is due to a malignant tumor if it is possible to remove the disease completely,

also for the removal of benign tumors which cannot be excised by enterotomy, and in all cases where gangrene has been caused by constriction, compression or over-distention. Carcinomatous stenosis is met with most frequently in the large intestine, while the causes which result in gangrene are most common above the ileo-cæcal valve. For malignant disease resection should be done if the entire tumor and all infected glands can be removed completely and with safety. Even if, on account of loss of substance, circular enterorrhaphy cannot be made in such cases, the continuity of the intestinal canal can be restored by lateral implantation, or by lateral apposition with decalcified bone discs. Immediate circular enterorrhaphy after resection for intestinal obstruction has always been attended by a great mortality, for reasons mentioned elsewhere. In a series of thirty-five resections of the large intestine, which Weir collected, when symptoms of obstruction indicated the operation, the mortality amounted to one hundred per cent. Reichel[1] has also shown that resection of the small intestines for conditions giving rise to obstruction, gave a mortality of 75 per cent., whereas in secondary resection for an artificial anus, the mortality is reduced to 37 per cent., a statement which is supported by Makins[2] in his report of fifteen deaths in thirty-nine resections for artificial anus. If after the resection is made, a primary circular enterorrhaphy is not made, Hahn recommends, so as to preserve the advantages of a clean wound and yet to allow the escape of fæces, that the intestine should be closed tightly around a rubber tube, which is left projecting some distance for this purpose.

In the removal of a tumor of the cæcum with partial resection of the intestinal wall, it may be advisable to follow the example of Porter[3] in restoring the continuity of the intestinal canal by suturing. In his case a part of the circumference of the cæcum including a portion of the ileo-cæcal valve was resected for the cure of a fæcal fistula. The wound was closed by slitting up a portion of the ileum from the seat of resection and uniting the margins of this wound

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[1] Kasuistische Beiträge zur cirkulären Darmresektion und Darmnaht, Deutsche Zeitschrift f. Chirurgie, B. XIX, Heft 2. u. 3.

[2] Med. Chir. Transactions, vol. LXVI.

[3] Excision of a Portion of Intestine, including Part of the Ileo-Cæcal Valve, for the Cure of Fæcal Fistula in Right Groin. Bost. Med. & Surg. Journal, May 15, 1884.

with the resected surface of the cæcum. The patient recovered. In cases where the lumina do not correspond it is advisable to follow the suggestion first made by Wehr in performing pylorectomy, viz.: to cut the end of the narrower part of the bowel not transversely, but sufficiently oblique so that the circumference of the oblong opening will correspond to the lumen of the larger end of the bowel. The obliquity should always be made at the expense of the convex portion of the bowel, so as to interfere as little as possible with the vascular supply from the mesenteric side. Madelung in resecting the bowel makes his incisions somewhat obliquely in the same direction, for the purpose of guarding more effectively against gangrene on the convex side of the bowel after circular enterorrhaphy. In such extensive resection of the colon where the possibility of circular suturing is precluded on account of the impossibility of approximating the cut ends, an artificial anus should never be established, as no subsequent treatment could restore the continuity of the intestinal canal. Two such cases were recently reported by Hahn.

It is possible that, in the future, experimental research will prove the practicability of restoring such defects by a plastic operation, consisting of transplantation of a corresponding portion of the small intestines between the separated ends, a procedure which would necessitate circular suturing at three different points. Until it has been shown that some such plan is feasible, the surgeon must content himself with establishing an anastomosis between the proximal and distal end by lateral apposition with decalcified perforated bone plates. The latter procedure offers all the advantages to be derived from approximation and keeping in uninterrupted coaptation a large serous surface, with immobilization of the parts it is intended to unite during the process of repair. In circumscribed gangrene, due to decubitus and involving not more than one-half of the circumference of the bowel, affecting its lateral or convex surfaces, such as is caused by constriction by a narrow band, resection is not necessary. After the constriction has been removed, the gangrenous spot is turned inwards and is covered by suturing the adjacent healthy margins of the bowel over it. The serous surfaces unite rapidly, so that perforation during the separation of the gangrenous part is prevented by union of the serous surfaces over it. When a whole loop or number of loops of the

intestine present evidences of gangrene from constriction, the indications for resection are clear as affording the only possible chance of preventing death from sepsis or perforation. Unfortunately in such cases septic peritonitis has usually set in before the operation is performed, and it becomes necessary after the resection has been made and the continuity of the intestinal canal restored by approximation plates, to treat the peritonitis by flushing the abdominal cavity with sterilized water, and disinfection with some mild antiseptic, as a one-third per cent. solution of salicylic acid, as advised by Mikulicz. Drainage in such cases is a necessity.

5. Direct Treatment of Obstruction in Strangulation by a Band or Diverticulum, Flexion, or Adhesion of the Intestines.

The most favorable cases of intestinal obstruction for laparotomy are those where the obstruction is due to constriction from a narrow ligamentous band. The history of such cases usually points to an antecedent attack of localized peritonitis. One or more of the adhesions during the course of time are drawn out into a band under which the intestine is caught, and strangulation takes place in the same manner as in strangulated hernia. These are the cases of intestinal obstruction which if left alone almost without exception result in death; if submitted to an early operation they are cured by one stroke of the scissors. If the strangulated loop presents no evidence of gangrene, and no signs of decubitus are found at the point of compression the strangulation is relieved by cutting the band. For the purpose of preventing a recurrence of the strangulation from the same cause, it is necessary to trace the band to its points of fixation and resect it between two ligatures. A diverticulum of the small intestines, remnants of the vessels of the vitelline duct, or the appendix vermiformis have often been found as causes of constriction when the free extremity of these structures had become adherent to some fixed point. It is always necessary to make a close examination of a constricting band before resorting to cutting instruments, as a mistake in recognizing the true anatomical character of the obstructing cause might lead to serious results. A narrow appendix may be tied and resected the same as a ligamentous band, but when the obstruction is caused by a diverticulum, greater care must be exercised in removing the cause of obstruction. Many of the diverticula which have been met with as a cause of obstruction

were nearly as large at their base as the intestine with which they were connected, and in such instances it would be unsafe to rely upon a ligature at the resected end in effecting permanent obliteration, as cutting through of the ligature might be followed by perforation, and death from septic peritonitis a few days after the apparent recovery of the patient. The proximal end of such a resected diverticulum must be closed with the same care and in the same manner as the ends of the intestine after permanent interruption of its continuity by resection, and its function by anastomosis.

If the obstruction is found to be due to flexion, the mechanical difficulty must be corrected by separating the adhesions, as the apex of the flexion is generally if not always adherent to some fixed point; after this has been done the proper shape and contour of the bowel should be restored and its permeability tested by pushing the contents beyond the flexed part, and if this can be done without meeting with resistance, and the condition of the intestinal walls at the site of flexion presents no serious textural changes, the intestine is returned and the abdominal incision closed. As the concavity of the flexion is usually directed towards the mesenteric attachment the vascular disturbances are most marked on the convex surface of the bowel, and if gangrene or perforation has taken place it is found at this point. In either of these events it would become necessary to liberate the intestine by separating the adhesions and then resort to a "V" shaped excision on the convex side of the intestine. The portion to be excised must be of sufficient size to include the diseased tissue and to enable the surgeon to rectify the malposition after suturing. Immobilization of a considerable portion of the intestinal canal by a large blood clot and extensive parietal and visceral adhesions may give rise to symptoms of intestinal obstruction. When intra-abdominal hæmorrhage is followed by a complexus of symptoms indicative of the presence of intestinal obstruction, the abdomen should be opened and the coagulated blood removed by sponging and flushing of the peritoneal cavity with sterilized water, and the recurrence of the same condition prevented by arresting further hæmorrhage.

A form of visceral adhesions between coils of intestines massed into a bunch has already been described as a cause of intestinal obstruction. If this condition has lasted for several days and the adhesions have become firm, it is absolutely impossible to unravel

the gut without running the risk of inflicting numberless and perhaps irreparable injuries. In such instances excision of the mass, followed by circular enterorrhaphy, or anastomosis between the intestine above and below the obstruction, as previously described, present themselves as the most appropriate methods of treatment. Each of these operations is applicable to special cases and adapted to meet particular indications. Thus if any of the embedded coils should present indications of incipient gangrene resection must be done. If no such textural changes are present intestinal anastomosis should be preferred, as by it the obstruction is removed and the portion temporarily excluded, after subsidence of the inflammation, and absorption of the adhesions, may again become permeable and resume its physiological function. Circumscribed parietal adhesions, as a cause of intestinal obstruction, are most frequently met with in the pelvis, and on account of the greater frequency of pelvic inflammation in the female occur more frequently in women than men. Pelvic intestinal adhesions produce obstruction in two distinctly different ways: 1. An adherent intestine becomes flexed or twisted by the peristaltic action of the free portions and obstruction results from sudden or gradual stenosis of the lumen of the bowel. 2. A portion of intestine becomes fixed at either end by adhesions and a loop is caught under it, when obstruction is caused in the same manner as from ligamentous bands.

The only case of intestinal obstruction after ovariotomy which occurred in my practice was produced in this manner. The pedicle was tied and its surface cauterized. No untoward symptoms until the end of the third week, when symptoms of intestinal obstruction appeared suddenly and increased in intensity in spite of irrigation of the stomach and high rectal injections. She died two weeks later. The post-mortem showed that a loop of the lower portion of the ileum had become adherent to the surface of the pedicle, and that the mesentery constituted the second fixed point; under this loop another loop four inches in length had slipped from above downwards and had become incarcerated in this position. The intestine below the obstruction was perfectly empty, while above it was enormously dilated and exceedingly vascular as far as the duodenum.

Quite a number of similar cases have been reported by different operators. In old cases of pelvic peritonitis and salpingitis the cause of a subsequent attack of intestinal obstruction is frequently

traceable to intestinal adhesions and the formation of ligamentous bands. In the separation of such old adhesions the greatest care must be exercised not to tear the bowel, as both the parietal and visceral peritoneum may have been transformed into a cicatricial mass which it is not safe to separate by tearing. The separation must be done by careful dissection, which for the sake of safety is done rather at the expense of the parietal than the visceral tissues. Defects of the peritoneum thus caused or made during other abdominal operations, should be covered either by suturing, by laying the omentum over it or, if need be, by omental grafts to prevent a recurrence of such complication. The parietal peritoneum is so loosely attached almost everywhere that it yields sufficiently to cover a defect at least two inches in width by suturing, and whenever this can be done it should not be neglected, as surfaces denuded of peritoneum are liable to become permanently adherent to adjacent abdominal viscera. When the omentum is within reach this should be utilized in covering the defect.

During the last year I have made a number of experiments on animals, which demonstrate that when a piece of parietal peritoneum three to four inches square is removed and not restored in some of the above ways, permanent adhesions form between the denuded place and the organ that comes in contact with it. Another series of experiments which it would be too tedious to describe in full, were made to show that peritoneal defects which cannot be restored by suturing or covering with the omentum can be treated successfully by transplantation of an omental or peritoneal graft. In some of the experiments I removed from each side of the abdominal wall at corresponding points, a piece of peritoneum four inches square, and transplanted the pieces to opposite points and sutured them to the margins of the wound with catgut. All of these experiments proved successful. Omental grafts answered the same purpose, and in only one instance did the graft fail to unite thoroughly, and here one of its margins projected into the median abdominal incision which did not unite by primary union. Infection of this margin led to gangrene of the graft and septic peritonitis.

### 6. Toilette of Peritoneal Cavity.

If everything that has come in contact with the abdominal cavity during a laparotomy for intestinal obstruction, has been

rendered aseptic by the most scrupulous antiseptic precautions, and the local conditions found have caused no infection and no soiling of the peritoneal cavity with intestinal contents has taken place during the operation, the abdominal cavity is aseptic after the operation and can be closed after the removal by gentle sponging, of any blood that may have collected. Unnecessary exposure of the intestines should always be most carefully guarded against by compresses around the incision during intra-abdominal exploration, and by keeping the intestines constantly covered by warm compresses as long as they are outside the peritoneal cavity, for the purpose of preventing infection by floating microbes and to guard against loss of heat during the operation. The case is, however, entirely different when the parts concerned in the obstruction have caused intra-peritoneal sepsis at the time the operation is undertaken, or when, during its performance, in spite of all care to prevent it, the peritoneal cavity has become contaminated by fæcal extravasation. Under these circumstances the peritoneal cavity should be flushed with gallons of sterilized warm water in which one-tenth per cent. of salicylic acid has been dissolved. The end of the glass tube or rubber tubing of the fountain syringe should be held in different parts of the abdominal cavity, especially in the deepest portion of the pelvis and the lumbar regions so as to direct the current of the antiseptic solution out of and not into the peritoneal cavity. After the abdominal cavity has been cleansed by flushing, it is dried by sponges wrung out of a 1-5000 solution of sublimate. In such cases drainage should never be omitted. The closure of the external incision when intra-abdominal pressure is excessive, is greatly facilitated by covering the intestines with a napkin or thin compress of gauze which is tucked underneath the margins of the wound all around. The sutures should be all introduced before any of them are tied. When the sutures are all in place they are tied from above downwards. If tension is considerable it is necessary to add two or more button sutures, which are passed down only to, but not through, the peritoneum, and are removed as soon as the tympanites disappears.

### 7. After-Treatment.

Uniform equable support of the abdomen by strapping and bandages over the antiseptic absorbent dressing furnishes efficient

support to the distended abdominal walls and the paretic intestines, and is not only grateful to the patient but is an important aid in relieving the distress due to distention and peristalsis. I have insisted that in all operations for intestinal obstruction, efforts should be made to empty the bowel not only at the seat of obstruction, but as far as it can be done, as such immediate evacuation constitutes one of the elements of success.

J. Greig Smith states distinctly that "No case of operation for intestinal obstruction is properly concluded until the distended bowels are relieved of their contents." One of the most favorable symptoms after a successful operation for intestinal obstruction is a spontaneous action of the bowels, as it not only proves the permeability of the intestinal canal, but is also an evidence that peristaltic action has been restored. The retention of fæcal material in the distended paretic intestines after operation for intestinal obstruction is a condition which not only retards recovery, but is in itself a grave source of danger. Through the sympathetic nerves the distended intestine exerts a most depressing effect on the cerebro-spinal centers, while the putrefactive changes which are constantly going on in the stagnant intestinal contents, must be a constant source of intoxication, while the migration of septic micro-organisms through the paretic walls threatens life from septic peritonitis.

Mr. Tait has taught us the value of cathartics in the prevention of peritonitis after abdominal operations. Would it not be rational to follow his example in the after-treatment of operations for intestinal obstruction? I have repeatedly made the observation that the paretic intestine above the seat of obstruction will respond slowly, but surely, to mechanical irritation, and it is only logical to conclude that the same effect would be produced by the administration of a brisk saline cathartic. *Dangerous as the use of cathartics necessarily must be before the obstruction is removed, so beneficial may their judicious employment be after the continuity of the intestinal canal has been restored by operative treatment.*

## IV. Anatomico-Pathological Forms of Obstruction.

### I. Entero-lithiasis.

#### a. Biliary calculi.

The term intestinal obstruction in the strict sense of the word, is applied most appropriately to that form of obstruction where the

lumen of the bowel is occupied and completely closed by a foreign body or an enterolith. A foreign body introduced into a healthy bowel, even if it completely fills its lumen, does not necessarily produce intestinal obstruction, as the healthy intestine is capable of dilatation to a sufficient extent to furnish an outlet to fluid intestinal contents between the wall of the bowel and the foreign body. The following experiments were made for the purpose of studying the effect of the presence of a foreign body of sufficient size to interfere with the passage of intestinal contents, and also with a view of ascertaining if the exclusion of peristaltic action of a certain segment of the intestine could produce intestinal obstruction. The operations were performed under strict antiseptic precautions, and the abdominal incision was always made through the linea alba. The animals were fed on the coarsest kind of food, and as a rule their appetites were not impaired by the operation.

*Experiment 1.* Dog, weight thirty-four pounds. The ileum was drawn forward into the abdominal wound, and an incision made about an inch in length, on the convex surface about twelve inches above the ileo-cæcal valve, and through this opening a stiff tube four inches in length, and three-quarters of an inch in diameter, was inserted in a downward direction. The rubber tube distended the bowel so thoroughly as to produce a limited longitudinal rupture of the peritoneal coat. This tube was pushed forward as far as the ileo-cæcal valve, when the intestinal wound and the peritoneal rent were sutured. The visceral wound was covered with an omental graft which was of sufficient length to embrace the entire circumference of the intestine, and was fixed in its place by two catgut sutures, which were passed through the mesentery and both ends of the graft. The intestine was now thoroughly cleansed, dried, and returned, and the abdominal wound closed. The tube was passed per rectum in sixty hours. No symptoms of obstruction were observed during this time, and the animal remained in perfect health until killed twenty days after the operation. The intestinal wound was recognizable upon the external surface of the bowel by a ridge, which consisted plainly of a portion of the omental flap; the remaining portion had evidently disappeared by absorption, at least it had become invisible to the naked eye. The interior surface of the bowel along which the rubber tube had to pass on its way out of the body presented nothing abnormal.

*Experiment 2.* Dog, weight twenty-four pounds. In this instance the incision of the bowel was made eighteen inches above the ileo-cæcal region, and instead of a rubber tube a glass tube three and three-quarters inches in length, and half an inch in diameter, was introduced and pushed along the bowel until its distal end was within six inches of the ileo-cæcal valve. Omental graft over the visceral wound. No symptoms. Tube passed in sixty-eight

hours. Dog killed fifty-seven days after operation. Intestinal canal throughout healthy. Omental graft had disappeared completely.

*Experiment 3.* Dog, weight sixty-two pounds. Incision of bowel twelve inches above ileo-cæcal region, and of sufficient size to permit the insertion of a glass tube five-eighths of an inch in diameter, and six inches in length, which was pushed in a downward direction to within an inch of the ileo-cæcal valve. The tube filled the lumen of the gut completely, but produced no tension in the walls. No symptoms. One month later the abdomen was again opened, and the tube was found in the descending colon. The abdomen was closed and the tube was passed per rectum four days later.

In these experiments hollow tubes were used, and it might be claimed that intestinal obstruction was not produced because the fluid intestinal contents could pass through the lumen of the tube. The effect of the peristaltic action of the bowel in that portion occupied by the tube was certainly eliminated as far as the fæcal circulation is concerned, and yet no symptoms of obstruction during life were observed, and the post-mortem appearances indicated that no obstruction had existed during life. It is certainly surprising that the peristaltic action of the intestine should be able to force a rigid tube of such length and dimensions as were used in the last two experiments through the ileo-cæcal valve into the colon.

In the following experiments the foreign body which was introduced was of such a structure that in case it filled the entire lumen of the bowel it would of necessity produce intestinal obstruction, unless a space for the passage of intestinal contents would be created between the foreign body and the intestinal wall, by dilatation of the bowel.

*Experiment 4.* Dog, weight thirty-four pounds. Intestine was incised at the junction of the ileum with the jejunum and the barrel of a glass female syringe six inches in length, and half an inch in diameter, was inserted with the closed end in a downward direction. The animal never showed any untoward symptoms, and as the syringe was not found in the fæcal discharges, the animal was killed six weeks later, when it was ascertained that it must have passed at some previous time through the normal outlet, as it could not be found, and the intestine presented throughout a normal appearance.

*Experiment 5.* Dog, weight sixty pounds. In this experiment the incision in the bowel was made thirty inches above the ileo-cæcal valve, and through it was inserted with considerable force a glass female syringe six and a half inches long and three-quarters of an inch in diameter, with a metal cap which considerably increased its diameter at this point. The piston of the syringe projected one inch and a half from the cap. The perforated end of the syringe was directed downwards. Visceral wound protected by a circular omental graft. For the first few weeks the animal appeared to be in good

condition, and the fæcal discharges were normal. Later the appetite became impaired and the last few days obstinate constipation appeared. The dog was killed forty days after the insertion of the foreign body. At this time the syringe could be plainly felt through the abdominal wall. The syringe was found in the ascending colon, having passed through the ileo-cæcal valve.

The ileo-cæcal region was distended and partially obstructed by a mass of straw, hair, fragments of bone, etc., for a distance of about ten inches. Above this point the bowel was considerably dilated and contained liquid fæcal matter. Several ulcerations were found in the portion of ileum traversed by the syringe. The lowest ulcer was about an inch and a half in length and half an inch wide, reaching as far as the ileo-cæcal valve, and apparently of recent date. The next ulcer, about one inch longer, but of the same width, was found six inches higher up. This ulcer presented a granulating surface and beginning cicatrization. The third point of ulceration was twelve inches above the ileo-cæcal valve, in an advanced stage of cicatrization. These ulcers were evidently of traumatic origin and were undoubtedly caused by friction of the intestinal wall against the projecting point of the piston, in the attempts of the bowel to propel the foreign body by increased peristaltic action. In this case the intestinal obstruction commenced with the accumulation of solid material on the proximal side of the syringe, being in reality not caused by the foreign body, but by the coprostasis. Had this latter condition not developed, the foreign body would undoubtedly have been expelled spontaneously, as in the former experiments.

These experiments furnish positive proof that a foreign body of sufficient size to fill the entire lumen of a healthy intestine above the ileo-cæcal valve causes no obstruction, and that when obstruction takes place in such instances, it is caused by tissue changes in the intestinal wall arising from prolonged contact with the foreign body. In reference to these points we shall consider the subject of entero-lithiasis as a cause of intestinal obstruction. Entero-lithiasis in man is due in the great majority of cases to the impaction of a gall-stone or the formation of an enterolith in the lumen of the bowel, the nucleus of which is a gall-stone. It has been a disputed question in what way a gall-stone of sufficient size to give rise to obstruction could enter the intestinal canal. Rokitansky asserted that a calculus the size of a hen's egg may pass through the bile-ducts. It is now generally believed that, as a rule, at least, such large concretions can only escape from the gall-bladder by ulceration through its walls, or that a gall-stone of smaller size after it has passed through the bile-ducts, subsequently becomes larger by the formation of concentric concretions during its retention in the intestinal canal. In reference to the frequency of this form of obstruction

Leichtenstern has found that out of fifteen hundred and forty-one cases of intestinal obstruction with different causes, tabulated by himself, forty-one were produced by gall-stones.

Wising[1] collected fifty-one cases of intestinal obstruction caused by the presence of biliary calculi, with the result that in only twenty-four of them could the anatomical condition of the gall-bladder be ascertained. In eighteen of these the post-mortem appearances showed that the calculus had entered the intestine from the gall-bladder by a process of ulceration, and only in three cases it appeared as though the calculus had passed through the common bile-duct. In thirty-three cases the place of obstruction was twelve times the jejunum, and twenty-one times the ileum. In the twenty-one cases where the calculus was impacted in the ileum, the seat of obstruction in two was in the middle, in six in the upper half, and in twelve in the lower half of this portion of intestine. Icterus was observed only in eight of the fifty one cases. The prognosis is always very grave, as of the fifty-one cases thirty-eight died. In twenty-five fatal cases, death occurred fourteen times between the sixth and the eighth day, while in isolated cases it did not occur until from the ninth to the twenty eighth day, and one patient died after two months from perforative peritonitis. Taking all cases of obstructions from gall-stones together, we can say that the seat of obstructions is located in the lower portion of the ileum in fifty per cent. of the cases. The upper part of the jejunum is the next most frequent site of obstruction, and in a few cases the gall-stone becomes impacted in the duodenum at the site where it has ulcerated through the walls of the gall-bladder and intestine. In thirty-two cases collected by Leichtenstern, the gall-stone occupied the duodenum and jejunum in ten cases, middle of ileum in five cases, lower part of ileum in seventeen cases.

Treves* is of the opinion that gall-stones causing intestinal obstruction ulcerate directly into the intestine. He had collected forty-eight cases of obstruction due to gall-stones. In the majority of cases direct evidence of ulceration between the gall-bladder and duodenum was to be obtained. The gall-bladder was entirely disorganized in a case in which the gall-stone was supposed to have traversed the biliary ducts. When impaction takes place high

[1] Ueber Gallenstein ileus. Nord Med. Archiv., B. XVII, No. 18.

up in the intestinal tube, tympanites may be entirely wanting and the symptoms point rather to the existence of pyloric stenosis than intestinal obstruction. The higher the location of the impaction the greater the probability that the calculus attained its size within the biliary passages, and that it entered the intestine by a process of ulceration. In some cases the communication between the gall bladder and the duodenum remained at the time of death, showing that perforation had only recently taken place. Wising has reported such a case. The patient was a woman, seventy years of age, who had never suffered from biliary colic or jaundice. The attack of intestinal obstruction was acute, fæcal vomiting being an early symptom, slight icterus and little tympanites, death on the fifth day. At the necropsy a biliary calculus 7 cm. in length and 10 cm. in circumference was found firmly impacted in the ileum. The intestine on the proximal side was found greatly distended and of a color suggesting incipient gangrene, while the bowel below the obstruction was pale and contracted. Gall-bladder ulcerated and contracted by cicatricial tissue communicating with the duodenum by a perforation above the common bile-duct. A smaller communication was also found between the gall-bladder and the transverse colon. Shattock[1] mentions a case under the care of Dr. Bristowe, in which the remains of the gall-bladder, which was very small, communicated directly with the intestine.

In some cases the pathological conditions within and around the gall-bladder show evidences which go to prove that perforation had taken place long before the development of the intestinal obstruction. In such cases the gall-stone must have occupied the intestinal canal for a variable period of time without having given rise to obstruction, the intestinal contents passing between it and the intestinal wall in the same manner as in the experiments detailed above. In some cases the gall-stone becomes encysted and symptoms of obstruction are not produced until the size of the stone has increased by the addition of concentric layers of concretion. Harley[2] reported a case where a gall-stone became encysted in the duodenum. Woodbury[3] reports a case that came under the observation of Dr. T. H. Andrews, of a woman sixty years of age, who was suddenly

[1] British Medical Journal, March 19, 1887.

[2] Path. Soc. Transactions, London, vol. VIII.

[3] Amer. Jour. Med. Sciences, January, 1880.

attacked with symptoms of acute intestinal obstruction without having previously suffered from any disorder of the biliary passages. She died on the seventh day. A concretion the size of an English walnut was found firmly impacted in the upper portion of the jejunum. Upon section the concretion was seen to consist of a brown, friable, cortical substance, enveloping a dense, white crystalline body as large as a cherry, which was evidently cholesterine. It appears that in this case a small gall-stone which had passed through the bile-ducts without producing symptoms, was in some way retained high up in the intestine, and served as a nucleus for the formation of an enterolith of sufficient size to give rise to intestinal obstruction.

Barlow[1] reports the case of a woman fifty-seven years of age who had symptoms of gall-stones for a year. She suddenly developed an acute intestinal obstruction from which she died. About the center of the ileum there was found a biliary calculus of the size of a walnut, partially sacculated. In some rare cases the obstruction is caused by the retention of numerous calculi in a circumscribed portion of the bowel. Metcalfe[2] presented to the New York Pathological Society a specimen taken from a man fifty-four years of age, where the duodenum was occupied by numerous gall-stones in such a way as to give rise to complete obstruction.

A calculus may attain great size before it becomes impacted. Smith[3] observed a case of acute intestinal obstruction which proved fatal on the fifth day, where the post-mortem revealed the cause to be a biliary calculus measuring four and a half by two and a half inches in circumference, which was found impacted in the jejunum thirty inches below the pyloric orifice of the stomach.

Clark[4] relates the case of a woman fifty-eight years of age who died of acute intestinal obstruction, where two large gall-stones were found impacted immediately above the ileo-cæcal valve, each of which was one inch in length and four inches in circumference, and together weighed one and one-fourth ounces. The stones were composed of cholesterine and coloring material of bile. The

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[1] Guy's Hospital Reports, 1884.

[2] Transactions New York Pathological Society, vol. II, pp. 2, 3.

[3] Pathological Society's Transactions, London, 1854.

[4] A Case of Large Biliary Concretion in the Ileum. Medico-Chirurg. Trans., vol. 55, p. 1.

intestine was perforated at the seat of impaction and a number of small gall-stones was found in the peritoneal cavity. The biliary passages were dilated and thickened, but the gall-bladder appeared to be normal in size and structure and not adherent to the duodenum; jaundice had never existed. Eight months previous to the last illness she had a similar attack of obstruction and at that time a firm tumor could be felt in the right hypochondriac region. This and the next case illustrate that the great danger of impaction of a gall-stone consists of textural changes of the intestine at the site of impaction. Meymott's[1] patient was a woman forty-seven years old, who died after a short illness during which symptoms of intestinal obstruction were well marked. At the necropsy a gall-stone composed of cholesterine, and weighing four hundred grains was found impacted in the ileum four inches above the ileo-cæcal valve. At the seat of impaction circumscribed gangrene and perforation had taken place.

Fagge,[2] in his excellent paper "On Intestinal Obstruction", gives an account of a case which he examined where, in a woman sixty-nine years of age, who had died with symptoms of intestinal obstruction, a gall-stone measuring four and a half inches in its largest circumference and two and a half inches in its smallest, was found impacted in the jejunum thirty inches below the pyloric orifice of the stomach. The stone had passed from the gall-bladder into the duodenum through a perforation, firm adhesions having prevented its escape into the peritoneal cavity. In two other cases to which the same author refers, the patients suffered from intestinal obstruction, and recovery followed after the evacuation of gall-stones of immense size. In cases terminating by spontaneous recovery he believes that perforation takes place into the colon. That the danger is not always passed when a large biliary calculus enters the colon directly through a perforation of the gall-bladder is well illustrated by a case reported by Bourdon,[3] where the calculus became lodged in the sigmoid flexure, where it produced an inflammation which

[1] Impaction of a Large Gall-stone in the Ileum. The Lancet, April 27, 1872.

[2] On Intestinal Obstruction. Guy's Hospital Reports, vol. XIV.

[3] Calcul biliare d'un volume considérable, tombé dans le tube digestif à travers les parois perforées de la vesicule et du colon transverse. Gaz. des Hôpitaux, No. 72, 1859.

proved fatal. In a number of cases recovery took place by discharge of the calculus per viam naturalis even after the symptoms had pointed to complete obstruction. The largest stone which has been successfully passed was three and a half inches in circumference.

Pye-Smith[1] narrates a case which tends to show that in cases of intestinal obstruction due to the presence of a biliary calculus, a spontaneous cure is possible even after the symptoms have continued for a number of days. The patient was a female seventy-eight years of age who had never suffered from jaundice, and gave no history of biliary colic. She had always been very constipated; obstruction finally ensued; and after some temporary relief became complete. By external palpation no tumor could be felt. On rectal examination, however, the finger could just reach a smooth, hard, movable tumor, and it seemed probable that there was malignant disease of the colon. After thirteen days of complete obstruction, however, a large gall-stone was passed, and the patient recovered quickly, and subsequently remained free from the trouble.

### Treatment.

Foreign bodies when impacted in the intestine set up inflammation, and this may go on to gangrene and perforation, and so it can be explained how cathartics under such circumstances are more likely to do harm than good. If impaction has taken place near the ileo-cæcal valve or in the colon, large injections and massage may be tried, provided symptoms of severe inflammation or gangrene at the site of impaction are absent. In the great majority of cases, however, the local lesions at the site of impaction are of such a nature at the time surgical aid is summoned, that nothing short of a laparotomy will promise any hope of success. It will be well for the surgeon not to place too much importance upon the presence of tympanitic distention of the abdomen in these cases as an indication for the necessity of an abdominal section, as this sign may be entirely absent if the impaction is located high up in the intestinal tract, and if the impaction is in the lower part of the ileum or colon an operation should not be postponed until such distention has taken place. After the abdomen has been opened in the median line, and the seat of obstruction determined, the course to be pursued will depend upon the pathological conditions at the seat of impaction.

[1] British Medical Journal, March 19, 1887.

As the mucous membrane in contact with the foregn body is always first to suffer in consequence of the impaction, puncture and incision should be avoided at this point.

As the cases must be few where such a stone, even soon after impaction has taken place, can be pushed along the intestinal canal and through the ileo-cæcal valve into the colon, submural crushing of the stone should be practiced where attempts at distant displacement have failed, and where the condition of the intestinal wall is such that no fear need be entertained that gangrene or perforation will take place. The stone should never be attacked at the seat of impaction, but should be pushed in an upward or downward direction, and then removed if possible by breaking it up by manual pressure, or, if this fail, the method suggested by Tait[1] of passing in a needle obliquely through the intestinal wall and attacking the calculus in this manner may be tried. A stout steel needle, such as is used for electrolysis, is best adapted for this purpose. The needle should always be introduced obliquely through the intestinal wall an inch or two below the impaction in order to secure healthy tissue for the seat of puncture. After the stone has been crushed and the debris within the gut has been pushed into a healthy segment of bowel below, the puncture in the serous coat should be closed by drawing the peritoneum over it with a fine superficial suture for the purpose of guarding against leakage.

When efforts at submural crushing or fracturing of the enterolith have failed and it is deemed necessary to excise it, it is also advisable to push the foreign body within the gut in an upward or downward direction sufficiently far to bring it to a perfectly healthy portion of the intestine, as the healing process of the visceral wound made for its extraction would proceed more satisfactorily here than where the tunics of the intestine had undergone pathological changes in consequence of the impaction. If the stone cannot be displaced and the incision must be made through an inflamed intestinal wall a graft of omentum should be placed around the intestine, after suturing the visceral wound so as to cover the wound, and its ends fastened together by two sutures passed through the mesenteric attachment. Such a procedure will place the visceral wound in the very best condition for healing and will furnish an

[1] The Lancet, December 10, 1887.

additional safeguard against subsequent perforation. If the intestine at the site of impaction shows evidences of gangrene or if perforation has already taken place no efforts should be made to extract the stone, as under such circumstances the surgeon is compelled to resect that portion of intestine in which the stone is imprisoned. As patients presenting such conditions are always more or less collapsed it becomes of the greatest importance to finish the operation as rapidly as possible; consequently after the resection has been made in the usual manner, the continuity of the intestinal canal should be restored by an operative procedure which can be executed without unnecessary loss of time.

As the bowel above the seat of obstruction is always found greatly dilated, circular enterorrhaphy for this reason alone would be a difficult if not impracticable task; hence both ends of the intestine should be invaginated to the extent of an inch and the invagination maintained by three or four superficial stitches of the continued suture, and the continuity of the intestinal canal restored by making an incision an inch in length in each closed end of the bowel, on the convex surface about two inches from the sutured extremity, and lateral apposition of the wounds secured by decalcified perforated bone plates. This method should always be preferred to circular enterorrhaphy in uniting the bowel after resection under such circumstances, as the extensive and secure coaptation of serous surfaces greatly enhances the chances of early union between the coaptated bowels, and at the same time establishes a communicating opening equally serviceable as that after circular suturing.

### b. Intestinal Concretions.

We have already seen that a small gall-stone when retained for a sufficient length of time in the intestinal canal may become the nucleus for an intestinal concretion, which by the addition of concentric layers gradually increases in size until it fills the lumen of the bowel, and after its impaction gives rise to intestinal obstruction. Enteroliths causing obstruction have been found in which a variety of foreign bodies have been found as nuclei.

Cloquet[1] divides the concretions found in the alimentary canal into two classes. The first includes enteroliths in man, and bezoars in animals, both being the result of calcareous deposits secreted by

[1] Amer. Jour. Med. Sciences, January, 1856, p. 216.

the parieties of the intestines. The second class comprises abnormal masses, such as solids, (animal or vegetable hairs which have escaped the process of digestion, and agglomerate to form ægagropili), pulverulent substances, and foreign bodies, such as kernels of fruit, biliary calculi, and hardened fæces. He described an enterolith which formed around a pin as a nucleus, by deposits of phosphate of lime and which had become arrested in the cæcum, where it caused the death of the patient. In another case he found that the nucleus was composed of an ivory pessary which had perforated the bowel on one side and the bladder on the other. The perforation of the bowel was covered by a concretion of phosphate of lime, while the part in the bladder was encrusted with uric acid.

Aberle[1] reported a case where chronic intestinal obstruction was caused by the presence of thirty-two enteroliths, each of which was composed of a concretion in concentric layers around a cherry stone as a nucleus. The concretions had collected in the colon and were successfully removed by rectal injections and cathartics. A chemical examination of the concretion showed that it was composed of phosphate of lime and a considerable quantity of fat, animal glue, and traces of cholesterine.

Schoor[2] described an enterolith which for five years had given rise to pain, first in the ileo-cæcal region and later in the left inguinal region, and was finally discharged spontaneously. It measured four and one-half inches in length and 2.9 inches in width and weighed 44.9 grammes. On making a section of it, it was found that the central portion or nucleus was composed of a triangular piece of bone around which in concentric layers the concretion was arranged. A chemical examination of the concretion showed that it was largely composed of phosphate of ammonia and magnesia, the remaining part of it consisting of vegetable fibres, coloring material of bile, cholesterine, and chloride of sodium.

Virchow[3] made a careful chemical and microscopical examination of an enterolith which had caused symptoms of obstruction in a woman, but was finally expelled after a severe attack of colica stercoralis. The stone measured 5 cm. in length and 8.5 cm. in its

[1] Ein Fall von Steinbildung in Darmkanale. · Würt. Med. Corresp. blatt, No. 23, 1868.

[2] Canstatt's Jahresbericht, B. 2, 1853, p. 64.

[3] Virchow's Archiv. B. XX, Heft 3 u. 4.

greatest circumference. On making a section through the center it was seen to be composed of a plum-stone surrounded by a shell 2 cm. in thickness, made up of concentric layers of crystalline bodies held together by a brownish mass. Chemical analysis showed that the shell was composed largely of phosphate of ammonia and magnesia.

In Friedlander's[1] case the obstruction was due to the impaction of an enterolith in the ileum 30 cm. above the ileo-cæcal valve, which was composed of shellac. The patient was a cabinet-maker, and it is said that the apprentices of this trade not infrequently consume the alcoholic solution of shellac used for varnishing; in the stomach the alcohol is absorbed, and the shellac is deposited. In this case the stomach contained a large number of the same kind of concretions.

At the meeting of the Congress of German Surgeons in Berlin, in April, 1880, Langenbuch[2] showed some large concretions, some of which he had removed by enterotomy in a patient who had suffered from repeated attacks of intestinal obstruction. As the symptoms became more urgent and failed to yield to simpler measures, abdominal section was performed in the median line, and the operator without much difficulty found a swelling in the jejunum, laid open the intestine, and removed the mass of concretions which completely filled the lumen of the bowel. Vomiting continued and the patient died a few hours after the operation. The necropsy revealed a second mass still larger, in the pyloric region of the stomach. Virchow examined the concretions and found that they consisted almost exclusively of organic substance, and especially of the derivative of the biliary acids known as dyslysin.

The surgical treatment of intestinal concretions is the same as in cases of impacted gall-stones.

### c. Parasites as a Cause of Intestinal Obstruction.

A few cases of intestinal obstruction have been recorded where the obstruction was caused by a mass of ascarides which interfered with the passage of intestinal contents in the same manner as an

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[1] Schellack-steine als Ursache von Ileus. Berl. Klin. Wochenschrift, No. 1, 1882.

[2] Verh. der deutschen Gesellschaft f. Chirurgie, 1880.

enterolith. Halma-Grund[1] refers to a patient ten years of age that came under his care suffering with the characteristic symptoms of acute intestinal obstruction, followed by hæmorrhage from the bowels, collapse and death. The necropsy revealed as the cause of obstruction a mass of ascarides eighteen in number which completely filled the lumen of the ileum. At the site of impaction an ulcer was found showing an eroded vessel which had been the source of hæmorrhage.

Saurel's[2] patient was twenty-three years of age, who suffered from symptoms which resembled closely an attack of intestinal obstruction. A swelling could be felt to the left of the umbilicus. Two ascarides were thrown up during a severe attack of vomiting. Anthelmintics were administered and injections given without any effect, and the patient died in collapse. The necropsy revealed the cause of obstruction to have been a mass of ascarides which were firmly impacted in the lower part of the ileum.

Pockels[3] was called to attend a patient who had suffered for some time from an intra-abdominal swelling the size of a hen's egg which could be distinctly felt below and to the left of the umbilicus. A purge of male fern and jalap expelled one hundred and three ascarides, after which the tumor disappeared and the patient's health was completely restored.

Stepp[4] has recently recorded an instance in a boy, aged four, who died with symptoms of acute intestinal obstruction an hour and a half after medical aid was summoned. The post-mortem showed that the intestine was completely obstructed by a twisted mass of some forty or fifty round worms, lodged just above the ileo-cæcal valve. The ileum contained about thirty-five more, higher up, and there were a few in the stomach and œsophagus. The mother of the child had given the patient some worm medicine a few days before the acute attack, and Stepp thinks that the worms, weakened by the medicine, were dislodged in numbers by the violent peristalsis

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[1] Enteritis Verminosa. Mit Darmblutung u. Einklemmungserscheinungen. Schmidt's Jahrbücher, B. 99, p. 92.

[2] Darmverstopfung durch Würmer. Schmidt's Jahrbücher, B. 99, p. 92.

[3] Briefliche Nachrichten über Rundwürmer. Schmidt's Jahrbücher, B. 99, p. 92.

[4] Centralblatt f. die med. Wissensch, No. 27, 1888.

set up by an injudicious diet afterwards, and so rolled down in a tangled mass too large to pass the ileo-cæcal valve.

When the surgeon is called upon to treat a case of intestinal obstruction in a child, such a cause should be borne in mind, as in a case of this kind, a timely anthelmintic remedy followed by a brisk cathartic may prove efficient in removing the cause of obstruction. If such treatment should prove unavailing, no time should be lost in resorting to operative treatment by abdominal section, which is to be conducted in the same manner as in operations for intestinal concretions.

### d. Fæcal Obstruction.

Fæcal obstruction is almost without exception met with only in the large intestine, and here in preference, in the cæcal region or in the sigmoid flexure. Cases have been reported where a congenital abnormal dilatation of some part of the colon predisposed to this affection. The acquired form of dilatation which attends all cases is the result of prolonged overdistention resulting in paresis of the distended segment of the bowel.

Boys de Loury[1] has collected a number of cases of retention of fæces in the cæcum and colon which finally gave rise to inflammation at the seat of impaction, and intestinal obstruction. Among them was one observed by Nélaton, where the fæcal tumor, occupying the cæcum and ascending colon, by prèssure against the under surface of the liver and gall-bladder, caused icterus. The icterus and symptoms of obstruction disappeared promptly after the removal of the fæcal accumulation by cathartics. Retention of fæces after a time produces more or less acute enteritis, attended by tympanites, pain, and dyspnœa. The patients usually have been constipated for a long time, sometimes alternating with diarrhœa. The retained fæces become inspissated and hard and form mural concretions, the middle often remaining tunneled for the passage of fluid fæces. The masses are modelled and when thrown off often describe in accurate outline the contour of the bowel. Distention of the bowel often takes place to an enormous extent. Cruveilhier found on making a necropsy on an old man, the transverse colon so dilated that it measured 35 cm. in circumference. The cæcum was even more dilated and was the size of a child's head. In one of my cases of periodical accumulation of

[1] Gaz. hebd., No. 28, 1858.

fæces in the sigmoid flexure, the patient would only return for treatment at a time when symptoms of obstruction set in, and every time he presented himself the swelling would occupy almost the entire space in the abdomen below the umbilicus. Mechanical removal of the fæcal accumulation followed by massage and the use of the Faradic current and galvanism had no effect in diminishing the size of the bowel, or in preventing the periodical accumulation of fæces. If the cæcum alone is the seat of impaction it often presents the appearance of a circumscribed tumor which may be, and has been mistaken for an ovarian tumor, abscess or carcinoma. The retained mass constitutes an irritant which sooner or later causes a catarrhal enteritis, which extends to the remaining tunics and is often the direct cause of perforation or diffuse peritonitis. In some instances the inflammation extends to the connective tissue around the intestine and an abscess forms without an antecedent perforation. The distended bowel gradually becomes paretic and the local and general symptoms are aggravated.

One of the most important diagnostic points is to make pressure over the tumor in chloroform narcosis, when the fæcal masses become displaced, leaving a permanent depression at the point of pressure. If the impaction is within reach the removal should be accomplished by the use of a scoop, assisted by copious injections. If the bowel at the seat of impaction has lost its contractility the use of cathartics is useless, and if it is in a state of inflammation, positively hurtful. In such cases massage and high injections are indicated. Perforation and suppurative inflammation in the connective tissue surrounding the bowel must be met by prompt surgical treatment. In cases where all ordinary measures fail in removing the fæcal accumulation and the symptoms of obstruction continue unabated, it would be not only justifiable, but good surgery, to cut down upon the distended bowel and to break up the mass within the gut and push it along to a portion of the intestine where peristaltic action has not been impaired. In cases where the intestinal wall presents pathological conditions which would contra-indicate such a course of treatment, it may become necessary to resort to enterotomy and remove the fæcal mass through the wound, and according to circumstances either close the visceral wound by suturing, or establish a temporary artificial anus in one of the inguinal regions.

## 2. Invagination.

Treves[1] asserts that thirty per cent. of all forms of intestinal obstruction, exclusive of hernia and congenital malformations, are cases of invagination. The same author recognizes clinically four forms. The ultra-acute is very rare, and terminates fatally in twenty-four hours; the acute, lasting from two to seven days, numbered about forty-eight per cent. of all cases of invagination; the sub-acute, lasting from seven to thirty days, are about thirty-four per cent.; and the chronic, lasting over thirty days, occurred about eighteen times out of every one hundred cases. As far as the operative treatment is concerned it is exceedingly important to classify all cases into acute and chronic, as in the former class the symptoms appear with great violence, and the pathological changes at the seat of invagination come on so rapidly that death is inevitable, unless efficient surgical treatment is resorted to before the tissues at the seat of invagination have undergone changes incapable of repair. In the chronic form the symptoms are never so urgent and the adoption of early radical measures is not so urgently indicated. Of the anatomical forms, in the cases collected by Treves, thirty per cent. were enteric; eighteen, colic; forty-four, ileo-cæcal; and eight, ileo-colic. The enteric forms are most common at the lower part of the jejunum, and are small. The colic forms are mostly to the left of the transverse colon. The latter as a rule belong to the chronic form of invagination.

Leichtenstern[2] calls an invagination ileo-cæcal when the ileo-cæcal valve is pushed forward and forms the apex of the intussusceptum; ileo-colonic when the ileum is pushed through the valve. The invagination always increases at the expense of the intussuscipiens. In examining four hundred and seventy-nine cases of invagination in reference to the anatomical location of the lesion he gives the following figures:

| | |
|---|---|
| Ileo-cæcal | 212 |
| Ileum | 142 |
| Colon | 86 |
| Ileo-colonic | 39 |
| | 479 |

[1] The Lancet, December 13, 1884.

[2] Ueber Darm-Invagination. Prager Vierteljahrsschrift f. Heilkunde. B. II u. III, 1873.

I shall not endeavor to elaborate upon the views entertained by different authors and experimenters concerning the mechanism of the ordinary forms of invagination, but from a surgical aspect it is important to allude to some of the pathological conditions which produce the invagination, and at the same time complicate the treatment. Mr. Bellamy[1] has described a case of a very rare form of intestinal obstruction, due to invagination of a portion of small intestine in the walls of the rectum, successfully treated by abdominal section. The obstruction had been complete for nine days. The patient was a female who had been subject to obstinate constipation, and on three occasions the retention of fæcal matter had given rise to serious symptoms, which, however, had always yielded to ordinary means. On admission into the hospital a hard swelling could be felt in the left iliac fossa, in the region of the inguinal canal and sigmoid flexure. Manual examination of the rectum disclosed an obstruction in the upper part of this portion of the intestine. As the symptoms of obstruction became urgent and failed to yield to ordinary treatment, abdominal section was performed after exploration of the left external inguinal ring, which had been the seat of an old hernia, by enlarging the incision upwards and obliquely outwards. On introducing the hand into the abdomen it was ascertained that the swelling in the iliac region was composed of a knuckle of small intestine which was obviously invaginated in the anterior aspect of the first part of the rectum, and in addition there was felt what appeared to the touch to be bands of organized lymph, stretching across in the same place, and probably the result of a former circumscribed peritonitis. The operator introduced his right hand into the rectum and pushed the prolapsed mass upwards and towards his left hand, which was in the pelvic cavity, at the same time breaking down the adhesions and gently drawing out the knuckle from its imprisoned position, and freeing it from the peritoneal fold. The symptoms of obstruction subsided promptly and the patient, after having passed through a moderate attack of peritonitis, made a complete recovery.

In examining the literature of the subject the author had been unable to find any case where abdominal section had been performed for a similar condition, although Lockhart described this form of hernia, but he stated that he had never known an operation neces-

[1] British Medical Journal, March 8, 1879.

sary. The cause of a chronic invagination is often a tumor attached to the inner surface of the bowel. The tumor by its weight drags the portion of intestine to which it is attached, into the segment of bowel below, and the descent of the intussusceptum is often very slow. In these cases the tumor is always found attached to the apex of the intussusceptum. Invagination caused by tumors is most frequent in the large intestine, as this is more frequently the seat of invagination than the intestinal canal above the ileo-cæcal valve. Tuffier[1] reports a case of invagination operated on by Marchand which is of special interest on account of the rare condition found which had led to the invagination.

The patient was a woman forty-three years of age, who had suffered from a gradually increasing intestinal obstruction. Rectal examination revealed a tumor, which had dragged an upper segment of the bowel with it into the rectum. Marchand opened the abdomen in the left inguinal region and found an invagination of the sigmoid flexure into the rectum. Reduction was found impossible. An artificial anus was established after the method of Littré. Death on the fifth day. The necropsy showed diffuse peritonitis, which in the small pelvis had assumed a suppurative type. The sigmoid flexure was found invaginated to the depth of 6 cm., and the serous surfaces adherent, which yielded only to considerable traction force. A pedunculated lipoma was attached to the apex of the intussusceptum.

Kulenkampff[2] reports the case of a woman, aged thirty-nine years, who had suffered from incomplete obstruction of the bowels with bloody discharge from the anus for six months. During the progress of the disease a mass could be felt in the rectum, which was thought to be a polypus. This proved to be a papilloma (probably malignant) that originated in the sigmoid flexure, and had been the cause of the invagination of that part of the colon into the rectum. The entire mass, including the intussusceptum, was removed through the rectum. An adherent coil of intestine was accidentally wounded and the wound was at once closed by suturing. The operation was followed by an aggravation of symptoms of obstruction, and on the tenth day laparotomy had to be performed, and an

[1] Invagination de l'iliaque dans le rectum. Laparotomie laterale. Anus de Littré. Lipome de l'intestin. Le Progrès Médical, 1882, p. 202.

[2] Centralblatt f. Chirurgie, No. 47, 1886.

artificial anus was established in the left groin. The patient recovered, but the fæcal fistula remained.

Bryant[1] related the case of a lady, aged seventy-four, who had been suffering from obstruction, due to invagination, for fourteen days. He suspected the existence of a growth, and this, after much difficulty, was found, drawn down and removed, the patient making a rapid and perfect recovery.

Barker,[2] in a case of invagination of the rectum, due to adenoid epithelioma of that part of the gut, succeeded in drawing down and excising the affected part, and reduced the invagination. The patient recovered completely. Three similar cases had been treated previously in the same manner, two by Verneuil, and one by Kulenkampff, only one of them recovering.

The case reported by Nicolaysen[3] is of special interest as illustrating the course to be pursued when it becomes necessary to resect a portion of the intestine with the tumor. The patient was a woman forty-nine years old, who had suffered from troublesome constipation and painful defecation for a year, due to chronic invagination of the sigmoid flexure of the colon into the rectum, produced by an epithelioma. Through the rectum a tumor could be felt which by traction could be drawn down to the anus. The diagnosis made was carcinoma of the colon and invagination of colon into rectum. The patient could produce the invagination at will. The extirpation was made by pulling the tumor downwards beyond the anal orifice. The healthy mucous surfaces 2.5 cm. above the base of the tumor were circumscribed by a row of silk sutures, which were carried through the entire thickness of both intestinal walls. The tumor was excised one cm. below the sutures; only one artery had to be tied. Posteriorly and on the left side of the circular wound the divided meso-colon could be seen. The wound was accurately united by a superficial continued suture. As soon as the bowel was replaced it retracted as far as the upper portion of the rectum. The patient had recovered after fifteen days and reported herself well at the end of two and a half months. The intestinal tube removed meas-

[1] British Medical Journal, April 9, 1887,

[2] The Lancet, May 14, 1887.

[3] Tumor carcinomatosus intestini S. romani: Resektion af S. romanum; Heltredelse. Nord. Med. Arkiv. B. XIV, No. 13.

ured 6.5 cm. The tumor under the microscope showed the typical structure of cylindrical-celled epithelioma.

Becker[1] has collected a number of cases from the literature, where the cause of the invagination was a diverticulum of the small intestine, and he believes that some of the reported cases of elimination of portions of the intestine with the appendix vermiformis were of this kind, and that in these cases, what appeared as the appendix was in reality a diverticulum.

The mechanical disturbances at the seat of invagination are sometimes the cause of an additional obstruction. In one of Dent's cases in a child six months old, who for three days before admission into St. George's Hospital had suffered from evident intussusception, the abdominal section revealed a two-fold cause for the obstruction, invagination and internal strangulation. When the abdomen was opened a loop of bowel was found constricted by the sharp edge of a piece of mesentery of the ileum which was invaginated into the cæcum. The band was divided and the invagination easily reduced. Peritonitis had set in before the operation, and the child died in five hours after it. This case should remind us to look for additional causes of obstruction around the site of the invagination in all cases where the abdomen is opened in the treatment of intussusception. Similar care should be exercised under the same circumstances after the reduction has been accomplished, to look for an additional invagination, as cases have been reported where two or more invaginations were present at the same time.

Claudot[2] has given an accurate description of a specimen of double invagination in a patient who had died with symptoms of intestinal obstruction. The first invagination was 80 cm. below the pylorus, the second two metres further down; the latter consisted of an invagination of the ileum into the colon, the intussusceptum having advanced nearly the entire length of the ascending colon. The upper invagination showed evidences of gangrene, of which no signs could be seen in the lower, and for this reason it is probable that the upper invagination occurred first. Intestinal hæmorrhage was one of the prominent symptoms during life in this case.

At a meeting of the Pathological Society of London, Power[3]

[1] Zur Aetiologie der Darmeinschiebung. Dissertation. Kiel, 1885.

[2] De l'occlusion intestinale. Thèse, Paris, 1884.

[3] Transactions, vol. XX, page 240.

demonstrated a specimen, obtained from a child five months old, of double intussusception, one in the ileo-cæcal region two inches in length, the other in the transverse colon, one inch in length. The latter was an ascending invagination. Both invaginations showed adhesions between the serous surfaces, and consequently must have been ante-mortem conditions.

In regard to the age of patients suffering from invagination, it can be said that fifty per cent. of all cases occurred in persons under ten years of age. Invagination in children, according to Heusner, is the cause of obstruction in three-fourths of all cases of intestinal obstruction. If all cases of invagination were tabulated it would be seen that one-fourth of the whole number would be children under one year of age. The acute form is most frequent in the young, and the chronic variety between the ages of twenty and forty.

Leichtenstern[1] has studied the mortality which attends invagination, and in five hundred and fifty-seven cases in which the termination was known the result was as follows:

| Age. | Total Mortality. | Mortality of Cases Without Elimination of Gangrenous Portion. |
|---|---|---|
| 1 Year | 88 | 86 |
| 2 Years | 82 | |
| 2–10 " | 72 | 80 |
| 11–20 " | 63 | 86 |
| 21–40 " | 63 | 82 |
| 41–50 " | 63 | 80 |
| 51–60 " | 71 | |
| More than 60 years | 77 | |

From this table it can be seen that the mortality up to the age of forty increases with the diminution of the age of the patients, being greatest in infants and children, in whom the invagination usually pursues an acute course.

### Pathology of Acute Invagination.

The pathological changes in the acute form of invagination are chiefly of two kinds: 1. Obstruction of the bowel; 2. Strangulation of the intussusceptum. Both of these results may be absent in the chronic form. The obstruction is due not only to the narrowing of the lumen of the bowel by the invagination, but also to the swelling of the invaginated portion, caused by the constriction of the blood vessels supplying the intussusceptum at the neck of the

[1] Ueber Darminvagination, III, Theil. Prager Vierteljahrsschrift f. Heilkunde, B. CXX, p. 17.

intussuscipiens. In cases of chronic invagination where no such vascular engorgement is present the lumen of the intussusceptum remains sufficiently large for a free passage of the intestinal contents, and no symptoms of obstruction are observed. In a number of my experiments on animals where I produced invagination artificially, no symptoms of obstruction were observed, and when the animals were killed weeks or months after the invagination had been made, the lumen of the intussusceptum was not larger than an ordinary lead pencil, and yet the bowel on the proximal side was not dilated, but somewhat hypertrophic. The greatest danger after invagination has taken place arises from the constriction of the intussusceptum at the neck of the intussuscipiens. The acuity of the symptoms are always proportionate to the severity of the strangulation at this point. The circular constriction interferes with the return of venous blood from the intussusceptum, which is followed by œdema, complete stasis and gangrene of the constricted portion. An acute invagination becomes irreducible by ordinary means within a few hours, on account of the appearance of œdema in the intussusceptum. If the strangulation is less intense the passive congestion precedes a plastic inflammation of the serous surfaces held in apposition, and adhesions form which again oppose or render a reduction impossible. In cases where gangrene of the invaginated portion follows a few hours or days after the invagination, no adhesions form between the serous surfaces. Adhesions at the neck of the intussuscipiens and throughout the extent of the invagination may form soon and they may be absent after six weeks, in the chronic variety. Adhesions are met with in about eighty per cent. of chronic cases, and forty per cent. of acute ones. In acute cases a fatal termination usually takes place from perforation at the neck of the intussuscipiens followed by septic peritonitis.

Numerous cases have been reported where a spontaneous cure was effected by sloughing and elimination of the intussusceptum. This favorable termination is only possible if the continuity of the intestine is restored at the neck of the intussuscipiens by firm unyielding adhesions, before the proximal end of the intussusceptum has become gangrenous, or if the line of demarcation is below the neck. Gangrene usually commences at the apex of the intussusceptum and travels in the direction of the neck. That sloughing and elimination of the intussusceptum are not always followed by recovery becomes

evident from a study of one hundred and forty-nine such cases collected by Leichtenstern. Out of this number sixty-one died and eighty-eight recovered, a mortality of forty-one per cent. Separation of the gangrenous intussusceptum usually takes place in acute cases from the eleventh to the twenty-first day, and in children somewhat earlier than in adults. The length of the slough corresponds with the length of the invaginated portion, and cases are on record where recovery followed after the elimination of five or six feet of intestine. According to Treves, spontaneous elimination takes place in about forty per cent. of all cases. The frequency with which it takes place in the different anatomical forms varies, being twenty per cent. in the ileo-cæcal form, twenty-eight per cent. in the colic form, and sixty-one per cent. in the enteric form, so that it is most rare in the most common form. Frequency of elimination also increases with the age of the patient, being least common in infants on account of the rapidly fatal course of the disease in them, and most frequent in patients advanced in life.

Birch-Hirschfeld[1] gives an accurate post-mortem description of a child two years of age, which had recovered from a double invagination by sloughing and elimination of the intussuscepta, and died four months later of measles. At the necropsy it was found that the lower portion of the ileum, the cæcum and appendix vermiformis were absent. A circular cicatrix in the lumen of the gut showed where separation had taken place; upon the serous surface at the same point, a circular depression indicated the site where separation had occurred. The second invagination had evidently been in the colon at the junction of the ascending with the transverse portion, as a similar cicatrix was also found in this locality. The cures after spontaneous elimination of the intussusceptum are often more apparent than real, as such an ideal restoration of the intestinal canal as that described by Birch-Hirschfeld is but rarely effected.

Kuettner[2] has followed up the history of several of these cases and has found that not an inconsiderable number of them die later from perforation and peritonitis. Stricture of the intestine has also been observed as a sequela in some of these cases.

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[1] Fall von Geheilten Invaginationen des Darmes. Archiv. der Heilkunde, Heft 1, 1869, p. 108.

[2] Drei Fälle von Intussusception und deren præsumptive. Heilung. Virchow's Archiv., B. 53, p. 274.

Gerry[1] reports such a case. The invagination was acute, and after three weeks a portion of the small intestine, seventeen and a half inches in length, passed per anum, followed later by a number of smaller fragments. Soon after the apparent recovery had taken place, symptoms of obstruction again set in, due to the formation of a stricture at the point where spontaneous resection had taken place, from the effects of which the patient died, seven months after the invagination. At the necropsy a circular stricture was found in the upper part of the small intestine with loss of several feet of the intestine by sloughing, a fistulous communication between the small intestine and the descending colon, and chronic peritonitis.

### Pathology of Chronic Invagination.

In cases of chronic invagination the symptoms are identical with those of intestinal stenosis from other causes. The constriction at the neck of the intussuscipiens is not sufficient in degree to arrest the circulation in the invaginated portion, consequently gangrene does not take place. The seat of the invagination and the bowel on the proximal side become the seat of hyperplastic changes, from the chronic congestion which attends the lesion, and from the increased peristalsis which is maintained by the chronic obstruction.

Pohl[2] has described an interesting specimen of chronic invagination taken from a man sixty-two years of age, who suffered from two attacks of intestinal obstruction eleven years apart. The second attack proved fatal after an illness of eleven days. The post-mortem appearances indicated that the invagination which was found had existed for eleven years, and that the second attack was due to an aggravation of the mechanical difficulties at the seat of invagination, which had given rise to ulcerative inflammation of the mucous membrane lining the intussusceptum, perforation and suppurative peritonitis. The intussusception was located in the lower portion of the ileum. The intussuscipiens was 30 cm. in length, its muscular coat hypertrophic, mucous membrane thickened and very vascular, and some of its folds adherent to the enclosed intestine; on the posterior wall near the mesenteric attachment two perforations were found. The intussusceptum was 24 cm. in length, and its mucous

[1] A Case of Intussusception. Boston Medical Journal, No. 25, 1877.

[2] Ueber den Befund einer durch viele Jahre getragene Darm-Intussusception. Prager Med. Wochenschrift, No. 21, 1884.

membrane extensively ulcerated; old and firm adhesions at the neck of the intussuscipiens. The mesentery of the ileum, throughout, but especially at the seat of invagination, much thickened. Ileum above obstruction dilated and its walls thickened.

Leichtenstern[1] reports a case of chronic invagination which presents a number of interesting points. The attack was brought on by indiscreet diet and was attended by well-marked symptoms, tenesmus, liquid stools mixed with mucus and blood. The patient lived for eleven weeks. After the first few days the stools were normal in size and consistence. Recurring colicky pains, often very severe, constituted the most troublesome and important symptom. A swelling in the region of the transverse colon could always be felt, but became firmer and more circumscribed during the attacks of colic or after a prolonged examination by palpation. The necropsy revealed an ileo-cæcal invagination, the lowest portion of which consisted of the point of entrance of the ileum into the colon, the inner cylinder of the cæcum and ascending colon, and the outer cylinder or sheath of the transverse colon. All of the parts involved in the invagination were the seat of hypertrophic changes.

### Treatment.

Early recognition of the existence of invagination is of the greatest importance for successful treatment, as the prospects for successful reduction by ordinary surgical means diminish with the development of secondary pathological conditions at the seat of invagination. Many of the artificial invaginations which I made in animals were reduced spontaneously within a few hours, and in order to study the effects of invagination I had finally to resort to suturing at the neck of the intussuscipiens in order to permanently retain the invaginated portion. Reduction was resisted after a time either by the swollen, œdematous intussusceptum or by the adhesions at the neck of the intussuscipiens, or between the sèrous surfaces throughout the invaginated portion of the bowel. From these observations I have come to the conclusion that reduction by gentle but efficient distention of the bowel below the invagination would succeed in the majority of cases, if this procedure were practiced before either of the two principal conditions which cause irreduci-

[1] Darm-Invagination von monatlicher Dauer. Deutsches Archiv. f. Klin. Medicin, B. XII, p. 381.

bility have had time to make their appearance. As soon as the existence of an invagination is suspected the large intestines should be emptied of their contents by the administration of a large enema, the patient being kept in Hegar's position. After this has been done the patient should be placed thoroughly under the influence of an anæsthetic so as to facilitate the next step in the treatment:

### Rectal Insufflation of Hydrogen Gas.

As gas can be readily forced beyond the ileo-cæcal valve, this method of treatment is applicable in the treatment of invagination in any portion of the intestinal canal, and as distention of the intestine below the seat of obstruction may prove successful in correcting the mechanical difficulties due to other causes, it should be resorted to both as a diagnostic and therapeutic measure in the beginning of all cases of intestinal obstruction, in which a positive diagnosis of other forms of obstruction cannot be made without it. The *modus operandi* of this surgical resource I witnessed in an animal, on the third day after the invagination had been made, by opening the abdomen and exposing to sight the seat of invagination before the insufflation was made. In this instance two inches of the ileum were invaginated into the colon and fixed by two fine silk sutures at the neck of the intussuscipiens. On the third day the abdominal cavity was re-opened by an incision along the outer border of the right rectus muscle, and the invaginated bowel drawn forward into the wound. The bowel at point of operation was very vascular, and the neck of the intussuscipiens covered with plastic exudation. The sutures were removed and the rectum and colon distended with gas for the purpose of effecting reduction. As soon as the colon had become thoroughly distended, the adhesions which had formed gave way with an audible noise, and complete reduction followed in such a manner that the part last invaginated was first released. As the force necessary to rupture the adhesions and to reduce the bowel produced no injury of any kind to the intestine below or at the seat of invagination, this experiment would tend to prove that insufflation can be practiced successfully in cases of invagination of several days' duration.

The rectal insufflation of hydrogen gas in the reduction of an invagination should always be made under the influence of an anæsthetic administered to the extent of complete muscular relaxation.

The pressure upon the rubber balloon should be uninterrupted and should never exceed two pounds to the square inch. Disinvagination is effected by inflation by two distinct forces. In the first place, the steady elastic pressure of the gas distends the bowel between the sheath and the returning cylinder, which makes traction upon the neck of the intussuscipiens, while the column of gas by its pressure against the apex of the intussusceptum acts as a direct reduction force. In order to accomplish the desired mechanical effect the inflation must be made slowly and continuously, as when this is done, there is less danger of rupturing the bowel than when rapid inflation is made under the same pressure but with interruptions, and the object of the inflation is more surely realized. The return of the gas is prevented most effectually by an assistant pressing the margins of the anus against the rectal tube. A small gutta-percha female syringe makes the best rectal tube. A sudden diminution of pressure indicates either that disinvagination has been effected or that a rupture of the intestine has occurred. It is exceedingly important that the surgeon should satisfy himself of the existence of a rupture if this accident has occurred. The best way to recognize the accident is to continue the inflation under a pressure of not more than a quarter to half a pound to the square inch. If the invagination has been reduced the intestine above it will become gradually distended by the gas, and the distention takes place first over the middle of the abdomen and above the pubes, ascending gradually as the inflation is continued in an upward direction. If the intestine has been ruptured the gas escapes into the peritoneal cavity, and the existence of the accident is proved by the appearance of a uniform free tympanites with disappearance of liver dullness. In a recent case there is no danger of rupturing the bowel under a pressure of two pounds to the square inch, and in cases where the tissue of the intestine yields under this pressure, a laparotomy is the only proper remedy, and the occurrence of the accident renders the indication for the performance of the operation imperative, without adding to its danger.

### Colotomy.

Two indications for colotomy might arise in the treatment of colic invagination: 1. In acute cases, when the general symptoms are so grave as to contra-indicate a laparotomy. 2. In irreducible chronic cases, when the lower portion of the colon is invaginated into

the upper part of the rectum, where it is impossible to make a resection or anastomosis by lateral apposition. According to the location of the invagination the operation is made either in the right or the left iliac region, in the former instance the opening being made in the cæcum, and in the latter in the descending colon.

Dubois[1] reports a case of intussusception where the invaginated portion could be felt in the region of the sigmoid flexure, through the abdominal wall. Colotomy was performed above the seat of obstruction, and the patient not only recovered, but four months later the permeability of the intestinal canal was restored spontaneously, although the artificial opening had not closed.

### Enterotomy.

In irreducible iliac and ileo-cæcal invagination, an enterotomy should only be made when the patient is in such a collapsed condition that more radical measures are inadmissible. As in the majority of cases the invagination is below the ileo-cæcal valve, the artificial opening should be made in the right iliac region. Should the invagination be located higher up in the intestinal canal, and an empty collapsed coil of intestine present itself in the opening, it should be pushed aside and search made for a distended loop. An enterotomy is justifiable even when the patient is in an almost pulseless condition, as this operation is attended by little if any shock, as it can be done in a few minutes, and, if necessary, without an anæsthetic. Emptying the bowel above the seat of obstruction will bring relief by removing the abdominal distention, and by favorably influencing the invaginated part by diminishing the hydrostatic pressure above the obstruction, which in itself is a potent cause in maintaining vascular engorgement.

Langenbeck[2] saved the life of a patient suffering from invagination of the colon, by an enterotomy. The invagination had advanced so far that the apex of the intussusceptum could be felt in the rectum. He performed Nélaton's operation and the patient recovered. Nine months after the operation both the invagination and the artificial anus remained.

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[1] Entérotomie pratiquée in extremis. Journ. de Méd. de Bruxelles, December, 1878.

[2] Vorstellung eines Falles von geheilter Enterotomie. Verh. der deutschen Gesellschaft f. Chirurgie, 1878.

### Laparotomy.

Remembering that the general mortality of invagination is seventy per cent. and in children less than eleven years of age spontaneous cure by elimination of intussusceptum does not exceed twelve per cent., it becomes plain that in cases where reduction is not accomplished by rectal inflation, a laparotomy is indicated in all instances where the general condition of the patient is such as to justify such a procedure. It is true that the experience of the past in the operative treatment of invagination is not such as to inspire confidence, but it must not be forgotten that almost without exception the abdomen was only opened as a last resort, after the patient had been completely prostrated by the disease, or after the invagination had given rise to irreparable local conditions. Instead of discouraging operative interference, the statistics collected so far are the best possible arguments in favor of early operation where simpler measures have failed.

Ashhurst[1] brought together, with more or less detail, the histories of thirteen cases in which laparotomy has been undertaken for the relief of intussusception. Of this number five recovered, and eight died. As the result of a study of his cases he has come to the conclusion that the operation is not admissible in patients less than one year of age, as all operations up to that time done in children less than a year of age proved fatal. He also advises against an operation when the symptoms present, and particularly the existence of intestinal hæmorrhage, render it probable that the tightness of the intussusception will lead to sloughing of the invaginated portion, as he claims that under these circumstances an operation would almost surely fail, while there is a fair hope that separation of the invaginated mass might lead to spontaneous recovery. Experience has shown that cure by spontaneous elimination of the intussusception seldom, if ever, takes place in very young children and infants; consequently the hopelessness of the situation in such cases, where legitimate efforts at reduction have failed, can be advanced as the most logical reason in favor of operative treatment, as the patient and surgeon have nothing to lose and everything to gain.

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[1] Laparotomy for Intussusception. Amer. Journ. Med. Sciences, July, 1874, p. 48.

Knaggs,[1] after reporting an unsuccessful case of abdominal section for invagination that occurred in his own practice, gives the results of thirty-seven operations including his own. Of this number eight recovered, and twenty-nine died. In many of these cases peritonitis had set in before the operation was performed, and this condition and not the operation, was answerable for the subsequent fatal issue.

Sands[2] has tabulated the records of twenty-one cases of laparotomy for intussusception, eight of which have occurred since the publication of Ashhurst's paper. Of twenty cases in which the result of the operation is given, seven recovered, and thirteen proved fatal, thus showing a mortality of sixty-five per cent. After a study of these cases he came to the conclusion that the prognosis after operation is also influenced by the age of the patient; thus, of twelve cases of two years old or under, three recovered, and nine died; of seven cases sixteen years old or over, four recovered, and three died, showing that the mortality is greater in infants than in adults. Sands remarks very properly that the mortality depends more on the condition of the intestine than the age of the patient. In taking all cases together, he has found that the mortality of the operation is fourteen per cent. in the easy, and ninety-one per cent. in the difficult cases. The largest number of operations for invagination has been collected by Braun.[3] He tabulated fifty-one operations performed since 1870; that is, operations done under antiseptic precautions. Of this number, eleven patients were cured, and forty died. In twenty-seven of these cases disinvagination was effected, and in twenty-four it was not; of the former eighteen were children, and nine adults. Four children recovered, while fourteen died. Seven adults lived and two died. Resection of the invaginated portion was practiced twelve times with only one recovery. An artificial anus was established in nine cases, followed by death in every instance.

Treves[4] gives the general mortality in one hundred and thirty-three recorded cases as seventy-two per cent.; where reduction was easy it was thirty per cent., and when difficult ninety-one per cent. No one can look over these tables without noticing that the mortality

[1] The Lancet, June 4, 11, 1887.

[2] New York Medical Journal, June, 1887.

[3] Verh. der deutschen Gesellschaft f. Chirurgie, 1885.

[4] The Lancet, December 13, 1884.

was greatly influenced by the local conditions, as when the reduction was easy it was greatly reduced. This fact alone should convince us that laparotomy should be resorted to without delay as soon as a faithful attempt at reduction by rectal insufflation has demonstrated that reduction cannot be accomplished in any other way. The operation should be done as a first, and not as a last resort. As in cases of strangulated hernia, the obstacles to reduction become more persistent as time advances, and the danger is augmented in proportion to the time which elapses until reduction is attempted. In reference to the time when the operation should be done, I can only caution against delay and make the positive statement that it should be done as soon as it has been shown that reduction cannot be effected by rectal insufflation. The age of the patient should not enter into consideration in deciding upon the propriety of an operation. Sands operated successfully upon an infant only six months old, where the ordinary treatment by injection and inflation had been only partially effective in accomplishing disinvagination. The cæcum and appendix vermiformis and a small portion of ileum remained firmly fixed in the sheath, and it required considerable traction force to release them.

Godlee[1] performed abdominal section successfully for invagination in a child nine months old, four days after the commencement of acute symptoms. In this case the invagination had progressed so far that the apex of the intussusceptum protruded at the anus.

Mr. Hutchinson[2] narrates the particulars of a successful abdominal section for intussusception in a child two years of age. The invagination had commenced in the ileo-cæcal region and during the course of one month had advanced to such an extent that the intussusceptum was extruded several inches at the child's anus. As rectal injections failed in reducing the bowel, the abdomen was opened by an incision through the linea alba below the umbilicus, and the intussusceptum was then easily found, and as easily reduced. The child made a rapid recovery.

As a rule, to which there should be no exception, the incision should be made in the median line, as it furnishes the most ready access to the invagination, and enables the operator to apply the various surgical resources with the greatest facility. For special

[1]The Lancet, December 16, 1882.

[2]Medical Times and Gazette, Nov. 29, 1883.

indications a lateral incision can be made later. If the swelling has not been previously located by palpation or insufflation, it is usually not difficult to find the seat of obstruction. As soon as the invaginated part has been found it should be brought into, or as near to the wound as possible for careful examination, as the future action of the surgeon will be guided by the local conditions of the invaginated bowel. If on examination no evidences of gangrene are found efforts should be made to effect reduction.

*a. Disinvagination.*

In recent and especially acute cases, I am satisfied that the difficulties which resist reduction should not be sought in the presence of adhesions as often as in the swollen œdematous intussusceptum. The same measures should be resorted to to enable reduction as in the preliminary treatment of a phimosis or paraphimosis. *The œdema and inflammatory swelling should be removed before any efforts at reduction are made. This can be readily accomplished by steady and uninterrupted manual compression of the invaginated portion.* As soon as the swelling has been reduced in this manner, reduction is attempted by making gentle traction upon the bowel aboye the neck of the intussuscipiens. Should this fail, inflation is practiced, and as soon as the bowel between the returning cylinder and the sheath has become expanded, traction is again made upon the upper and lower ends. If this maneuver fails to effect reduction, Rydygier's[1] device of making traction above and pushing from below can be tried. Rydygier also directs that reduction should be facilitated by inserting the finger between the intussusceptum and the intussuscipiens, for the purpose of breaking up adhesions. Any one who has had much experience with such cases must have observed that the neck of the instussuscipiens grasps the bowel very tightly, and that any such efforts as the introduction of a finger would be almost certain to result in a rupture of the bowel. If the treatment as above directed does not effect reduction the presence of adhesions must be suspected. These should be broken up, not by the introduction of the finger, but by inserting and passing around the bowel a Kocher's director or a small probe. When the adhesions have been severed, the efforts at reduction by traction and inflation are repeated.

[1] Beilage, Centralblatt f. Chirurgie, 1887, p. 31.

Roser has suggested that after reduction has been effected, the invaginated portion should be sutured to the abdominal wall for the purpose of preventing re-invagination. Under proper treatment it is not very likely that re-invagination will take place, and such fixation might subsequently result in another form of intestinal obstruction. Re-invagination can positively be prevented by shortening the mesentery at the point of invagination, by folding it upon itself in a direction parallel to the bowel, and maintaining it in this position by a few catgut sutures.

Should repeated attempts at reduction fail, one of two courses of treatment may be pursued: 1. The establishment of an intestinal anastomosis. 2. Resection of the invaginated portion with or without circular enterorrhaphy. Resection of the invaginated portion, especially if the invagination is extensive, is a very grave undertaking, as it requires a long time for its execution, a matter of vital importance in these cases, and involves the removal of important parts, and on these accounts should never be resorted to unless the invaginated parts show evidences of gangrene.

### *b. Intestinal Anastomosis.*

An intestinal anastomosis between the bowel above and below the invagination by decalcified perforated bone discs can be made in fifteen minutes, and at once restores the continuity of the intestinal canal. As soon as the hydrostatic pressure above the obstruction has been removed by this operation, the danger of gangrene is diminished, and the bowel may again become permeable by a subsequent spontaneous reduction or by elimination of the intussusceptum. If the invagination remains permanently it does no particular harm, as the obstructed portion has been excluded by the anastomosis and subsequently undergoes atrophic changes. In cases where the intussusceptum has advanced beyond the sigmoid flexure, it would become necessary after ligation to remove a part of it through the lower incision, in order to render the bowel permeable below this point. I have in my possession a number of beautiful specimens of intestinal anastomosis obtained from animals in which I had made an artificial invagination, and subsequently treated them by making an intestinal anastomosis, and I am firmly convinced that the same treatment will prove useful in practice.

Korcynski[1] reports an exceedingly interesting case where intestinal anastomosis was established spontaneously in a case of invagination, followed by cure. The patient was forty-one years of age, and the symptoms of obstruction had lasted for six weeks but were completely relieved by the new opening. The existence of such an opening could be readily verified by digital exploration of the rectum. After the symptoms of obstruction had subsided, the exclusion of a part of the intestinal tract could be ascertained by insufflation of the rectum, which at once produced a tympanitic distention of the middle of the abdomen without distention of the colon. A similar but small communication was found on post-mortem examination, as in the case reported by Gerry, previously referred to.

### *c. Resection.*

The only indication for resection is furnished by gangrene of the invaginated portion. The extent of the gangrene is immaterial in reference to the advisability of making a resection, as a small gangrenous spot necessarily would lead to perforation and death from septic peritonitis, unless this radical measure were adopted. The resection must always include the entire intussusceptum, but not necessarily the entire sheath. The first evidences of gangrene upon the external surface of the bowel appear about the neck of the intussuscipiens. When the invagination is extensive and the lower portion of the sheath presents a healthy appearance, it is only necessary to resect the neck of the intussuscipiens and the intussusceptum, which after division and isolation about the neck, can be drawn out and removed. The bowel above and below the proposed points of section should be tied with a rubber band to prevent fæcal extravasation during the operation. The mesenteric attachments must be tied in small sections with fine silk ligatures, as tying in large sections or with catgut is liable to be followed by hæmorrhage.

After the resection has been made it becomes a serious question how to proceed further. Shall the continuity of the intestinal canal be restored at once by suturing, or shall an artificial anus be established? When the resection involves the ileum above and the colon below, it is exceedingly difficult to restore the continuity of the intestinal canal by circular enterorrhaphy, on account of the difference in

[1] Zwei Fälle von Darminvagination langer Dauer. Virchow u. Hirsch's Jahresbericht, B. 11, 1881, p. 193.

the lumina of the bowel to be united. As ileo-cæcal invagination is the most common form, it is evident that, as a rule, some other plan must be followed. Under these circumstances one of two methods of procedure can be chosen. The colon at the point of division is inverted to the extent of an inch or more, and closed by making a few stitches of the continued suture, which should embrace only the serous and muscular coats, and the iliac end is implanted into a slit, corresponding in size to the circumference of the bowel, made in the colon on the side opposite to the meso-colon, at a point just below the closed end. Fixation is most efficiently secured by a rubber ring and two inversion sutures, to which should be added as a matter of precaution a superficial continued suture. If lateral implantation cannot be readily done, an equally efficient method consists in closing both ends and establishing the continuity of the intestinal canal by lateral apposition with decalcified perforated bone plates in the same manner as has been described under the head of intestinal anastomosis. Restoration of the continuity of the intestinal canal after resection of an invaginated bowel by lateral implantation or lateral apposition, requires much less time than a circular enterorrhaphy, while both operations secure better conditions for definitive healing than circular enterorrhaphy, and on these accounts should, under these and similar circumstances, be preferred to the latter procedure.

In cases of colic invagination requiring an extensive resection, approximation of the two ends is not possible on account of their distance from each other and the comparatively slight immobility of this part of the intestine. In such a case lateral implantation is impracticable for the same reasons. The choice lies between the establishment of an artificial anus and lateral apposition; the former should never be made, as in case of recovery of the patient, the fæcal fistula would remain as a permanent condition without any prospects of an ultimate cure. The continuity of the intestinal canal can be restored at once in these cases by making an ileo-colostomy, or a colo-colostomy by lateral apposition with perforated decalcified bone plates, according to the location or extent of the resection.

Wassiljew[1] reports a very interesting case of resection for in-

[1] Invaginatio ileo-cæcalis. Laparotomia, Resectio intestini. Heilung. Centralblatt f. Chirurgie, No. 12, 1888.

vagination which ultimately terminated in recovery. The patient was a man, aged twenty-five years, who was seized with abdominal pain and vomiting. As the symptoms of obstruction did not yield to ordinary treatment laparotomy was performed on the second day. On opening the abdominal cavity a swelling was readily detected in the right hypogastric region. This swelling was drawn forwards, and found to be an extensive invagination of the ileum into the colon. As reduction could not be accomplished an elastic ligature was tied around the gut in two places and the ileum and mesentery were divided. Then the invaginated portion was readily withdrawn and about seventeen inches were resected. The abdominal cavity was washed out with a solution of sublimate, and the cut ends of the gut were fixed by sutures to the abdominal wound. Much gas and fæcal matter escaped, when the ligatures were united. During the sixth week an operation was performed for the cure of the artificial anus. About six inches more of the intestine were resected and the cut ends united by Czerny's suture. On the third day the bowels moved, but on the fifth day the fæcal discharges again escaped through the wound. The different attempts to close the fistulous opening failed. Digital exploration showed that a spur was beginning to form. To this spur a pressure forceps was applied; it fell off on the third day; ultimately the fistula closed.

### 3. Volvulus.

Volvulus or twisting of a loop of intestine around its axis constitutes a well-defined form of intestinal obstruction. This pathological condition can only occur where the mesentery of the bowel is of considerable length, and is therefore most frequently met with in the lower portion of the ileum and at the sigmoid flexure of the colon. This condition as compared with some other forms of intestinal obstruction is quite rare. In fifteen hundred and forty-one cases of obstruction from different causes, collected by Leichtenstern[1] and analyzed with special reference to the anatomical cause of the obstruction, after deducting one hundred and seventy-eight due to carcinoma, thirty-three cases only were due to twisting of the bowel, this including twists of both the sigmoid flexure and the ileum.

[1] Ziemssen's Cyclopædia of the Practice of Medicine. Amer. Translation, Vol. III.

Upon another page the same author gives the result of his examination of seventy-six cases of volvulus which he has collected, and of this number the lesion was found in forty-five cases in the sigmoid flexure, in twenty-three cases in the ileum, and in eight cases in the jejunum and ileum combined.

A simple twist of a long loop of intestine one-half to once around its axis does not necessarily lead to intestinal obstruction. I made a number of experiments on animals by rotating a loop of intestine from one-half to twice around its axis and keeping it fixed in this position by suturing at the base of the loop. These experiments are interesting, inasmuch as they show that the primary constriction produced in making and maintaining the volvulus which was sufficient to cause venous engorgement in the twisted loop, must have been only of short duration, the disappearance of the constriction being undoubtedly due to the gradual yielding of the sutured parts; while the faulty axis of the twisted loop was maintained by the sutures, the circulation improved and remained in a sufficiently vigorous condition to adequately nourish the most distant portions of the volvulus. In most cases where I made a volvulus artificially, the animals did not suffer from intestinal obstruction, and yet the examination of the specimens showed that the twist had remained. The shortness of the mesentery had undoubtedly a great deal to do with the restoration of the circulation in the twisted loop, as this portion of the bowel immediately after fixation always presented a cyanosed appearance. While it was found difficult to force fluid through a specimen of volvulus, during life, propulsion of the intestinal contents by peristaltic action was carried on in a satisfactory manner, as the bowel above the volvulus was not dilated, and contained no abnormal amount of fluid, and the animals manifested no symptoms indicative of intestinal obstruction. In cases where death has been produced by volvulus the post-mortem appearances will show that the obstruction was caused not so much from mechanical causes as from the secondary pathological conditions in the twisted loop. The abnormal length of the mesentery found in these cases precludes the possibility of partial or complete spontaneous reposition, and the consequence is that the parts involved in the volvulus become the seat of serious vascular disturbances which lead to œdema and paresis. These secondary conditions are followed by distention of the intestine and accumulation of

intestinal contents, which cannot fail in aggravating the mechanical difficulties which initiated the obstruction.

A number of these points are well illustrated by a case of volvulus reported by Wilson.[1] A boy, nineteen years of age, without any premonitory symptoms, was suddenly seized with symptoms of acute intestinal obstruction. Colicky pains and persistent vomiting were the most conspicuous symptoms. Tenderness over the umbilicus and slight fullness between pubic arch and umbilicus. Whole abdomen tympanitic. Pulse rapid and small. Skin pale and cold. The patient died thirty-two hours after the commencement of the attack. The necropsy showed moderate distention of the intestines, which were also found congested. Four or five loops of the small intestines occupying the hypogastrium were of a deep purplish-black color, and gangrenous. They were also considerably more distended than the surrounding gut, and taken together, they compared exactly with the outline of the circumscribed tympanitic distention observed during life in this region of the abdomen. On careful examination, these blackened coils of intestine were found to constitute a portion of the ileum, five feet in length, tightly twisted upon itself in its mesenteric axis. The lower point of crossing was five inches above the ileo-cæcal valve. At the point of crossing of the upper and lower end of the volvulus the intestines were flattened, and with the corresponding mesentery tightly twisted upon itself, formed a firm, hard, cord-like pedicle about an inch and a half in length, and a little more than one-third of an inch in diameter. The twist was from left to right, and amounted to a complete turn upon the vertebro-enteric axis of the mesentery. The gangrene and rapidly fatal termination in this case were due to the compression of veins at the base of the volvulus and not to the obstruction. In reference to the causation of volvulus a number of theories have been advanced. All authors are agreed upon one point, that the mesentery must be of abnormal length.

Grawitz[2] asserts that the immediate cause of a volvulus is to be found in an accumulation of intestinal contents above a constricted portion of bowel; that the distended portion of intestine above the seat of constriction undergoes elongation, and that this

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[1] Amer. Journal of Med. Sciences, July, 1878, p. 78.

[2] Virchow u. Hirsch's Jahresbericht, B. 1, 1876, p. 284.

elongated portion then rotates around its axis. Henning[1] studied the ætiology of volvulus experimentally. He firmly ligated the intestine in animals and then injected water above the seat of obstruction. In the small intestines the distended and elongated coils above the ligature always showed a tendency to rotate upon their vertebro-mesenteric axis, and thus a volvulus was produced. In the large intestines, on account of the shortness of the mesenteric attachment, the same experiment caused rupture of the bowel before a volvulus could be produced. He collected a number of cases of volvulus scattered through the literature, where, in the post-mortem description of the twisted bowel, it was distinctly stated that the lumen of the intestine was narrowed by some form of acquired or congenital stenosis. While it cannot be denied that chronic obstruction may be a direct or indirect cause of volvulus by producing not only elongation of the intestine, but also of the mesentery above the seat of obstruction, many cases have been reported where no such condition was found, and where, therefore, the lesion was due to other causes.

Nieberding[2] has recently called attention to another cause of volvulus. He has reported a case which occurred in Bumm's practice, where, after an ovariotomy, a volvulus of the small intestine occurred which proved fatal after a few days. During the operation, the omentum, which was adherent to the cyst, was separated and a portion was excised. The necropsy showed that the raw surface of the omental stump had formed an adhesion to a loop of the small intestine, and above the fixed point a volvulus was found. He reported another and somewhat similar case which came under his own observation. A large cysto-sarcoma of the left ovary was removed, in a girl twenty-nine years of age. Before closing the wound it was noticed that the omentum was so short that the intestines could not be covered by it in the region of the incision. At the end of the second day symptoms of acute obstruction set in, the temperature remaining normal. As the symptoms increased in gravity, and the ordinary treatment proved fruitless, the wound was opened and a loop of intestine was found adherent to the left margin

[1] Beiträge zur Kenntniss der Pathogenese des Volvulus. Dissertation. Berlin, 1883.

[2] Beiträge zur Darmocclusion nach ovariotomie. Centralblatt f. Gynäkologie, No. 12, 1888.

of the peritoneal wound, and after this was separated a volvulus was detected. The bowel was untwisted and its contents forced into the segment further down, beyond the seat of obstruction, the detached loop pushed beyond the reach of the abdominal wound, and the abdomen closed. The day after the operation the intestinal canal appeared to be permeable, as gas escaped per rectum, but evidences of peritonitis set in and the patient died with symptoms of collapse. He believes that the peritonitis was produced by the obstruction.

G. Braun[1] reports a case of volvulus in a woman occurring at the end of pregnancy, and believes that the pressure of the gravid uterus upon the sigmoid flexure produced the obstinate constipation which preceded the attack, and gave rise to elongation of the mesentery and bowel above the seat of compression, to a sufficient extent to cause volvulus. At the time she was admitted to the hospital the abdomen was enormously distended, nausea but no vomiting. On the next day labor pains set in and she was delivered of a dead child. On the same day vomiting commenced and a tendency to collapse was observed. The day after delivery she complained of intense pain in the abdomen, difficulty in breathing, and great prostration, and in a few days she died, the symptoms pointing to an intestinal obstruction remaining constant. At the necropsy the sigmoid flexure and its mesentery were found greatly elongated and rotated twice around its axis. That volvulus is not a frequent complication of pregnancy becomes apparent from the statement of Braun, that this was the first case in sixty thousand deliveries which had come under his own observation.

Kuettner[2] had unusual opportunities to study this form of intestinal obstruction, as four cases came under his own treatment in the short space of two and a half years. As predisposing causes he mentions advanced age and emaciation, as the latter is attended by an absence of fat in the omentum and mesentery, which renders the peritoneal cavity more spacious. Abnormal length of mesentery and intestinal tract is also enumerated as an important element in the causation of volvulus. Among the exciting causes he mentions as

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[1] Enterostenosen in ihrer Beziehung zur Gravidität und Geburt. Wiener Med. Wochenschrift, No. 24, 1885.

[2] Ueber innere Incarcerationen. Virchow's Archiv., B. 43, p. 478.

the most important, unequal distribution of intestinal contents and exaggerated peristalsis. He never observed peritonitis in any of his cases, even if life was prolonged for five to six days. He believes that in these cases the rapid fatal termination is due to pressure upon the sympathetic nerves, which causes paralysis and destroys life in the same manner as in peritonitis. He asserts that the complicated forms of knotting of the intestine which are still described in the text-books as rare but distinct forms of obstruction, are only varieties of volvulus.

### Treatment.

Treves in his paper on "The Operative Treatment of Intestinal Obstruction"[1] claims that this form of obstruction is only aggravated by forcible rectal injections, as such a procedure will tend to tighten rather than to relax the twist. Of the operative treatment he says that simple laparotomy is an unpromising procedure, but that in the future he will make the incision in the median line, puncture the gut, and attempt its reduction; if this fail, or the result appear unsatisfactory, he will evacuate the involved gut through an opening in the summit of the flexure, unfold the volvulus, and establish an artificial anus, using the opening just mentioned for that purpose. In some cases of volvulus the rotation around the vertebro-mesenteric axis is often less than one complete circle, and before the involved bowel has become considerably changed by the twist, a reduction might be effected by dilating and elongating the bowel below the seat of obstruction, thus bringing the same causes to bear which have produced the displacement, but in an opposite direction. Careful inflation with hydrogen gas soon after the obstruction has occurred will be a harmless procedure, and in favorable cases might lead to the desired result. Why this method of reduction should not be tried after the twisted loop has become softened and greatly distended by intestinal contents, requires no explanation.

Of all forms of intestinal obstruction volvulus leads most rapidly to a fatal termination. This fact alone is a sufficient warning to lose but little time by temporizing measures. If life is to be saved prompt operative treatment must be adopted. After the symptoms have become sufficiently well marked, if insufflation proves unavail-

[1] The British Medical Journal, August 29, 1885.

ing, laparotomy should be resorted to at once without reference to the time which has elapsed. If the abdomen is opened before the bowel has undergone serious pathological changes reduction will not be difficult, and as the intestine is otherwise in a healthy condition the prospects of a favorable termination are good. In such a favorable case it would not only be prudent, but imperative to resort to means to prevent a recurrence of the volvulus. As an elongated mesentery plays the most important rôle in its production the best prophylactic means against a recurrence would be to shorten the mesentery. Resection of the mesentery is out of question, as such a procedure might result in gangrene of a corresponding portion of the gut. Shortening of the mesentery, however, can be effected by folding and suturing the mesentery in the same manner as has been described in treating of the operative treatment of invagination. Such an expedient would shorten the mesenteric attachment without interfering with the intestinal circulation. If the twisted portion of the intestine presents evidences of gangrene, resection becomes necessary, and after it has been done the continuity of the intestinal canal should be restored by circular enterorrhaphy or by lateral approximation with decalcified perforated bone plates. If reduction cannot be accomplished without evacuating the distended bowel, an incision should be made on its convex surface at the summit of the loop, and its contents removed by pouring out, taking, of course, all the necessary precautions not to soil the peritoneal cavity. After this has been done the visceral wound should be sutured and another attempt made at reduction. If this does not succeed and the symptoms are such that the necessary time required for resection would prove an element of danger, the volvulus should be left and the obstruction rendered harmless by establishing a communication between the bowel above and below the volvulus, by lateral apposition with decalcified perforated bone plates.

### 4. Obstruction by Flexions and Adhesions.

Every pathologist who has carefully examined the intestinal canal of persons who have acute peritonitis, must have noticed the presence of numerous flexions caused by visceral and parietal adhesions, and yet such patients seldom exhibited well-marked symptoms of intestinal obstruction during life. I have observed the same conditions in animals during my experimental work on the intestinal

canal and seldom found that simple flexion gave rise to intestinal obstruction. I have made numerous flexions when performing operations for establishing intestinal anastomosis, and in most instances satisfied myself by examination of the specimens that fluids passed them without great difficulty. If the bowel at the point of flexion remains free, certain portions of its walls will yield to pressure from within of the fluid intestinal contents, and gradually the lumen of the bowel will become restored. If, on the other hand, the entire circumference of the bowel at the point of flexion has become fixed and immovable by inflammatory adhesions or other pathological products, a compensating dilatation becomes impossible and flexion becomes a direct and serious cause of obstruction. In recent cases of flexion, of course the circumference of the lumen of the bowel at the point of flexion is equal in size to that above or below the obstruction. The obstruction in such cases is not caused by stenosis, but by compression of the distal limb of the flexion by the intestinal contents in the proximal portion, thus causing a valvular closure not at, but just beyond the seat of flexion. This is more likely to take place if the apex of the flexed portion of the bowel is adherent to some fixed point, as in this case a compensatory dilatation of the intestinal wall at a point corresponding to the apex of the flexion, cannot take place. When a flexion has existed for a long time without having given rise to symptoms of obstruction, it finally may cause occlusion by a cicatricial stenosis at the seat of flexion, due to a circumscribed plastic inflammation and cicatricial contraction of the inflammatory product.

Such a case came under the observation of Obalinski.[1] A boy, eighteen years old, had suffered from typhoid fever eight months before the attack of intestinal obstruction set in. Some time before the acute symptoms appeared he suffered from pain in the abdomen which gradually increased in intensity until the clinical picture of obstruction was well marked. On the eighth day after the attack, the abdomen was opened by a median incision. Distended and collapsed intestinal coils came within easy reach. The obstruction consisted of a rectangular flexion of the small intestine caused by a pseudo-ligament the size of a lead pencil. After division of this band

[1] Weitere Beiträge zur Laparotomie bei inneren Darmocclusionen. Wiener Med. Presse, Nos. 4–12, 1886.

and straightening the bowel, it was seen that it was considerably contracted at the point of flexion by a circular cicatrix, but as it was permeable nothing further was done. The boy was discharged cured four weeks after the operation. That the pressure of intestinal contents in the proximal bar is exerted mainly upon the spur which forms in acute flexions between the two bars, is well shown by a specimen described by Birkett,[1] where an intestinal anastomosis was established spontaneously by ulceration between the approximated adherent tubes at the point of compression, so that the intestinal contents passed directly from one intestine to the other through this "fistula bimucosa," instead of traversing the loop. The patient was a man, aged fifty-eight, who six months before his death had presented a strangulated hernia that had been reduced by taxis.

When the flexion is very acute, the spur formed by the apex of the approximated walls of both bars acts like a valve in closing the lumen of the distal bar, under the influence of the hydrostatic pressure from the accumulation of intestinal contents above the seat of flexion. Nicaise[2] has reported a typical case of this kind. A man, aged twenty-five years, was operated upon for strangulated hernia five years before the attack of intestinal obstruction. Since the herniotomy he had suffered frequently from attacks of vomiting and constipation with abdominal pain. The last attack was so severe that enterotomy was performed. He died the next day. The necropsy revealed an acute flexion which had become permanent by old adhesions. The flexion was so acute that the mucous membrane at its apex constituted a kind of valve across the lumen of the bowel. After liberation of a flexed bowel the seat of an intestinal obstruction, it becomes a step in the operation to resort to such prophylactic measures as may appear necessary to prevent a return of the malposition, and to cover as far as possible the peritoneal defects which have been made during the separation of the loop. Winslow[3] reports a case in point. In this case a loop of the small intestines was found firmly adherent in the pelvis over an area of six inches and sharply flexed. After it was carefully detached it was found denuded of peritoneum over a small space. The continuity of the peritoneal surface was restored by applying a number of sutures transversely

[1] Pathological Soc. Transactions, vol. X, 1859.

[2] Bulletin et Mem. de la Soc. de Chirurgie, Paris, 1880, p. 583.

[3] Amer. Journal Med. Sciences, vol. 41, p. 411.

to the long axis of the bowel. It is distinctly stated that this portion of the bowel was deeply congested, hence the seat of the textural changes consequent upon the obstruction. In most cases of flexion which have been described in connection with intestinal obstruction, the flexed bowel was found either in the pelvis near the internal inguinal rings, or in the ileo-cæcal region, localities where localized peritonitis is most frequently met with.

If, after the reduction of a strangulated hernia, the replaced loop of intestine is or becomes the seat of a plastic peritonitis, it forms an attachment to the abdominal parietes or viscera with which it comes in contact. In case the adhesion thus formed remains firm and is not drawn out in the form of a band, a flexion may form by the free portion of the bowel changing its relative position, and the two bars of the flexion thus formed, when in close contact and the seat of the same plastic inflammation, become adherent and the flexion becomes permanent. If the continuity of the bowel cannot be restored by separation of the adhesions in the operative treatment of obstruction caused by flexion, and the tissues at the seat of obstruction present no evidences of gangrene, an anastomosis between the two bars of the flexion should be made in preference to resection and circular suturing. Circumscribed spots of gangrene can be excised and the wound sutured transversely to the long axis of the bowel, as this will cause no stenosis and will tend to correct the faulty position of the bowel. As in cases of constriction by bands, if it is found difficult to separate the adhesions, no attempt should be made to liberate the gut until a rubber ligature has been applied to each bar of the flexion, to prevent fæcal extravasation should the bowel be ruptured during the separation.

### Adhesions.

Quite recently a number of abdominal surgeons have published their experience in reference to the occurrence of intestinal obstruction after laparotomy. A number of cases of intestinal obstruction which occurred soon after ovariotomy were found to have been caused by extensive parietal adhesions of the intestines; hence the question has been discussed how such adhesions are to be prevented.

P. Mueller[1] has advised that in difficult ovariotomies adhesions

[1] Zur Nachbehandlung schwerer Laparotomien. Archiv. f. Gynäkologie, B. 28, Heft 3.

of the intestines amongst themselves, and with the abdominal walls should be prevented by avoiding external compression by bandages, and by filling the abdominal cavity with a physiological solution of common salt (0.7 per cent.) For the purpose of limiting peritoneal absorption, he suggests that the solution should be introduced from time to time and finally should be withdrawn through the drainage tube.

Olshausen[1] has found in all the cases of intestinal obstruction after ovariotomy that occurred in his practice, that the obstruction was caused by adhesion of an intestinal loop to the surface of the stump. Mueller's prophylactic treatment he considers rational, especially in cases where the operation is attended by considerable hæmorrhage. Schatz holds that visceral and parietal adhesions of the intestines after ovariotomy are a much more frequent condition than is generally believed. He is of the opinion that serious consequences do not necessarily follow such a condition. Gusserow asserts that adhesions are frequently found on making a second laparotomy in the same patient, which had not produced any untoward symptoms.

Kaltenbach now uses a 1-6000 solution of sublimate in place of carbolic acid solution, and since he has made this change he has not observed a case of intestinal obstruction in fifty-four consecutive laparotomies, while of twenty-four cases where carbolic acid was used he lost two cases from this cause. Kruckenberg attributes to the use of sublimate an influence in causing plastic adhesions and asserts that since he has abandoned this agent he has had no cases of internal obstruction after ovariotomy. Sänger's experiments appear to prove that for the formation of a firm and permanent adhesion only one wounded surface is necessary. Schwarz believes that parietal adhesions along the internal surface of the abdominal wound are of frequent occurrence, because intestinal loops are caught in the furrow of peritoneum along the line of suturing, where additional irritation is caused by the sutures.

Martin[2] as early as 1865 reported two cases which illustrate one of the dangers which follow puerperal pelvic peritonitis. In one case the peritonitis followed a manual separation of the placenta.

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[1] Verh. der Deutschen Gesellschaft für Gynäkologie, 1886.

[2] Zwei Fälle von Darmeinklemmung durch Exsudatfäden nach Wochenbetten. Monatsschrift für Geburtskunde, July, 1865.

The patient made a rapid recovery, but six weeks later symptoms of acute intestinal obstruction developed, from which the patient died on the fourth day. On post-mortem the cause of obstruction was found to be a firm pseudo-membranous band which connected the anterior surface of the cæcum with a coil of the small intestine. In the second case a metro-peritonitis followed a normal delivery, which, however, yielded to proper treatment on the fifth day. During the seventh week after delivery symptoms of acute intestinal obstruction set in and the disease proved fatal after a few days. A condition similar to that in the first case was found at the post-mortem.

Hirsch[1] presents at length the results of his observations and researches on intestinal obstruction after ovariotomy. He attributes intestinal obstruction after ovariotomy to one of three causes: 1. Adhesions of an intestinal loop to abdominal incision, and occlusion from the traction of the cicatrix. 2. Aseptic plastic peritonitis, which by causing extensive adhesions results in immobilization of a considerable portion of the intestinal canal, which leads to coprostasis and complete obstruction. 3. Impaction of an intestinal loop between a pedicle, treated by the extra-peritoneal method, and the abdominal wall. Sir Spencer Wells reported eleven deaths from this cause in one thousand cases of ovariotomy. Usually the obstruction occurs soon after the operation, but several years may elapse before the accident takes place. The symptoms are the same as in obstruction from other causes.

The prognosis in cases of obstruction from intestinal adhesions is extremely unfavorable. Of the fourteen cases collected by the writer, only one recovered after secondary laparotomy. In view of the great mortality which attends this, the most serious complication after laparotomy, it is exceedingly important to resort to proper prophylactic measures in all cases of intra-abdominal operations. In the first place, when the operation is done in an aseptic peritoneal cavity, all irritating antiseptic solutions should be kept from coming in contact with the peritoneum, as their local irritant action might produce a plastic peritonitis. The peritoneum should not be unnecessarily bruised or sponged, as a slight traumatic irritation might be productive of a circumscribed adhesive inflammation. Finally, it should be the aim of the surgeon to restore, if possible, the

[1] Archiv. f. Gynäkologie, B. XXXII, Heft 2.

continuity of the peritoneal surface, should any defects be found during, or caused by the operation, before the abdomen is closed. Adhesion of the intestines to the abdominal incision can be prevented by spreading the omentum carefully over the intestines the whole length of the incision. Limited defects can be readily closed by suturing. The cut surface of the pedicle after ovariotomy should be covered by stitching the peritoneum over it. The stump, after supra-vaginal amputation, is treated in a similar manner. Parietal and visceral defects not amenable to suturing can be covered with an omental graft, which is stitched to the margins of the defect with catgut sutures. In cases of intestinal obstruction due to extensive adhesions after operations, or attacks of circumscribed peritonitis, it is essential to resort to early operative treatment, which consists in separating the adhesions and in restoring peritoneal defects as far as possible, for the purpose of guarding against similar attacks in the future. After the intestine has been liberated, it is advisable to place the detached portion in some part of the abdominal cavity where a similar condition is less likely to occur.

### 5. Strangulation by Ligamentous Bands or Diverticula.

Ligamentous bands resulting from old adhesions are usually found in parts of the abdominal cavity most frequently the seat of peritonitis, viz.: in the pelvis and the ileo-cæcal region. Their formation can generally be traced to a broad parietal adhesion, which by the peristaltic action of the free portion of the intestine, has become elongated and often narrowed to a delicate cord. It becomes a cause of obstruction when the migrating or free end forms an attachment to some fixed point, which then renders the band tense and unyielding. In case a loop of intestine becomes ensnared underneath it strangulation takes place in the same manner as in strangulated hernia, the constricting cord by its pressure causing venous engorgement below the constriction, and by the increased peristaltic action of the proximal limb of the loop forcing intestinal contents into, but not through, the constricted loop. As in hernia, an intestine may have become adherent and fixed underneath such a band for an indefinite period of time without strangulation taking place, as long as the immediate causes of strangulation are absent. Any causes which disturb the mechanical relations still further in such a case, as a fall, lifting, coughing, the administration of an active

cathartic, etc., may bring on an acute attack of intestinal obstruction. The history of cases of obstruction due to the presence of a ligamentous band frequently refers to an attack of peritonitis through which the patient passed perhaps years before, and as frequently alludes to one of the above-mentioned proximate causes as preceding the attack of intestinal obstruction.

A displaced neck of hernial sac may cause obstruction in the same manner as a ligamentous band. Kurz[1] treated such a case successfully by laparotomy. The patient, a man thirty-three years of age, had been the subject of a small inguinal hernia for several years without causing much inconvenience. When symptoms of acute intestinal obstruction set in, the inguinal canal was carefully examined and was found empty. The symptoms of obstruction were very grave, including a subnormal temperature and fæcal vomiting, at the time the operation was performed. Digital exploration of the ileo-cæcal region through a median abdominal incision, led to the discovery of a ring in which the colon had become ensnared. Reduction by moderate traction was found impossible, and it was found necessary to incise the ring at two points, when the bowel, which was deeply congested, was readily withdrawn. The ring was found displaced four inches from the internal ring. The patient made a rapid and satisfactory recovery. In other instances the contents of a hernia, either the omentum or the intestinal loop, when in a condition of plastic inflammation, may lead to the formation of a ligamentous band when either of these structures becomes attached near to the internal ring, the adhesion which forms lengthening out until it is attached to some other fixed point. Obre[2] described the post-mortem appearances of such a case. The strangulated loop had wandered nearly to the xiphoid cartilage; while between it and the inguinal ring a cord seventeen inches long was found.

A band of constriction can also be formed by the margins of an opening in the mesentery or omentum in which a loop of intestine can become strangulated. In such cases it becomes necessary after reduction has been effected, to close the opening by sutures to prevent a possible relapse of the obstruction from the same cause.

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[1] Deutsche Med. Wochenschrift, March 26, 1885.

[2] Pathological Society Transactions, 1851, p. 95.

An adherent portion of omentum in the course of time may become drawn out into a narrow twisted cord which may become a cause of internal strangulation. In operating for intestinal obstruction caused by constricting bands, it is always necessary, after relieving the point of constriction first found, to search for additional bands, as it is not unusual to find more than one. Obalinski[1] made a laparotomy for intestinal obstruction on the third day after the appearance of acute symptoms. On introducing his hand through a median incision he felt in the right iliac region distended and empty coils, and by tracing the latter in an upward direction found as the cause of obstruction two bands, each the size of a goose-quill, extending from the cæcum to the abdominal wall, between which a loop of intestine 30 cm. in length had become strangulated. Both bands were ligated and divided. Bowels moved on the fourth day and patient was discharged cured in two weeks. Fowler[2] has met with two cases where, at the autopsy, a second band was found close to the divided one.

Another frequent location for bands is in the umbilical region, where the remains of the umbilical artery may become a cause of constriction. Polaillon[3] opened the abdomen, in a young man, by lateral incision on right side for intestinal obstruction, one week after the appearance of the first symptoms. As the patient was the subject of an inguinal hernia, both inguinal canals were examined by digital exploration through this incision, but nothing was found to explain the obstruction. The incision was enlarged and the whole hand introduced, and after careful exploration a falciform fold was found to the left of the median line, which extended from the left inguinal ring toward the umbilicus. Between the band and the abdominal wall a sac was found which contained numerous coils of intestine. The whole intestine was carefully examined, and finally an empty loop about ten inches in length was found. The cause of strangulation was the peritoneal band, reduction having taken place by the introduction of the hand. The band was not divided for fear of hæmorrhage. The patient recovered after a slight attack of peritonitis.

Intestinal obstruction by a constricting band furnishes the

[1] Wiener Med. Presse, No. 4-12, 1886.

[2] The Lancet, June 30, 1883, p. 1120.

[3] Gazette Médicale de Paris, April 25, 1885.

simplest and most favorable conditions for early operative treatment by abdominal section. Without prompt surgical treatment a fatal termination is almost inevitable, as death results either from the mechanical effects of the obstruction, or the constriction produces gangrene of the entire loop, or circumscribed gangrene under the sharp margin of the band, followed by perforation, and death from septic peritonitis. An operation undertaken before the strangulation has caused great abdominal distension and serious textural changes by pressure or constriction would be almost sure to be rewarded by success. Two cases of intestinal obstruction caused by ligamentous bands, recently reported by Bull[1], illustrate in a most striking manner the importance of early operative interference. Both cases were treated by laparotomy, and the difference in the results obtained was plainly traceable to the length of time which had intervened between the onset of the disease and the operation. In the first case the operation was delayed until the eleventh day, and during the separation of the band a gangrenous spot in the bowel gave way, followed by fæcal extravasation. The circumscribed gangrenous patch was excised, making a wound an inch in length, and parallel to the long axis of the bowel, which was closed with twelve Lembert sutures. Death twelve hours after operation. In the second case laparotomy was performed almost under identical circumstances, but the strangulation had existed only six days. In this case the operation was limited to the removal of the cause of obstruction, as the constricted bowel had not undergone irreparable damage, and the patient recovered.

The operative treatment of the obstruction in this form of intestinal strangulation is usually not attended by any difficulties. The band of constriction, whatever its location or mode of origin may be, is traced to both the fixed points of attachment and excised between two ligatures. This not only relieves the strangulation, but prevents a possible recurrence of a similar attack from the same cause. In some instances, however, the local conditions may be more complicated. Reali met with a case where it was found impossible to liberate the intestine from a constricting band, and where he divided the intestine at the point of constriction and united the ends again by circular suturing, and his patient recovered. If on

[1] Report of Cases of Intestinal Obstruction treated by Laparotomy. Gaillard's Medical Journal, March, 1888.

careful examination the conditions at the seat of constriction are such as make it probable that the gut is the seat of gangrene from compression underneath the band, or that the separation of the band from the intestine is not readily accomplished, no attempts should be made to liberate the intestine until measures have been employed to guard against fæcal extravasation in case the gut should be ruptured. This precaution consists in emptying the intestine on each side of the constriction to a distance of from two to four inches, by displacing the contents in its interior between the thumb and index finger and applying a rubber ligature, which is passed through the mesentery with a pair of hæmostatic forceps. The ligatures are not removed until the bowel has been liberated, and if it is injured or presents evidences of gangrene, not until its continuity has been restored by suturing or excision, or by establishing an anastomosis after resection.

From a surgical standpoint in the causation and treatment of intestinal obstruction, the appendix vermiformis must be looked upon as a diverticulum. The appendix vermiformis may become a cause of obstruction when it is of abnormal length and supplied by a long mesentery, and when it is transformed into an unyielding band by fixation of its free extremity to some firm point, by adhesive inflammation. Greves[1] reports such a case. A boy, six years of age, who had suffered frequently from attacks of constipation lasting from a few days to a week or fortnight, was seized with a violent pain in the bladder and other symptoms of acute internal strangulation. On the fourth day the pain was referred to the iliac region, where a resonant swelling could be located. As the usual means proved of no avail laparotomy was performed on the fifth day. About twelve inches of the small intestines were found to be tightly strangulated by an abnormal appendix vermiformis, whose free end had become fixed to the iliac fossa, forming a complete ring, through which the small intestine had slipped and become strangulated. Strangulation was relieved by division of the ring. Patient had not a single bad symptom after the operation. Excision of the appendix vermiformis, when the cause of obstruction, should always be practiced with a view of preventing a similar attack from the same cause. As in such cases the process has undergone elongation by traction,

[1] The Lancet, December 6, 1884.

it is sufficient to apply a ligature near its base and then remove it by excision.

Quite a number of cases of intestinal obstruction are on record where the obstruction was caused by a diverticulum, and in a number of these cases the strangulation was successfully treated by laparotomy. To the same class belong bands, the remains of obliterated omphalo-mesenteric vessels.

In 1851 Parise[1] published his paper on a new cause of strangulation, in which he claimed that he was the first one to show that strangulation may take place from constriction by a diverticulum. The same year Bonvier[2] described a case where a diverticulum of unusual length, springing from the ileum three feet above the ileo-cæcal valve, encircled a loop of the small intestine so firmly as to give rise to complete obstruction. Where the diverticulum joined the ileum the lumina of both were equal in diameter, but the diverticulum tapered towards its end, ending in a bifid extremity, adherent to intestinal coils. Omentum and abdominal wall furnished the unyielding points. The constriction was not very firm and reduction could have been readily effected had an abdominal section been made.

Fitz,[3] in an exhaustive article on "Persistent Omphalo-mesenteric Remains", has collected all material facts pertaining to Meckel's diverticulum, with especial reference to the causation of internal strangulation. As the result of a careful study of this subject he has come to the following conclusions:

1. Bands and cords as a cause of acute intestinal obstruction are second in importance to intussusception alone.

2. Their seat, structure, and relation are such as frequently admit their origin from obliterated or patent omphalo-mesenteric vessels, either alone or in connection with Meckel's diverticulum, and oppose their origin from peritonitis.

3. Recorded cases of intestinal obstruction from Meckel's diverticulum, in most instances at least, belong in the above series.

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[1] Mémoire sur le mécanisme de l' étranglement intestinal par un noeud diverticulair. Bull. de l' Acad. de Méd., 1851, p. 373.

[2] Note sur un Cas de l' étranglement interne de l' intestin grêle par un diverticule de l' ileon. Gaz. des Hôpitaux, No. 87, 1851.

[3] Amer. Journal Med. Sciences.

4. In the region where these congenital causes are most frequently met with, an occasional cause of intestinal strangulation, viz.: the vermiform appendix, is also found.

5. It would seem, therefore, that in the operation of abdominal section for the relief of acute intestinal obstruction, not due to intussusception, and in the absence of local symptoms calling for the preferable exploration of other parts of the abdominal cavity, the lower right quadrant should be selected as the seat of incision. The vicinity of the navel and the lower three feet of the ileum should then receive the earliest attention. If a band is discovered it is most likely to be a persistent vitelline duct, i. e.: Meckel's diverticulum, or an omphalo-mesenteric vessel either patent or obliterated, or both these structures in continuity. The section of the band may thus necessitate opening the intestinal canal or a blood-vessel of large size. Each of these alternatives is to be guarded against, and the removal of the entire band is to be sought for, lest subsequent adherence prove a fresh source of strangulation.

According to Schröder[1] a diverticulum is only supplied with a mesentery when it springs from the lateral aspect of the intestine, or near the mesenteric attachment. Diverticula on the convex surface of the bowel are free and supplied with vessels from the intestinal wall. Meckel found in several specimens a valve at the junction of the diverticulum with the bowel, and in one instance Phœbus found the opening of the diverticulum into the bowel crossed by a bridge of tissue connecting its margins. The so-called false diverticula always form on the concave side of the bowel, and are hernial protrusions, their walls being composed of peritoneum and mucous membrane.

Greenhow[2] observed a case where a coil of the ileum had slipped through a slit in the mesentery of a diverticulum, which in this case contained omphalo-mesenteric vessels, and had become strangulated in this position. Sometimes a number of congenital diverticula are found in close proximity and at times associated with other congenital defects of the intestine.

Moore[3] exhibited to the Pathological Society of London the intestines of a man aged forty, showing three diverticula in the first

[1] Ueber Divertikel-Bildung im Darmkanale. Dissertation, Erlangen, 1854.

[2] The Lancet, May 17, 1884.

[3] The Lancet, Nov. 10, 1883, p. 816.

three feet of the small intestine, and a congenital stricture at the commencement of the jejunum. The diverticula were each an inch long and about as much in diameter, and were on the mesenteric side of the intestine. Their walls consisted of all intestinal coats, and were not mere hernial protrusions. As long as the free end of a diverticulum remains unattached, strangulation from this cause cannot take place. Strangulation can only occur when both extremities are fixed, either as a congenital condition, or when later, the free end becomes adherent to some fixed point. Harris[1] showed a specimen to the Pathological Society of Manchester of internal strangulation from a man aged twenty. There was a whipcord-like adhesion about an inch and a half long, stretching from the tip of Meckel's diverticulum to the mesentery of the lower part of the ileum, and through the aperture so formed a loop of the lower part of the bowel had become strangulated. There had also been a twist of Meckel's diverticulum which had ruptured near its base, and death ensued from acute peritonitis consequent upon fæcal extravasation.

That the danger of perforation and peritonitis from strangulation by a Meckel's diverticulum is greater than when the obstruction is caused by a ligamentous band, is shown by another case reported by Heiberg.[2] The patient was a woman, forty years of age, who died in a few days from an acute attack of intestinal obstruction. At the necropsy he found a diverticulum seven inches in length, thirty inches above the ileo-cæcal region, which constricted a loop of the ileum twenty-one inches in length. The free end of the diverticulum had passed between its base and the intestine, and was found here with its terminal end somewhat dilated. The softened wall of the diverticulum was found perforated at one point, which had given rise to fæcal extravasation and septic peritonitis. A somewhat similar mechanism of strangulation by a diverticulum was described by Concato.[3] A man, otherwise in perfect health, was attacked by acute intestinal obstruction and died on the fourth day. A loop of the small intestine was found constricted by a diverticulum located several feet above the ileo-cæcal valve, the free end of which had insinuated itself between the junction of the diverticulum with the

[1] British Medical Journal, May 28, 1887.

[2] Ueber innere Incarcerationen. Virchow's Archiv, B. 54, p. 30.

[3] Virchow u. Hirsch's Jahresbericht, B. 11, 1871, p. 155.

intestine and constricted bowel, thus forming a firm knot around the bowel.

That in most cases where a diverticulum causes an obstruction the free end has found a firm point of attachment is well shown by the cases tabulated by Cazin.[1] He collected thirty cases of intestinal obstruction caused by diverticula, and of this number, in twenty-five the free end was found adherent. A diverticulum may give rise to symptoms of intestinal obstruction without directly interfering with the fæcal circulation. Such a case has been reported by Doran.[2] A boy, four years old, died on the fourth day after an attack of what resembled acute intestinal obstruction. At the necropsy a diverticulum the size of a pear was found at the junction of the ileum with the jejunum, which contained a pea. The foreign body had caused ulcerative inflammation and perforation of the diverticulum and death from perforative peritonitis. The diverticulum was supplied with a mesentery and its walls were composed of all the tunics of the bowel.

Southey[3] alludes to another variety of obstruction caused by a diverticulum, viz.: contraction of the intestine at a point where the diverticulum is given off. He gives a description of two such specimens. In one the diverticulum formed a band the size of a goose-quill, and extended from a point two feet above the ileo-cæcal valve to the abdominal wall two inches below the umbilicus. The ileum just above the diverticulum was so constricted as only to admit the tip of the little finger, and at the point of constriction the coats of the intestine, both muscular and mucous, were ulcerated through, the continuity of the intestine being preserved only by the thickened peritoneum. In the second case the bowel, at a point about eighteen inches above the ileo-cæcal valve, was abruptly constricted to a diameter of about half an inch, and a diverticulum five inches long, having a calibre, at first large enough to admit the little finger, passed from the intestine and was attached at its extremity to the umbilicus. In this case death was hastened by acute diffuse peritonitis. That not all constricting bands are the remains of the vitelline duct,

[1] Etude anatomique et pathologique sur les diverticules de l' intestin. Thèse. Paris, 1862.

[2] Case of Acute Intestinal Obstruction; perforation of a diverticulum. Transactions of the Pathological Society, Vol. XXIV, p. 122.

[3] Transactions of the Clinical Society of London. Vol. V, 1872.

requires no argument in speaking of the operative treatment of obstruction from constriction by bands; but the possibility of mistaking a peritoneal fold enclosing unobliterated umbilical vessels for an ordinary cicatricial band must be remembered and the necessary sections of the band made between ligatures. If a Meckel's diverticulum is found to be the cause of obstruction, this appendage should always be resected by ligating it at its base with a rubber ligature, and after the incision, the end invaginated and the invagination maintained by a few stitches of the continued suture. Weir recommends in the excision of a constricting diverticulum to apply a ligature and after cutting it off, to stitch the peritoneal surface over the divided muscular and mucous coat; but when the diverticulum is nearly of the same diameter as the intestine from which it springs, such a course would not afford ample protection against perforation.

Clutton[1] related a case to the Clinical Society of London, of intestinal obstruction caused by a diverticulum, successfully treated by operation. The patient was a boy aged ten years, who had suffered on several occasions from colicky pains lasting for two or three days and always terminating with a copious evacuation from the bowels. This attack commenced with vomiting and great pain in the abdomen, which persisted in spite of opium treatment for four days, when he was brought into the hospital and at once submitted to an operation. On opening the abdomen through the linea alba a collapsed portion of bowel was soon found, and, on bringing it to the surface, a tight ring-like cord could be felt and seen to be the cause of strangulation. The cord was divided between two pairs of forceps and each end tied with a catgut ligature. This step of the operation relieved the bowel from strangulation. On making an investigation as to the nature of the band divided it was found that one of the ligatures was situated at the extreme end of a diverticulum two inches in length, and the other was placed upon the wall of the same loop of intestine at a distance of about six inches. A portion of bowel of about three inches in length between these two points of attachment was the part strangulated, and was of an extremely dark color with a deep sulcus at each side. The boy made an uninterrupted and rapid recovery.

[1] The Lancet, May 17, 1884.

Clutton explained the condition as follows: "The vitelline duct had obliterated at the umbilicus, and set free from the abdominal wall, but remaining patent towards the ileum the lower end had become a pouch-like diverticulum from the intestine. This diverticulum terminating in a pointed extremity or cord part also of the vitelline duct which had been obliterated had remained floating about among the intestines till it became attached to the bowel in contact with it. The gut between the two points of attachment had slipped beneath the cord which united them, and being unable to extricate itself had become strangulated."

Another interesting case of intestinal strangulation caused by a Meckel's diverticulum and successfully treated by laparotomy is reported by McGill.[1] The patient was a man, aged thirty years, who had suffered from acute intestinal obstruction for nine days. The abdomen was very much distended at the time of operation. As the seat of obstruction could not be readily found by intra-abdominal palpation, partial extrusion of intestines was allowed to take place, but as soon as three feet of the small intestines had escaped the junction of the distended with the empty intestine came into view. At this point a Meckel's diverticulum, much dilated and about six inches in length, was seen, passing downwards and forwards, to be attached to the fundus of the bladder. A loop of collapsed intestine passed under the diverticulum, the obstruction being caused by the twisting of the bowel at the point where the diverticulum was attached. Slight traction proved efficient in releasing the bowel from the grasp of the diverticulum, and as soon as this was accomplished, the empty portion of the bowel became filled with the intestinal contents. Nothing was done to the diverticulum. On the tenth day a small fæcal fistula formed at the lower angle of the wound; this continued two weeks, when the discharge ceased and the patient recovered without any further untoward symptoms. The author believes that this is the first recorded case where the free end of the diverticulum had its attachment to the fundus of the bladder. There can be but little doubt that the fæcal fistula in this case was caused by a perforation of the diverticulum, an accident which might have proved fatal if extrava-

[1] Remarks on a Case of Acute Intestinal Obstruction due to the Presence of a Meckel's Diverticulum Successfully Treated by Laparotomy. British Medical Journal, January 14, 1888.

sation had taken place into the peritoneal cavity, and which might have been avoided had the diverticulum been removed, which would also have protected the patient with certainty against a possible recurrence in the future, of obstruction from the same cause.

## 6. Non-malignant Stenosis.

### 1. Congenital.

Congenital narrowing of the bowel varies in degree from a slight contraction to complete atresia. In my experiments on animals I have shown that when the lumen of the small intestines is diminished one-half in size by partial enterectomy and suturing of the wound in a direction parallel to the long axis of the bowel, the function of the bowel is not impaired, and obstruction does not occur, but if the stenosis is carried beyond this point there is great danger of obstruction arising from accumulation of solid intestinal contents on the proximal side of the stenosis. The same holds true of congenital stenosis of the small intestines. Even if the narrowing is considerable no serious symptoms are produced until some foreign bodies collect above the seat of constriction and cause obstruction from coprostasis.

Legg[1] reports an exceedingly interesting case where a congenital stenosis of the ileo-cæcal opening led to chronic obstruction, dilatation of ileum, and finally to perforation into the ascending colon. A female twenty-six years of age was admitted into the hospital April, 1858. She stated that since she was five years of age she had suffered from occasional attacks of colic, perhaps five times during a year, attended by constipation and vomiting. After such an attack eight years ago a number of cherry-stones passed with the fæces. Recently the attacks became more frequent, and the last was so severe that she found it necessary to seek admission into the hospital. When admitted she presented many symptoms of obstruction. In the right iliac fossa on percussion a dry crackling sound could be heard and felt. In a few days she again passed a few cherry and plum stones and felt relieved. She was given five gutta-percha pills, which never passed through. She left the hospital improved, and was not seen again until six years later. At this time she again

[1] Congenital Constriction of the Ileo-cæcal Orifice and Dilatation of the Ileum; Retention of Fruit-stones in Jejunum and Ileum. Trans. Pathological Society Vol. XXI, p. 171.

suffered from well-marked symptoms of intestinal obstruction, and during the first few days vomited a number of cherry and plum stones, and a black round mass which, on cutting, was believed to be one of the gutta-percha pills which she had taken six years before. Below the umbilicus the same crackling sound could be heard and felt as before. The symptoms of obstruction gradually became worse, and a few weeks after admission she died. At the necropsy the entire colon was found empty and contracted, the ileum very much dilated, so much so that the lower portion measured seven inches in circumference. On opening it fluid fæces and a few fruit-stones escaped. Ileo-cæcal orifice contracted so that it would admit only a number nine catheter. Above the ileo-cæcal valve a communicating bimucous fistulous opening the size of a quarter of a dollar had formed between the colon and ileum, and a little distance above this point, another but smaller opening had formed in the same manner by adhesion and perforation. In the small intestines a pint of cherry-stones were found, all of them covered with a black crust, which on examination proved to contain iron. The author could find in the literature only six cases of non-malignant stenosis of the ileo-cæcal opening. In Schrœder van der Kolk's case the opening was even smaller, and in the lower portion of the ileum, which was enormously dilated, a large mass of cherry-stones and fragments of bone were found.

Bourdon[1] observed another case of congenital stenosis of the ileo-cæcal orifice like that narrated by Dor.[2] The patient, a man thirty-two years of age, had suffered for a month from pain in the abdomen, nausea and vomiting. The bowels were moved with difficulty by cathartics. On examination nothing could be found except a doughy condition of the middle portion of the abdomen, where percussion revealed also a certain degree of dullness. He remained two weeks in the hospital without any improvement being noticeable, when he left, but returned three days later. At this time an irregular, uneven swelling could be distinctly felt in the right groin. The swelling rapidly increased in size and the patient died in a few days of peritonitis. At the necropsy the small intestines were found very much distended, colon and rectum contracted and empty. Just above the ileo-cæcal valve the ileum was distended to

[1] L'Union Médicale 57, 1856. Schmidt's Jahrbücher, B. 96, p. 204.

[2] Gaz. Méd. de Paris, No. 9, 1835.

the size of a fœtal head adherent to the posterior abdominal wall, mesentery and intestinal coils. The walls of this pouch were thickened and of a brown color. When opened it was found to contain one hundred and twenty plum-stones and ninety-two lead bullets. The ileo-cæcal valve was nearly closed and was permeable only to fluids. The patient had probably swallowed the bullets to overcome obstinate constipation.

In all of these cases of congenital stenosis no symptoms were caused by the congenital defect until the foreign bodies which collected above it, finally produced death from intestinal obstruction or perforative peritonitis. The clinical history in each case distinctly points to aggravation of the obstruction by the occurrence of coprostatis above the seat of stenosis. The surgical treatment in such cases consists in removing the impacted substances through an incision above the stenosis, and after clearing the bowel of its contents uniting it with a similar incision in the bowel below the obstruction, by lateral apposition with decalcified perforated bone plates, thus establishing a free anastomosis between the bowel above and below the obstruction, and excluding at the same time permanently from the intestinal circulation, the contracted portion of the intestine. Excision and restoration of the continuity of the intestinal canal by circular enterorrhaphy can only be thought of in case perforation has taken place.

### 2. Acquired or Cicatricial.

Cicatricial stenosis of the intestines is one of the remote consequences of deep ulcerative lesions, such as are caused by dysentery, typhlitis stercoralis, tuberculosis, and ileo-typhus. The cicatrix which forms during the reparative stage of the ulceration contracts slowly and gives rise to stenosis and chronic intestinal obstruction. As in cases of congenital stenosis, the obstruction often becomes complete and gives rise to acute symptoms when foreign bodies or solid fæces become impacted above the seat of constriction. Not infrequently the causes which have led to cicatricial stenosis are located at the same time or appear successively in different parts of the intestine, producing consequently also multiple strictures.

Sharkey[1] presented to the Pathological Society of London a specimen of multiple strictures of the ileum, taken from a woman

[1] The Lancet, May 24, 1884.

thirty-three years of age, who had suffered frequently from indigestion and vomiting. The immediate cause of death was facial erysipelas. The lower two-thirds of the small intestines exhibited numerous ulcers apparently healed. They were so near together and produced such marked constriction that the appearance of a succession of pouches was simulated. There were no distinct evidences of tuberculosis in the intestine or any of the other organs. In the discussion which followed the demonstration of this specimen Treves spoke of other, somewhat similar, recorded cases in which typhoid fever and tuberculosis seemed to be excluded. Treves[1] has described another cause of cicatricial stenosis. He has met with such cases in patients who suffered from strangulated hernia, when the prolonged compression during the strangulation had produced a circumscribed gangrene of the mucous coat. In all of the recorded cases the patients appear to have recovered well from the hernial trouble, and after a varying time to have gradually developed symptoms of cicatricial stenosis of the small intestines.

Another form of cicatricial stenosis of the intestines is caused by the formation of a cicatrix in the peritoneal coat, as the result of a circumscribed plastic peritonitis. In this form the mucous and muscular coats are intact, but the bowel is narrowed and puckered by a band of cicatricial tissue. Cicatricial stenosis of the colon is caused most frequently by dysentery, while the same condition in the rectum often appears as a syphilitic lesion. In the treatment of cicatricial stricture of the intestine the question of resection again confronts us. Maydl[2] reports two successful cases of circular resection and suturing for cicatricial stricture of the ileo-cæcal valve. In the first case he relieved the obstruction by an enterotomy, and a year later excised the constricted portion of the cæcum and united the ileum with the ascending colon. In the second case the general condition of the patient warranted a radical operation, which consisted in the excision of the cæcum and immediate restoration of the continuity of the intestinal canal by suturing, The conditions in these cases for circular enterorrhaphy were unusually favorable, as the colon must have been in a contracted state, while the lower por-

[1] Intestinal Obstruction that May Follow after Hernia. The Lancet.

[2] Ueber einen zweiten Fall von narbiger Striktur der Ileo-cæcal Klappe durch cirkuläre Darmresektion und Naht gebeilt. Allgem. Wiener Med. Zeitung. No. 17, 1881.

tion of the ileum, from the prolonged obstruction, was much dilated, so that the lumina of the resected ends must have been nearly equal in size. Both patients recovered. In the first case, where the patient suffered all the inconveniences of an artificial anus for one year, a radical operation by an ileo-colostomy could have been made with no more risk than was incident to the enterotomy, and would have thus avoided the necessity of establishing an artificial anus and of performing a second operation. Where no gangrene or perforation is present, I should strongly recommend the substitution of intestinal anastomosis for resection and circular enterorrhaphy. In cases of multiple stricture where they involve a limited area of the intestine an anastomosis should be made between the intestines at a point above the first and below the last stricture, excluding permanently the intervening portion from the fæcal circulation.

Eddowes[1] operated on a case of intestinal obstruction due to a cicatrical stricture where the symptoms were promptly relieved by the formation of an artificial anus, and the patient recovered with a permanent fistula. A woman forty-six years old, was seized nineteen days before the operation with abdominal pain, which had persisted ever since. For twelve days there had been no action of the bowels without enemata; complete constipation had existed for five days. There was no history of syphilis, tuberculosis or cancer. The abdomen was distended, but soft and free from tenderness; the walls were very thin, and moving coils of small intestine were plainly seen. The abdomen was opened by an incision four inches long in the median line between umbilicus and pubes. A small quantity of peritoneal fluid mixed with lymph escaped, and the abdominal contents appeared congested. A stricture of the small intestine was soon found, forming a complete obstruction, impermeable even to flatus. An artificial anus was formed at the lower extremity of the wound, about two inches from the pubes. The operation was followed by a great sense of relief. The lower portion of the wound suppurated on account of escape of fæces, otherwise the recovery progressed favorably. Seven months after the operation the patient was in perfect health, had gained considerably in weight, and was able to go about her household work as before. The bowels acted very regularly every morning, the motion was gradually formed, and

[1] British Medical Journal, July 24, 1886.

in this case she had very good control, but she was unable to control liquid motions and flatus. On introducing the finger, it was felt to be distinctly grasped by a sphincter.

Although the symptoms of obstruction were successfully removed by establishing an artificial anus in the median line, this course of practice is open to serious objections. An artificial anus should never be established in the median incision, as the contact of fæces with the wound necessarily prevents healing by first intention. If such a course is contemplated after the abdomen has been explored through a median incision, a small incision for the enterotomy should be made in one of the inguinal regions, and the median incision closed and dressed separately. In following such a course the large incision will heal by primary union and the abdomen can subsequently be opened again to better advantage through the median line for the performance of a radical operation. This, like all similar cases, would have been a proper subject for intestinal anastomosis.

In non-malignant stricture of the colon, colectomy and circular enterorrhaphy should be done in all cases where approximation of the bowel ends is possible. In multiple strictures of this portion of the intestinal canal resection is inapplicable, and the obstruction can only be rendered harmless and the continuity of the intestinal canal restored by lateral implantation or by establishing an intestinal anastomosis.

Coupland and Morris[1] have collected a number of cases of stricture of the intestine, and in commenting on the material, assert that in three-fourths of all the cases, the disease affected the lower part of the bowel, being about equally divided between the rectum and the sigmoid flexure. With few exceptions strictures are located below the cæcum. In many of the fatal cases death occurred from perforation either above the stricture or in the cæcum. From Bryant's investigations it appears that one-third of the cases of stricture of the rectum or lower bowel are not malignant, a most important practical point with regard to treatment. He lays down the following general rule for performing lumbar colotomy in cases of stricture of the rectum: "In all cases of cancerous stricture of the rectum or colon, including the annular, which are not amenable to

[1] On Strictures of the Intestine; with Remarks upon Statistics as a Guide to Diagnosis and Treatment, 1878.

lumbar colectomy or anal excision, right or left lumbar colotomy is strongly to be advocated, with the well-grounded hope of relieving suffering, retarding the progress of the disease, and prolonging life even for five or six years. To secure these advantages it is necessary for the operation to be performed before the pernicious effects of obstruction occur."

Against lumbar colotomy I have already, in another part of the paper, entered my protest, and in cases of inoperable carcinoma of the rectum producing evidences of obstruction, I wish to call attention to the method of operating devised by Madelung.[1] In cases of malignant stricture of the rectum, where it is desirable to exclude the part at and below the seat of obstruction completely and permanently from the fæcal circulation, he opens the abdomen by a lateral incision and divides the colon completely in a transverse direction, and as low down as possible. The distal end is closed by invagination and two rows of sutures, and dropped into the peritoneal cavity, while the proximal end is sutured into the wound. This operation secures absolute physiological rest for the diseased portion of the bowel and is less likely to be followed by prolapse, as is the case when the bowel is simply stitched into the wound and opened. Anal extirpation of the rectum, both for cicatricial and carcinomatous stenosis, should always be practiced when the obstruction and the local conditions which have caused it, can be removed by this method.

## 7. Tumors.

A tumor can give rise to intestinal obstruction in different ways, according to its location and anatomico-pathological character. A tumor or swelling outside of the intestinal tube may cause obstruction by compression. A polypoid growth springing from the mucous or sub-mucous tissue interrupts the fæcal circulation either by blocking the lumen of the bowel by its size, or by causing an invagination or flexion. A circular carcinoma produces a stenosis which leads to chronic obstruction, but which is frequently the indirect cause of acute intestinal obstruction when either by additional pathological changes at the seat of the malignant disease, or by the accumulation of foreign bodies or solid fæcal masses above the seat of constriction the fæcal circulation is completely arrested.

[1] Modification der Colotomie wegen Carcinoma Recti. Verh. der Deutschen Gesellschaft f. Chirurgie, 1884.

### 1. Non-Malignant Tumors.

Benign polypoid tumors seldom attain a sufficient size to give rise to intestinal obstruction, unless they cause additional mechanical disturbance, such as invagination or flexion, conditions which have already been alluded to. If the tumor alone is the cause of obstruction it is removed by laparo-enterotomy. A few cases have recently been reported where the obstruction was caused by cysts. In Buchwald's[1] case the symptoms of obstruction were acute, and laparotomy was performed on the third day. The patient was a boy who had previously been in good health. As soon as the peritoneal cavity was opened, two cysts attached to the small intestine presented themselves in the wound. As the cysts had produced a sharp flexion, 9 cm. of the bowel, including the cysts, were resected and the ends united by circular suturing. Twenty-seven hours after the operation the patient died. The necropsy showed that the resected piece was taken from the jejunum one-half metre below the duodenum. One cyst measured 17 and the other 10 cm. in diameter. The walls of the cysts were white and very thin. The microscopical examination showed that they were composed of the same tunics as the bowel, but the mucous membrane was atrophied and contained no glands. The cysts communicated with each other and the lumen of the bowel. The latter was not diminished in size. The cysts contained a yellowish fluid, with a strong odor of acetone. Under the microscope the contents showed cylindrical cells in a state of fatty degeneration, cholesterine crystals, granules of leucin, fat globules, and rod-shaped bacteria, but no intestinal contents. He believes that the cysts had no connection whatever with the vitelline duct.

Kulenkampff[2] reports the case of a child three years old that had suffered occasionally from colic and constipation, and was attacked suddenly with symptoms indicative of acute intestinal obstruction. Abdomen somewhat tympanitic, but no swelling could be made out by percussion and palpation. Tenderness and slight dullness in the right inguinal region. The boy died on the second day. The autopsy revealed as the cause of death a cyst in the region of the cæcum. The cyst was as large as a man's fist, and had thin,

[1] Ueber Darmcysten als Ursache eines kompleten Darmverschlusses. Deutsche Med. Wochenschrift, No. 40, 1887.

Ein Fall von Entero-kystom. Tod durch Darmverschlingung. Centralblatt f. die gesammte Medicin, No. 42, 1883.

almost transparent walls. It showed several depressions which gave it the appearance of being composed of three or four parts. It was located in the mesentery of the ileum, about 40 cm. above the ileo-cæcal valve. It did not communicate with the lumen of the bowel, and contained a thin chocolate-colored fluid. The mesentery at this point was drawn out like a string and encircled a loop of the ileum. Above this point the bowel was greatly distended. He believed with Roth [1] that the cyst was congenital and had developed from a diverticulum of the ileum. As a rule such cysts are located on the convex side of the bowel, but in this instance it occupied a position opposite. At first sight the cyst appeared like a greatly distended loop of intestine. As in both these cases the cyst had produced intestinal obstruction by secondary mechanical conditions, the operative treatment of the obstruction would include the removal of the primary cause and the correction of the secondary mechanical difficulties. This would include resection of the bowel at the seat of obstruction including the tumor, and restoration of the continuity of the intestinal canal by circular suturing.

### 2. Malignant Tumors.

Malignant stenosis of the intestines may be caused either by a sarcoma or carcinoma, of which the former is more frequent above and the latter below the ileo-cæcal valve. A sarcoma in the intestine, as in any other organ, primarily starts from an embryonal matrix of connective tissue, and hence it always has its starting-point in the wall beneath the mucous membrane; while carcinoma, being an atypical proliferation of epithelial cells, either commences in the mucous membrane or its glandular appendages.

#### a. Sarcoma.

Nicolaysen[2] reports an exceedingly interesting case of enterectomy for a sarcomatous stenosis of the small intestine. The patient was twenty-eight years of age. A firm nodulated, kidney-shaped tumor could be felt in the abdomen below the umbilicus. The tumor was first noticed six months before, when it was as large as a hen's egg. In the morning the tumor usually could be felt

[1] Virchow's Archiv. B. LXXXVI, p. 311.

[2] Myosarkom des Dünndarmes. Extirpation mit Darmresecktion. Centralblatt f. die ges. Medicin, No. 28, 1886.

under the costal arch, while during the day it descended into the hypogastric region where it always caused more pain. As the symptoms of obstruction gradually increased in severity and did not yield to ordinary treament laparotomy was performed. Median incision 14 cm. long. It was found somewhat difficult to bring the tumor forward into the wound. The tumor occupied the mesenteric side of the bowel and behind it a number of enlarged lymphatic glands could be felt. Eighteen centimetres of intestine, including the tumor and a triangular piece of mesentery were excised, and the ends of the intestine united with sutures, embracing only serous and muscular coats, whereupon the proximal end was invaginated to the extent of 2 cm. and the invagination retained with five Lembert sutures, over which the peritoneum was once more stitched with a continued suture of fine catgut. The mesenteric wound was also closed by suturing. The tumor consisted of several nodules the size of a goose-egg, which had perforated the intestine. Microscopical examination of the tumor and lymphatic glands showed sarcomatous tissue. The patient recovered.

Bessel-Hagen[1] described a somewhat similar specimen which he found in a child. A boy seven years old, after a trauma, suffered from a rapidly growing tumor in the abdomen, which resulted in death from marasmus in four months. At the autopsy a large sarcoma of the jejunum was found which had perforated into the gut by necrotic destruction of the interior of the tumor. Microscopic examination proved it to be a small-celled, round-celled sarcoma which had originated in the submucosa of the jejunum. Multiple metastasis in kidneys, on back and in the lymphatic glands. Peritonitic adhesions had caused flexion of the intestine below the tumor, and dilatation of the proximal portion from obstruction thus produced. As a sarcoma of the intestine only gives rise to symptoms of obstruction, and consequently comes under surgical treatment, usually after extensive infiltration of the mesentery and retroperitoneal tissues has taken place, it is questionable if it is prudent to attempt a radical operation, as in case the patient recovers from the operation, an early recurrence is almost inevitable. If a sufficiently early diagnosis were possible, resection could be made with a fair prospect of a permanent result; but if the infection has extended

[1] Ulcerőses Sarcom des Jejunum bei einem Kinde. Virchow's Archiv. B. XCIX, Heft 1.

to the tissues around the bowel, it is more judicious to leave the sarcoma and to exclude the obstruction by an intestinal anastomosis.

### b. Carcinoma.

In most cases of carcinoma of the intestine the disease commences in the mucous membrane, in which case the parenchyma of the tumor is composed of cells which resemble the columnar epithelium which lines the intestinal canal. Carcinoma is found most frequently in the region of the sigmoid flexure, the cæcum and rectum. A malignant stenosis may have existed for months without symptoms, when suddenly symptoms of acute intestinal obstruction are developed, as in a case here related. In cases of acute intestinal obstruction in elderly people, where no cause for it can be found in the abdomen, a thorough rectal examination should never be neglected.

During my visit in Zurich last year I was present at a very interesting autopsy made by Klebs upon one of Krönlein's patients. A few days before a woman forty years of age was brought into the hospital, presenting well-marked symptoms of intestinal obstruction, which had lasted for two weeks. On examination no cause for the obstruction could be found. The abdomen was very tympanitic, rendering palpation difficult and unsatisfactory. Laparotomy was made, but as nothing could be found and the small intestines were enormously distended throughout, inguinal colotomy was performed. The operation was followed by decided relief, the abdomen collapsed and a large quantity of fæces was discharged through the artificial anus; but the patient died of exhaustion the next day. At the post-mortem examination the cause of the obstruction was found 20 cm. below the artificial anus, in the shape of a narrow, annular, carcinomatous stricture of the colon. In his remarks on the case Krönlein stated that he had observed four similar cases during the time he had been in Zurich. It would be well in the future, when a similar condition is suspected, to explore, if need be, the upper portion of the rectum and lower extremity of the colon as far as accessible by Simon's method, as in case the lesion is recognized and accurately located, some of these cases might be amenable for a radical operation by excision.

Schede[1] made a resection of the small intestine for carcinoma

[1] Verh. der Deutschen Gesellschaft für Chirurgie, 1884.

in a case where the tumor had extended to the abdominal wall. The intestine was excised with the tumor and the ends united by circular suturing. The patient recovered. A few weeks later he returned to the hospital with symptoms of complete intestinal obstruction. The abdomen was again opened and an artificial anus was established. The patient died on the fifth day. The cause of obstruction was a constricting band which was divided during the operation. Schede is of the opinion that in cases of complete obstruction of the bowels by a malignant tumor, excision is contra-indicated, as in eighteen cases of intestinal resection for malignant disease, of six cases in which the occlusion was complete all died, while of the remaining twelve, where the occlusion was only partial, only three died. These statistics should only induce us to endeavor to make a correct diagnosis before urgent symptoms have set in, and to resort to operative treatment at a time when the general condition of the patient is such as to warrant a radical operation, and the local conditions at the seat of obstruction are favorable to a speedy process of repair.

If, after resection of the lower portion of the colon, it is found impossible to approximate the two ends of the bowel, and the distal end is not sufficiently accessible to make an intestinal anastomosis or lateral implantation, then the course adopted by Gussenbauer[1] in a case of this kind should be chosen. The patient was a man forty-six years of age, who had suffered for years from obstinate constipation. On examination a tumor was discovered the size of a hen's egg in the left hypogastric region, two fingers' breadth below a line drawn from one anterior superior spinous process of the ilium to the other. The tumor could also be felt high up in the rectum by pressing it downwards into the pelvis. The abdomen was opened by an incision over the tumor parallel with the course of the descending colon. The tumor was found to occupy the most prominent portion of the sigmoid flexure, freely movable, and not attached to any of the surrounding organs. A few glands behind the affected portion of the colon were enlarged. Circular resection was made, including a corresponding portion of the meso-colon and the enlarged lymphatic glands. On account of too great loss of substance, circular enterorrhaphy could not be made, consequently the distal end was closed by invagination and suturing and dropped into the abdominal

[1] Zur operativen Behandlung der Carcinome des S. Romanum. Prager Zeitschrift f. Heilkunde, 1881.

cavity, while the proximal end was sutured into the external wound. The patient made a good recovery, and at the end of ten months the disease had not returned.

Bull[1] reports two cases of carcinoma of the sigmoid flexure where, in each instance, he opened the abdomen through the median line and stitched the descending colon into the wound without incising it, reserving this step of the operation until adhesions had taken place. Both patients recovered. In one of these cases he resected six inches of the colon, including the artificial anus, and the tumor twelve months later, and the patient again recovered from the operation. At the time the report was made the operator had in view a third operation for the closure of the second artificial anus, which was made at the close of the second operation. In all cases where the seat of obstruction can be located in the cæcum or colon before the operation, lateral incision should be selected, as it will afford better access to the seat of obstruction than median incision.

If it is found impossible to remove the obstruction, one of two things must be done. If the bowel below the obstruction can be reached, an intestinal anastomosis is made, or the ileum is divided just above the ileo-cæcal valve, the distal end closed, and the proximal implanted into the bowel below the seat of obstruction. If resection can be done with a prospect of removing all the diseased tissues it should be invariably practiced as a primary radical operation, and if, on account of its extent, circular enterorrhaphy cannot be done, the distal end is permanently closed, and the proximal stitched into the wound. If the distal portion can be reached the continuity of the intestinal canal is restored by intestinal anastomosis or lateral implantation. If the seat of obstruction cannot be ascertained before the operation and exploration through a median incision locates it in the cæcum, colon, or rectum, it may become necessary to make a lateral incision if a radical operation is decided upon, and when this appears impossible or unjustifiable, an intestinal anastomosis or lateral implantation can be made through the median incision. If on account of the location of the obstruction, either of these operations are also inapplicable, an artificial anus should be established in the right or left inguinal region, and the median incision closed and dressed separately.

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[1] Gaillard's Medical Journal, March, 1888.

## V. Dynamic Intestinal Obstruction Caused by Suspension of Peristalsis.

A number of pathological conditions are known to produce symptoms which so closely resemble intestinal obstruction that the abdomen has been repeatedly opened in such cases, with the expectation of removing the cause of the obstruction, but no occlusion of any kind could be found. These are the cases that have caused the greatest difficulty in diagnosis, and have often brought disappointment and reproach upon the surgeon. The obstruction in these cases is not caused by a narrowing of the lumen of the intestine, but by suspension of the dynamic forces which propel the intestinal contents, and which results in accumulation of fæces and gases in the paralyzed portion of the bowel; which is followed by distention of the intestines, constipation and obstinate vomiting, which in rare cases may become fæcal. Circumscribed or diffuse paresis of the intestines is caused either by an inflammatory affection, such as peritonitis or enteritis, which produces suspension of muscular contractions in the same manner as when an inflammatory process in any other organ affects directly the muscular tissue, or the tunics of the intestines are in an intact condition, but a paralysis has resulted from reflex causes.

Pitts[1] narrates two cases in which, after reduction of a strangulated hernia, he performed laparotomy on account of persisting symptoms, and found no cause for these symptoms save that presented by the free but lifeless coil that had been liberated too late.

The contents in a paretic bowel are liable to undergo fermentative and putrefactive changes, and the gases which are developed during such changes accumulate and cause such an extensive tympanites that the latter may become a mechanical cause of obstruction.

### 1. Tympanites.

Cases of sudden death from over-distention of the intestines and stomach by rapid accumulation of gas have been reported by Dechambre, Mercier, L' Pereyra, and others. The patients were generally aged persons, or young persons during convalesence from protracted diseases.

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[1] St. Thomas' Hospital Reports. Vol. 11, 1882, p. 75.

Guéneau de Mussy,[1] in a clinical lecture, treats of the mechanical conditions which cause accumulation of gas in the intestines. Where no mechanical obstruction is present the gaseous distention is due to paralysis of the sympathetic nerves. The failure of the expulsion of the gas is owing to the formation of numerous flexions from the over-distention, and later, to compression of some parts of the intestines by the distended loops. The lowest portion of the ileum may be compressed against the ascending colon so firmly as to become a cause of complete mechanical obstruction. Proof of the existence of such a mechanical condition is furnished in cases of extensive tympanites where the introduction of a rectal tube affords no relief. In such cases the distention increases even after death.

The author has also furnished experimental proof. The cadaver of a child was inflated moderately through the œsophagus, after which the œsophagus was tied, and a tube was introduced into the rectum and its distal end immersed under water. Pressure upon the abdomen expelled the air through the rectal tube. When he repeated the experiment, but carried the distention further, no air could be made to escape through the rectal tube by compressing the abdomen. On opening the abdomen with great care, it was seen that the lower portion of the distended ileum was pressed against the ascending colon so firmly as to completely interrupt the communication between them. From these observations it can be readily seen how the formation of an intestinal anastomosis would frequently prove the means not only of relieving the obstruction, but also of the removal of its cause.

If gas is present in the peritoneal cavity as the result of putrefactive changes of the products of peritoneal inflammation, it presses the liver away from the diaphragm, and the percussion dullness disappears completely when the patient lies on his back. In distention of the abdomen from the presence of gas in the intestines, the diaphragm and liver are crowded upwards, but the latter remains in contact with the chest wall, and the area of liver dullness remains the same, but is displaced in an upward direction. Where life is threatened by tympanitic distention of the abdomen during the convalescence from acute diseases, the symptoms appear very rapidly and death results from mechanical compression of important organs.

[1] Des conditions Mécaniques de la tympanite. Gaz. hebd., No. 31, 1867.

Puncture of the distended intestines followed by aspiration, if need be, repeated at short intervals, is positively indicated in such cases. There can be no doubt that in many cases of peritonitis attended by diffuse and excessive tympanites the symptoms which point to intestinal obstruction are due to the same causes, viz.: flexions and compression, and such cases would also be greatly benefited and sometimes cured by the same treatment.

## 2. Peritonitis.

Peritonitis may lead to symptoms resembling intestinal occlusion in different ways, according to the extent and type of the disease. In extensive plastic peritonitis the immobilization of a considerable portion of the small intestines may give rise to persistent vomiting, and absolute constipation. Again, as we have just seen, arrest of the fæcal circulation may be caused by the tympanites alone, while perforative peritonitis is attended by a local and general shock, which causes intestinal paresis through the sympathetic nerves. Heusner[1] has observed that perforative peritonitis gives rise to disturbances simulating intestinal obstruction, by arresting intestinal movements. He narrates the histories of two cases of this kind where the symptoms of intestinal obstruction were so prominent that laparotomy was performed. In both cases perforative peritonitis, but no occlusion, was found.

Henrot,[2] in his classical monograph on pseudo-strangulation, describes a number of cases of perforation of the gall-bladder and the processus vermiformis, where the symptoms during life had pointed so strongly to the existence of intestinal obstruction that a wrong diagnosis was made by able clinicians. He also calls attention to those cases of paralytic obstruction which are often observed after herniotomy, and in cases of strangulation of the appendix vermiformis and testicle. The intestinal paresis, where it is not the result of inflammation, must be looked upon as a reflex symptom.

Physical signs and symptoms are sometimes utterly inadequate to distinguish between acute intestinal obstruction and diffuse peritonitis. In differentiating between these two conditions, it must be remembered that in the absence of a tumor, absolute constipation and fæcal vomiting are the most characteristic symptoms of obstruction,

[1] Deutsche Med. Wochenschrift, 1877.

[2] Des Pseudo-étranglements, etc., Thèse, Paris, 1865.

and that in peritonitis the pain is severe and continuous, with diffuse tenderness, tympanites, and absence of visible intestinal coils. In mechanical obstruction of the bowels the temperature as a rule is not above normal unless complications have set in, while in peritonitis a rise in temperature is the rule, although in some of the gravest cases it is sub-normal. Many cases of supposed recovery from intestinal obstruction without operation undoubtedly were cases of dynamic obstruction, and the recovery was either entirely spontaneous, or facilitated by means which assisted in the restoration of peristaltic action. In 1851 a patient was admitted into Dupuytren's ward with well-marked symptoms of acute intestinal obstruction. This eminent surgeon gave it as his opinion that without an operation a fatal termination was inevitable, but the patient objected to the operation and was transferred to another ward, where he recovered in three days under the use of simple cathartics. Numerous similar cases could be cited in illustration of the difficulty of differentiating in all cases between mechanical occlusion and dynamic obstruction.

## 3. Catarrhal and Ulcerative Enteritis.

For some reasons which at present it is difficult to explain, simple catarrhal enteritis and circumscribed ulcerations of the small intestines have occasionally been the cause of rapid accumulations of gas, followed by symptoms of intestinal obstruction. Mercier[1] has recorded a case where a patient died after a brief illness, during which all symptoms pointed to the existence of intestinal obstruction, including complete constipation and fæcal vomiting. The necropsy showed no stenosis or any other form of mechanical obstruction, but several large ulcers in the middle of the ileum.

Mosler[2] reports a case of acute intestinal obstruction which followed a catarrhal enteritis, where on post-mortem no primary mechanical obstruction could be found. The small intestines were so enormously distended that they filled the entire abdominal cavity, compressing the ascending colon so firmly as to render it completely impermeable; the transverse colon was also compressed, but to a lesser extent.

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[1] Note sur deux cas d ileus. Gazette Méd. de Paris, 1867, p. 151.

[2] Ueber den Ileus. Archiv der Heilkunde, No. 2, 1864.

Zimmermann[1] described a case of acute intestinal obstruction, where during life the collapse came on so rapidly as to resemble cholera. The bowels remained completely constipated, and the vomiting was so severe and persistent that on the seventh day it became stercoraceous. The patient lived six weeks. At the necropsy the small intestines were found enormously distended and their walls very much attenuated; the colon was also distended. In the ileum a number of small ulcers were found, which had destroyed the entire thickness of the mucous membrane. In a case of this kind Obalinski made a laparotomy, and as he found the external surface of the lower portion of the ileum only congested, but no mechanical obstruction, he closed the external incision and the patient recovered. He believed that in this case there were typhoid ulcers which caused a functional stricture of the gut and the symptoms which induced him to open the abdomen.

## 4. Exventration.

At a recent meeting of the Berlin Obstetrical Society, Olshausen reported several cases of laparatomy, in which more or less exventration became unavoidable during the operation. A few days after the operation the patients presented all the appearances of an attack of acute intestinal obstruction, and death followed five to ten days after the operation. Olshausen explained the symptoms during life and the fatal termination, by assuming the existence of intestinal paralysis, distention of the bowel and absorption of toxic agents from the intestinal canal. During the exventration the intestines became engorged by venous hyperæmia, which in turn again was followed by exudation into the tissues of the bowel.

Sebileau[2] re-opened the abdomen in two cases of acute intestinal obstruction after laparotomy, and no mechanical occlusion or exudation of any kind, but enormous meteorism was found. He attributes this condition to intestinal paresis and rapid accumulation of gas. The prophylactic treatment of such cases is more important than the curative. The administration of a brisk cathartic on the second or third day after the operation, will usually prevent tympan-

[1] Ein Beitrag zur Lehre vom dynamischen Ileus. Canstatt's Jahresbericht, B. 3, 1860, p. 245

[2] De quelques accidents intestinaux survenant après les opérations abdominales. Annal. de Gynécologie, T. XXV, p. 118.

itic distention of the abdomen by stimulating the paretic walls to active muscular contractions, and by removing the intestinal contents, the source of putrefactive changes. This treatment should never be postponed until the paralysis has been aggravated by over-distention, but should be resorted to either before, or upon the first appearance of intestinal distention.

Uniform compression of the abdomen with strips of adhesive plaster and bandage applied over the antiseptic absorbent dressing immediately after the operation should be kept up until all danger from the occurrence of tympanites has passed. When the distention has become so great as to threaten life, the treatment should consist of the employment of such prompt mechanical measures as will diminish the intra-abdominal pressure. As the stomach may also be dilated, its contents should be removed through a flexible stomach tube, followed by an irrigation with a harmless antiseptic solution. Tubage of the colon followed by a turpentine enema is used for the same purpose. If these measures fail in relieving the distention, a prompt resort to intestinal puncture with a fine hollow needle becomes imperative. This surgical resource may be repeated as often as it may become necessary to avert danger from an increasing intra-abdominal pressure.

# AN EXPERIMENTAL CONTRIBUTION TO INTESTINAL SURGERY WITH SPECIAL REFERENCE TO THE TREATMENT OF INTESTINAL OBSTRUCTION.[1]

The most important, and, at the same time, the most popular topic for discussion among surgeons of the present day is intestinal surgery. The current medical literature is teeming with reports of cases, and at the meetings of almost every medical and surgical society, large or small, this subject comes up for discussion and occupies a liberal space and conspicuous place in their printed transactions. The unusual activity which has been manifested in all parts of the civilized world in the development of this, one of the most modern and aggressive departments of abdominal surgery, is sufficient evidence that the subject is comparatively new, and as yet imperfectly understood. A study of the literature of intestinal surgery must convince every unprejudiced mind that here, as in many other difficult problems in surgery, the positive knowledge which we have acquired rests almost exclusively on the results obtained by experimental research. Gunshot wounds of the abdominal cavity have been made the object of careful and patient experimentation by a number of enthusiastic surgeons, and the results obtained have laid the foundation for a rational method of treatment of these injuries, which has been eagerly accepted by all modern aggressive and progressive surgeons. The practical results which have been obtained thus far in the hands of a number of surgeons have been the means of saving a number of lives, which by the old conservative method of treatment would have been doomed to inevitable death from hæmorrhage or septic peritonitis. The numerous valuable practical suggestions for treatment of gunshot injuries of the intestines are the direct outcome of experiments on animals, and this, as well as

[1] Read in the Surgical Section of the Ninth International Medical Congress, Washington, September 5, 1887.

the remarkable recoveries following gunshot wounds of the abdomen treated by laparotomy, have so firmly convinced the profession of the necessity of resorting to operative measures in such cases, that few surgeons could be found at the present day who would be willing to trust to conservative treatment any case where positive, or only probable, evidences pointed towards the existence of a visceral injury of any portion of the intestine.

While a decided advance has been made in the treatment of injuries of the intestinal tract, the operative treatment of intestinal obstruction still constitutes one of the darkest and most unsatisfactory chapters in the wide domain of intestinal surgery. The obscurity and uncertainty which cling to this subject are due to the difficulties which often surround an accurate diagnosis. At the same time we have every reason to believe that the appalling mortality which has so far attended the surgical treatment of intestinal obstruction is mainly due to late operations, and not infrequently to a faulty technique in the removal of the cause of the obstruction, and in the restoration of the continuity of the intestinal canal. An accurate anatomical or pathological diagnosis in such cases during life is often difficult, if not impossible, and when, as a *dernier ressort*, laparotomy is performed, and the surgeon is confronted by an unexpected condition of things, he is often in doubt as to what course to pursue, and frequently ends the operation by establishing an artificial anus. No one who has been forced to resort to this measure has left his patient with a feeling of satisfaction, as he must have been sadly impressed with the fact, that, at best, he has only been instrumental in relieving the urgent symptoms of the obstruction, while he has failed to remove its cause, and consequently also in restoring the continuity of the intestinal canal. A patient with an artificial anus is indeed an object of commiseration, as experience has sufficiently demonstrated how difficult it is in many instances to close the abnormal outlet, even after the cause of obstruction is subsequently removed or corrected spontaneously, without exposing him a second time to the risks of life incident to another abdominal section. If the causes which have led to the obstruction are of a permanent character, all attempts at closing the fistulous opening will, of course, prove worse than useless, and the patient is condemned to suffer from this loathsome condition the balance of his or her lifetime, without a hope of ultimate relief. I believe I can safely make the statement

without fear of contradiction that most of these unfortunate patients would prefer death itself to such a life of misery. The ideal of an operation for intestinal obstruction embraces the fulfillment of two principal indications:

1. The removal or rendering harmless of the cause of obstruction.

2. The immediate restoration of the continuity of the intestinal canal.

To meet the first indication the cause of obstruction must be found, its nature determined, and whenever advisable or practicable, it is removed, a step in the operation which may be very easy, or may demand a most formidable and serious undertaking, more especially in cases where the pathological conditions which have given rise to the obstruction are of such a nature as to constitute in themselves an imminent or remote source of danger, as, for instance, malignant disease or gangrene of the bowel from constriction. In all cases of inoperable conditions the cause of obstruction is rendered harmless as far as obstruction is concerned by establishing an anastomosis between the bowel above and below the obstruction by an operation which will be described further on.

Immediate restoration of the continuity of the intestinal canal should be secured in the operative treatment of all cases of intestinal obstruction, with the exception of inoperable cases of carcinoma of the rectum, but is most urgently indicated in cases of obstruction in the upper portion of the small intestines and the colon, as the formation of an artificial anus in the former locality would prove a direct source of danger from marasmus, by excluding too large a surface for intestinal digestion and absorption, while in the latter situation the cure of a fæcal fistula only too often proves an opprobrium of surgery. A careful perusal of the literature on the treatment of intestinal obstruction proves only too plainly the imperfection of this branch of surgery. The rules laid down in our text-books are often given with so much hesitation that it becomes impossible to apply them in practice. Opinions are so widely at variance that every surgeon finally acts upon the impulse of the moment and adopts a method which he deems appropriate for his case. It can be said that no uniformity of action exists, consequently the statistics which have been produced so far are of but little value from a practical standpoint. A rational and successful surgical

treatment of intestinal obstruction, like other abdominal operations, can only be established upon a basis founded upon the results obtained by experimental investigation. In view of this fact it is astonishing that so little has been accomplished in this direction. I am convinced that accurate work of this kind will render essential information in the diagnosis of the obscure causes of obstruction, and will point out more clearly the indications for operative interference, while improved methods of operation will have to be studied exclusively in this manner.

During the last eighteen months I have made one hundred and fifty operations on animals for the purpose of studying the effects of the principal varieties of intestinal obstruction, which were produced artificially; at the same time I have attempted to establish a number of new operations for the relief of certain forms of intestinal obstruction where it is impossible or inadvisable to remove the local conditions which gave rise to the obstruction. One of the greatest dangers in all operations for intestinal obstruction is the length of time required to perform the ordinary operations; hence it has been my object to simplify the operations, and thus by shortening the time diminish the danger from shock. All patients requiring an operation for intestinal obstruction are invariably in a condition not well adapted for prolonged operations, which necessitate the opening of the peritoneal cavity and exposure of its contents to the cooling influences of the atmospheric air. An operation which can be completed in twenty minutes must certainly prove less disastrous to the patient than one requiring from one to two hours. A prolonged operation on the intestines is attended by two great risks: 1. Immediate, due to shock. 2. Remote, prolonged exposure to infection. Both of these dangers are diminished in proportion to the shortening of the time consumed in the operation, which is made possible by resorting to simpler measures, provided they are equally safe and efficient.

## General Remarks on Experiments.

With few exceptions the experiments detailed in this paper were made at the Milwaukee County Hospital, located at Wauwatosa, six miles from Milwaukee; and here I desire to return my thanks to Dr. M. E. Connel, superintendent of the hospital, and his assistants, as well as to Dr. William Mackie, of Milwaukee, for

valuable services rendered in my experimental work. As the main object of these experiments was not to show favorable statistics, but more for the purpose of studying the effect of different forms of intestinal obstruction and to establish new principles of treatment, the animals were not submitted to any special treatment before or after the operation; the diet was not restricted and no internal medicines were given. I pursued this course in order to bring the intestinal canal in the most unfavorable conditions for operative interference, so as to expose the operations to the severest test. Ether was used exclusively as an anæsthetic. The abdomen was shaved, thoroughly washed with soap and warm water, and disinfected with a 1-1000 solution of corrosive sublimate or a two and a half per cent. solution of carbolic acid. For the sponges the same solution of carbolic acid or a weaker solution of corrosive sublimate was used. The abdomen was covered by several layers of aseptic gauze, with a slit in the centre.

Whenever division or incision of the bowel was made, fæcal extravasation was guarded against by compressing the bowel on each side by compressors made for this special purpose, or by constriction with an elastic rubber band. Experience showed that the latter method was preferable, as it proved less injurious to the tissues of the bowel, and afforded greater security against extravasation, while at the same time it proved less disastrous to the circulation between the points of compression. The rubber bands for this purpose should be about an eighth of an inch in width, rendered properly aseptic by prolonged immersion in a five per cent. solution of carbolic acid, and can be readily applied by perforating the mesentery with an ordinary hæmostatic forceps at a point not supplied with visible blood vessels, and tied in a loop with sufficient firmness to obstruct the lumen of the bowel. Elastic constriction practiced in this manner prevents all possibility of extravasation, and does not interfere with the free manipulations of the operator, as is the case with clamps or the hands of an assistant, while the degree of compression that is necessary exerts no injurious effects on the vessels and tissues at the seat of constriction. Drainage was never resorted to, and the abdominal wound was always closed by deep interrupted sutures including the peritoneum. In all cases where partial or complete exventration was made necessary, the bowels were kept covered with warm gauze compresses. In all cases where complete exventration

became necessary, and where the bowels remained out of the abdomen for half an hour or more, a certain degree of shock was always noticed, and a number of animals died within a few hours after the operation, death being referable directly to this cause. For an external dressing we used iodoform ointment applied directly over the wound, and a compress of cotton, retained by a bandage, and a jacket made of coarse cloth. As a rule the sutures were removed at the end of six days, when the wound was usually found healed by primary union.

## I. Artificial Intestinal Obstruction.

In imitation of the more common forms of intestinal obstruction in the human subject, due to congenital malformation or pathological conditions, the following kinds of obstruction were produced on animals: (1) stenosis, (2) flexion, (3) volvulus, (4) invagination. It is a noteworthy fact that even in cases where the obstruction was complete from the beginning, vomiting was moderate, and in some instances entirely absent. As vomiting constitutes one of the earliest and most conspicuous and persistent symptoms in most cases of intestinal obstruction in man, we can only explain its lesser intensity or complete absence in animals from the circumstance that animals suffering from this condition, as a rule, refuse all food and drink. As a rule, the tympanitis was also less marked than in the human subject.

### 1. Stenosis.

Circular narrowing of the lumen of the bowel was produced by excision of a semi-lunar piece of the intestinal wall and double suturing of the wound in a direction parallel to the intestine; and by circular constriction with bands of aseptic gauze.

#### a. Partial Enterectomy.

*Experiment 1.* Dog, weight thirty-nine pounds. A semi-lunar portion embracing half the circumference of the bowel removed from the convex surface, two inches above the ileo-cæcal valve. Wound closed in a longitudinal direction by Czerny-Lembert suture. The first two weeks the discharges from the bowels were fluid and dark in color, subsequently normal in color and consistence. Animal killed thirty-six days after operation. Body well nourished; abdominal wound indicated by a firm linear cicatrix. Omentum adherent at point of operation; lumen of bowel at point of operation reduced one-half in size; lumen of bowel above and below the contraction equal in size, showing that the stenosis had not furnished an obstacle to the passage of

intestinal contents. A few of the sutures remained attached, their free ends floating in the bowel.

*Experiment 2.* Large, full-grown cat. The same operation was performed on the concave side of the bowel about the middle of the ileum, a semi-lunar piece of the wall of the intestine with the corresponding mesentery being removed and the wound closed in a similar manner, which diminished the diameter of the lumen of the bowel to about one-eighth of an inch. It was noticed during the operation that the convex surface of the bowel over an area corresponding to the partial excision presented a cyanosed appearance. The animal died on the fourth day after operation, and the whole segment of the sutured bowel was found gangrenous, but no fluid in the abdominal cavity.

*Experiment 3.* Large, adult cat. In this case a segment of the ileum was emptied of its contents, and before cutting away a semi-lunar piece from the convex surface, a back-stitch, continuous suture was applied on the inner margin of the proposed line of incision, which left about one-third of the lumen of the bowel. After excision of the semi-lunar piece the margins of the cut surface were turned inwards and covered with serous surface by a continuous catgut suture. Several small passages occurred after the operation, but the animal died on the fourth day with symptoms of intestinal obstruction. The visceral wound was found healed, but the lumen had become so narrow from the inflammatory swelling of the tunics of the bowel that it was entirely inadequate for the passage of intestinal contents, and as a result of this obstruction the bowel had become considerably dilated above the point of operation.

Remarks.—These experiments illustrate conclusively that in wounds of the convex side of the intestine, where from the nature of the injury transverse suturing is impossible, longitudinal approximation and suturing can be safely done, provided at least one-half of the lumen of the bowel can be preserved. If the stenosis is carried beyond this point there is great danger that the inflammatory swelling following the operation will still further narrow the tube and lead to the most serious consequences due to intestinal obstruction, and place the visceral wound in the most unfavorable condition for the healing process.

Experiment No. 2 shows the great danger of interference with the blood supply from the mesentery in longitudinal suturing of wounds on the concave side of the bowel, as such a procedure is invariably followed by gangrene of the corresponding segment of bowel on the convex side.

### b. Circular Constriction.

The following experiments were made to study the effect of circular constriction upon the circulation of the isolated constricted

loop of bowel. In all cases where the constriction was made with a gauze band, this was tied with the same degree of firmness, so as to determine whether the same degree of strangulation would produce identical results.

*Experiment 4.* Adult cat. A loop of bowel about the middle of the ileum, six inches in length, was tied with a band of aseptic gauze with sufficient firmness to cause slight congestion, but without interfering with a free arterial supply, as the arteries in the ligated portion continued to pulsate freely. The day after operation a few small fæcal discharges stained with blood. The cat died forty-eight hours after the operation. No rise in temperature was observed, and death was evidently caused by collapse from perforation. The loop of bowel showed gangrene on convex side equidistant from the point of strangulation, and a small perforation which had given rise to diffuse septic peritonitis. The whole visceral and parietal peritoneum was uniformly affected and the peritoneal cavity contained a considerable quantity of sero-sanguinolent fluid.

*Experiment 5.* Large, adult cat. A loop of the ileum of the same length was tied in a similar manner and with same degree of firmness. The animal absolutely refused food until the eighth day. Rise in temperature second and third day. Only one fæcal discharge on the second day. Killed eight days after operation. Abdominal wound completely united; no peritonitis. Four inches of bowel below the point of constriction showed that partial reduction had taken place. The gauze band was found completely covered with adherent omentum, and a thick layer of plastic lymph which formed a complete bridge connecting the intestine above and below the ligature. The ligated portion showed no evidence of defective circulation, and no ulceration underneath the ligature. The obstruction was complete, as no fluid could be forced through the bowel, and in proof that the same condition existed during life, it was found that the bowel above the constriction was considerably dilated, while below the strangulation it was empty and contracted.

*Experiment 6.* Large, Maltese cat. A loop of the ileum, six inches in length, tied in a similar manner. On the third day fæces stained with blood. On the same day the temperature, which had remained nearly normal until this time, rose to 105° F., and on the following day the animal died, having manifested symptoms of perforative peritonitis for twenty-four hours. Abdominal wound united; recent diffuse peritonitis. The abdominal cavity contained several ounces of sero-purulent fluid. Bowel above constriction distended with fluid contents, below the obstruction empty and slightly contracted. The greater portion of strangulated loop was found gangrenous and adherent to adjacent loops of bowel. Perforation had taken place in the middle of the loop on the convex surface, showing that gangrene had taken place first at this point and had extended from here towards the ligature.

*Experiment 7.* Adult dog, weight twenty-six pounds. In this case an opening was made in the mesentery through which a loop of the small intestine, six inches in length, was pushed. With sutures this opening was made

sufficiently small so that its margins produced slight strangulation. The dog remained perfectly well after the operation, and was killed on the twenty-second day. Abdominal wound completely healed. No signs of peritonitis. On searching for the seat of obstruction it was found that spontaneous reduction had taken place, the site of perforation in the mesentery being indicated by a recent cicatrix.

Remarks.—The post-mortem appearances in these cases demonstrate clearly that the gangrene was not produced by the primary mechanical strangulation, but that it depended upon consecutive pathological changes in the loop or its vessels. In experiment No. 5 the primary strangulation was fully as great as in the preceding experiment, and yet gangrene did not take place, and we have positive proof that vascular engorgement in the ligated portion was less intense from the fact that partial reduction took place. In all cases where gangrene resulted, it must not have been from deficient arterial blood supply, but from an obstruction to the return of blood through the veins. If defective arterial blood supply had been the immediate cause of the gangrene, we would have found more constantly gangrene of the entire loop, while every specimen illustrated that gangrene always commenced at a point where the return of venous blood met with the greatest resistance, viz., on the convex surface in the middle portion of the loop. As in cases of hernia, or in any other form of intestinal strangulation, where a firm constricting band surrounds the loop of bowel, the danger of complete strangulation is increased if by the peristaltic action additional portions of the intestine are forced through the ring; and the immediate cause of the gangrene is always referable to obstruction to the return of venous blood, which leads rapidly to œdema, complete stasis, and moist gangrene in that portion where the venous circulation is most seriously impaired. Violent peristalsis under such circumstances always aggravates the existing conditions, and is often the precursor of symptoms of complete strangulation. In such cases opiates act favorably by arresting peristaltic action, and in so doing may avert gangrene by preventing the causes which otherwise would have led to complete venous stasis.

## 2. Flexion.

As many instances are on record where flexion of the bowel constituted the cause of intestinal obstruction, this condition was artificially produced in animals either by making a partial enterec-

tomy by removing a wedge-shaped piece from one side of the bowel, or by bending the bowel upon itself acutely, and fixing it in this position with catgut sutures.

*Experiment 8.* Dog, weight sixty pounds. A wedge-shaped piece of the wall of the ileum was removed from the concave side with a corresponding portion of the mesenteric attachment, and after arresting the bleeding by tying several vessels with catgut, the wound was closed transversely by two rows of sutures. The excised piece measured one inch at its base, and the apex reached as far as the median line of the bowel. Immediately after excision, the convex portion of the bowel which had become acutely flexed by uniting the wound, presented a livid, congested appearance, and after tying the sutures the cyanosis increased. The area of disturbance of the circulation corresponded to the width of the base of the excised portion. About fourteen inches from this place a similar piece was excised from the convex side of the bowel, and the wound closed in the same manner. At this point the flexion was only slight, the mesenteric portion forming the prominence of the curve. On the third day the temperature rose to 105.6° F., and the following day the animal died with symptoms indicative of perforative peritonitis. On opening the abdomen, diffuse general peritonitis was found with numerous adhesions. Gangrene and perforation were found on the convex side directly opposite the place of first operation. Second visceral wound closed, and lumen of bowel at this point somewhat contracted, but permeable to fluids.

*Experiment 9.* Large, adult cat. Removed from convex side of ileum a triangular piece measuring one inch at its base, the apex reaching a little beyond the middle line of the bowel. Wound closed transversely by Czerny-Lembert sutures. After closure of the wound the bowel presented at point of partial resection an obtuse angle, the apex being formed by the mesenteric portion. The stools were bloody the second day after operation. The animal remained in excellent condition until it was killed, forty-three days after operation. Adhesions of loops of small intestines to abdominal wound, and of omentum and adjacent intestines at point of operation. The extent of flexion was found somewhat diminished, yet the concavity on convex side of bowel was well marked. Size of bowel above and below the operation was equal, showing that the flexion had not acted as a cause of obstruction. On opening the bowel a pouch-like bulging was found on the mesenteric side, which appeared to compensate for the narrowing caused by the artificial stenosis. Two of the deep sutures still remained attached to the inner surface of the bowel.

*Experiment 10.* Large, adult cat. In this case a loop of the middle portion of the ileum, four inches in length, was acutely flexed in such a manner that the peritoneal surfaces of the convex side were brought in contact, and in this position the bowel was fixed by a number of fine catgut sutures. No symptoms pointing towards intestinal obstruction were observed, and the animal was killed sixteen days after the operation. Wound was found completely united, and no signs of peritonitis. The angle of flexion had somewhat diminished, but otherwise the bowel was adherent in position left after

operation. The bowel presented no dilatation above nor contraction below the flexion, showing that complete permeability of the canal at the point of flexion was quickly restored.

Remarks.—The partial excision on concave side of bowel in experiment No. 8, illustrates the danger of suturing wounds in this locality where the blood supply from the mesentery is likewise impaired, as gangrene of the remaining portion of the bowel is almost certain to take place. In all wounds on this side of the bowel more than half an inch in length, there is also another great danger which attends transverse suturing, viz., stenosis, which may become the cause of intestinal obstruction. As the small intestines naturally describe quite a strong curve with the concavity on the mesenteric side, closure of a wound involving this portion of the bowel gives rise to acute flexion which, at least during the process of healing, must cause more or less obstruction, until by yielding of the opposite portion of the intestinal wall an adequate dilatation of the calibre of the tube has taken place. A considerable portion of the wall on the convex side of the bowel can be removed and sutured transversely until the bowel has been transformed into a straight tube, and a wound an inch in length will make only a slight flexion which furnishes no serious mechanical obstacle to the passage of the intestinal contents. In this connection the question arises: Does simple flexion, even if acute, without diminution of the lumen of the bowel, give rise to symptoms of obstruction? I have made numerous flexions when performing operations for establishing intestinal anastomosis, and in most instances satisfied myself by examination of the specimens that fluids passed them without great difficulty. If the bowel at the point of flexion remains free, certain portions of its wall will yield to pressure of the fluid intestinal contents, and gradually the lumen of the bowel will become restored. If, on the other hand, the entire circumference of the bowel at the point of flexion has become fixed and immovable by inflammatory adhesions or other pathological products, a compensating dilatation becomes impossible, and the flexion becomes a direct and serious cause of obstruction.

### 3. Volvulus.

This condition, only another form of flexion, was experimentally produced by rotating a loop of intestine one and a half or two times around its axis, and retaining it in this position by a number of fine

sutures, which were applied in places at the base of the volvulus, where fixation was most required.

*Experiment 11.* Dog, weight twelve pounds. A loop of the ileum, eight inches in length, was brought out through a small incision and the tubes turned around their axis twice and the twist maintained by two catgut sutures. The constriction was sufficiently firm to cause considerable venous engorgement in the twisted loop. The dog manifested no unpleasant symptoms after the operation. The specimen was not obtained, as after a few days the dog ran away.

*Experiment 12.* Medium-sized adult cat. In this case the volvulus was made by twisting a loop of the ileum, about four inches in length, twice around its axis, and retaining it in this position by a number of fine silk sutures. Vomited several times during the first day. The first three days in taking the temperature in the rectum, the thermometer when taken out was bloody. The first two days the temperature was normal, followed by an increase to 104.6° and 103.2° F. the two succeeding days; then it became normal. No constipation; appetite good throughout the whole time. Animal killed twenty-two days after operation. Abdominal wound completely united; no peritonitis. Volvulus remains as after operation, with the exception that where the bowel had been flattened by the twisting it had, at least partially, resumed its tubular form. Serous surfaces where approximated had become firmly adherent at point of constriction, size of bowel considerably diminished. The twisted loop contained liquid fæces. Connecting the specimen with the faucet of a hydrant, water could be forced through, but on increasing the force of the current the peritoneum ruptured extensively in a longitudinal direction to point of partial obstruction.

Remarks.—These experiments are interesting, inasmuch as the primary constriction produced in making and maintaining the volvulus, which was sufficient to cause venous engorgement in the twisted loop, must have been only of short duration, the disappearance of the effects of constriction being undoubtedly due to the gradual yielding of the sutured parts. While the faulty axis of the twisted loop was maintained by the sutures, the circulation improved and remained in a sufficiently vigorous condition to adequately nourish the most distant portions of the volvulus. While it was found difficult to force fluid through a specimen of volvulus during life, propulsion of the intestinal contents by peristaltic action was carried on in a satisfactory manner, as the bowel above the volvulus was not dilated, and contained no abnormal amount of fluid, and the animal manifested no symptoms indicative of intestinal obstruction.

### 4. Invagination.

The most frequent and, from a surgical standpoint, the most important form of intestinal obstruction is invagination. Leichten-

stern and Leubuscher have made careful experimental studies to explain the mechanism and pathological conditions which give rise to this kind of intestinal obstruction; but in the following experiments this part of the subject was ignored, and the invaginations were made by direct manipulation. It was found impossible to make an invagination at any point, as long as the bowel was in a condition of contraction, consequently it was always found necessary to wait until the peristaltic wave had passed by, or to cause relaxation by firm pressure continued for several minutes. Usually, it was found easy to produce an invagination of the bowel, when in a state of relaxation, by indenting one side of the bowel, and pushing the pouch forward with a blunt instrument until the entire lumen of the intestine had passed into the section of the bowel below. After this was accomplished, further invagination was readily effected by manipulation, consisting in pushing gently the intussusceptum and intussuscipiens in opposite directions. After I had learned by experience that disinvagination frequently takes place spontaneously, I resorted sometimes to suturing of the intussusceptum to the neck of the intussuscipiens for the purpose of maintaining the invagination. But even this expedient did not always succeed in retaining the malposition, as spontaneous reduction was observed in several of these cases.

*Experiment 13.* Adult cat. The lower portion of the ileum and the cæcum and upper portion of the colon were drawn forward into an incision through the linea alba, and five inches of the ileum were pushed into the colon through the ileo-cæcal valve, when the parts were replaced and the abdominal wound closed. For six days the animal had a temperature from 102.6° to 105° F., and suffered from tenesmus. The stools contained mucus and blood. After the sixth day the symptoms due to invagination subsided, and were replaced by symptoms of peritonitis. The animal was killed twenty-two days after operation. Great emaciation; abdominal wound completely united; diffuse purulent peritonitis. The disease had evidently commenced in the ileo-cæcal region, as at this point the pathological changes were found most advanced. Complete spontaneous reduction of the invagination; colon greatly distended, and intensely congested.

*Experiment 14.* Large, adult cat. Invagination was made in the lower part of the ileum. Length of intussusceptum three inches. For nine days the scanty fæcal discharges contained mucus and at times blood. On the ninth day the temperature registered 105° F.; absolute refusal of food, and only occasional vomiting; death on the thirty-third day after invagination. Abdominal wound healed; small ventral hernia; no peritonitis. Apparently, the greater portion of the intussusceptum had disappeared by sloughing, and

the subsequent healing process had produced an acute flexion at the neck of the intussuscipiens. Firm adhesions between peritoneal surfaces in the concavity of the flexion, nearly an inch in length. Above this point the intestine was enormously dilated and distended with fluid contents. Below the obstruction the bowel was found contracted and empty. Water could not be forced through the obstruction from either direction. On slitting open the bowel in a longitudinal direction, it was found that the lumen at the point of flexion was contracted to such an extent that only a fine probe could be passed. On the concave side of the flexion the mucous membrane presented a prominence marked by a number of longitudinal ridges. These folds had undoubtedly acted like valves in completely preventing the passage of intestinal contents, and later, the injection of water. Death in this case resulted from intestinal obstruction caused by cicatricial contraction after the sloughing of the invaginated portion of the bowel.

*Experiment 15.* Adult cat. Two inches of the ileum were invaginated into the colon and fixed by two fine silk sutures at the neck of the intussuscipiens. For two days after the invagination the stools were scanty and contained mucous and blood. On the third day the abdominal cavity was re-opened by an incision along the outer border of the right rectus muscle, and the invaginated bowel drawn forward into the wound. No peritonitis. The bowel at point of operation was very vascular, and the neck of the intussuscipiens covered with plastic exudation. The sutures were removed and the rectum and colon distended with water for the purpose of effecting reduction. As soon as the colon had become thoroughly distended the adhesions gave way with an audible noise, and complete reduction followed in such a manner that the portion last invaginated was first reduced. After reduction had been accomplished the injection was continued to test the competency of the ileo-cæcal valve. As soon as the cæcum was well distended the fluid passed readily through the valve into the small intestines, showing that the valve had been rendered incompetent by the invagination. The force required to overcome the adhesions in the reduction of the invagination was sufficient to rupture the peritoneal covering of the large intestines in three different places, the rents always taking place parallel to the bowel. The animal died on the following day with symptoms of diffuse peritonitis.

*Experiment 16.* Ascending invagination in a cat. A few inches above the ileo-cæcal region the ileum was invaginated in an upward direction to the extent of two inches. At the time the invagination was made the intussuscipiens contracted firmly. In consequence of this, a tear occurred in its peritoneal covering in a direction parallel to the bowel. The stools were few and scanty. On the fourth day the animal died of perforative peritonitis. Abdominal wound not united, but the peritoneal wound closed by omental adhesions. Spontaneous reduction of half an inch of the invagination had taken place. Reduction by traction was found impossible on account of firm adhesions about the neck of the invagination. Recent diffuse peritonitis caused by two perforations, one at the neck of the intussusceptum on mesenteric side, and the other a little to one side of this one and on proximal side of the bowel.

The perforation resulted from beginning sloughing of the invaginated portion of the bowel. About two inches above the invagination the bowel was acutely flexed towards the mesenteric side by recent firm adhesions. Flexion was undoubtedly caused by circumscribed plastic peritonitis and increased peristalsis.

*Experiment 17.* Large, adult cat. Descending invagination of ileum to the extent of two inches in the upper portion of this part of the bowel. Second and third days the scanty discharges from the bowel bloody. Temperature from second day after operation varied between 103.4° and 105.4° F. Death from perforative peritonitis on the seventh day after invagination. Abdominal wound united. Recent diffuse peritonitis from a perforation at the neck of the invagination on the mesenteric side. Gangrene of intussusceptum and partial separation which had again caused a sharp flexion of the bowel at the neck of the invagination. Above the seat of obstruction the bowel dilated and distended with fluid contents; below empty and contracted.

*Experiment 18.* Young cat. Invagination of ileum into ascending colon to the extent of three inches. For a week after operation frequent tenesmus, followed by mucous discharges mixed with blood. The temperature during this time varied from 102.6° to 105° F. After this the animal improved and was in good condition when killed fourteen days after operation. Abdominal wound united. No omental adhesions or peritonitis. Firm union between the serous surfaces. No dilatation of bowel above seat of obstruction. Intussusceptum not gangrenous, its lumen about the size of an ordinary lead-pencil. It was found impossible to reduce the invagination by traction or by forcible injection of fluid from below. When the traction was increased, the peritoneal surface of the neck of the intussuscipiens ruptured in a longitudinal direction.

*Experiment 19.* Large, adult cat. Six inches of the ileum were invaginated into the colon. Frequent bloody discharges until the third day, when the abdomen was reopened and the neck of the intussuscipiens exposed to sight, so as to observe directly the mechanism of disinvagination by rectal injection of water. As soon as the colon was well distended the adhesions at the neck of the intussuscipiens began to give way, and complete reduction followed, as the adhesions gave way under the pressure from below. The abdominal wound was again closed and dressed in the usual manner. The animal recovered completely from the operation, and was killed twenty-four days after the first operation. Abdominal wound well united. In the ileocæcal region, numerous adhesions around the portion of bowel which had been invaginated and subsequently reduced.

*Experiment 20.* Invagination of colon into colon was commenced about the middle of the bowel, and advanced as far as the cæcum. Second day bloody discharges from the bowels. Animal killed five days after operation. External wound united only on peritoneal side. Invagination completely reduced. Localized plastic peritonitis limited to the portion of the bowel which had been invaginated; otherwise peritoneum and intestines in a healthy condition.

*Experiment 21.* Invagination of colon into colon to the extent of four inches, in a cat. The subsequent symptoms only for a short time indicated

the existence of invagination, which after they had subsided, were followed by evidence of peritonitis. Death occurred on the nineteenth day after the invagination. Abdominal wound well united; diffuse purulent peritonitis; under surface of diaphragm covered with plastic lymph. Although sought for, no perforation could be found in the disinvaginated bowel, but as the peritonitis appeared to have started at the site of operation, it is probable that infection took place through the paretic walls of the disinvaginated bowel.

*Experiment 22.* Same kind of invagination made in a cat as in the preceding case. For two days the stools were frequent, scanty, and contained mucus and blood. After this the animal remained in good condition until it was killed thirty-five days after the invagination. Abdominal cavity showed no trace of inflammation. The invagination was completely reduced and the entire colon presented a normal appearance.

Remarks.—With the exception of experiment No. 16, the invagination was always made in a downward direction. In the case of ascending invagination, gangrene of the intussusceptum and perforation resulted in death from diffuse peritonitis on the fourth day after partial spontaneous reduction had taken place. In experiments Nos. 15 and 19, both cases of ileo-cæcal invagination, complete reduction was effected by distention of the colon with water; in the first case the force required to accomplish this result was sufficient to produce multiple longitudinal lacerations of the peritoneal surface of the distended bowel, which undoubtedly were responsible for the death on the following day from diffuse peritonitis; while in the second case no such accident occurred, and the animal recovered, although the abdominal wound was re-opened for the purpose of observing the mechanism of reduction by this method of procedure. In one case of ileo-cæcal invagination, experiment No. 18, the intussusceptum remained *in situ* after the invagination, and became so firmly adherent to the intussuscipiens that even in the specimen, reduction by traction was found impossible. In this case, although the lumen of the invaginated portion barely permitted the introduction of an ordinary lead pencil, no symptoms of obstruction were manifested during life, and the bowel above the invagination was not found dilated after death. In experiment No. 14, the sloughing of the intussusceptum led to cicatricial contraction of the bowel and flexion at site of invagination, conditions which resulted in death from obstruction twenty-three days after invagination.

The great danger which attends sloughing of the invaginated portion is circumscribed gangrene and perforation of the intussuscipiens at the neck, and death from perforative peritonitis, as

illustrated by experiments Nos. 16 and 17. Experiment No. 16 illustrates that ascending invagination, should it occur, is not more likely to be reduced spontaneously than the more common form of descending invagination. These experiments also demonstrate conclusively that the danger attending the invagination increases the higher it is located in the intestinal canal, being greatest when it is situated high up in the tract of the small intestines, and gradually less as the ileo-cæcal region is approached. The ileo-cæcal form is less dangerous, as spontaneous reduction is more likely to take place; and gangrene of the intussusceptum, when it occurs, does so after a longer time, after firm adhesions about the neck of the intussuscipiens have formed, a condition which is well adapted to prevent perforation. Of the three invaginations of the colon, experiments Nos. 20, 21 and 22, complete spontaneous reduction took place in all of them from the first to the fourth day, and in only one of them was the result fatal, in experiment No. 21, where purulent peritonitis, either from infection through the operation wound or, what is more probable, through the damaged wall of the colon occurred, and was the cause of death on the nineteenth day after the invagination. Experiments Nos. 15 and 19 prove both the danger and the utility of distention of the colon in cases of ileo-cæcal and colonic invaginations. As a rule, the longer the invagination has existed the firmer the adhesions, and consequently the greater the danger of relying too persistently on this measure in reducing the invagination. In resorting to this expedient in the reduction of an ileo-cæcal invagination, it is of the greatest importance to relax the abdominal wall completely by placing the patient fully under the influence of an anæsthetic; and to add to the distending force as much as possible by gravitation, the patient should be inverted and the injection should always be made very slowly and with requisite care to prevent rupture of the peritoneal coat by rapid over-distention. When the obstruction is located beyond the ileo-cæcal valve, no reliance can be placed upon this measure, as can be seen from the following experiments made to determine the

### Permeability of the Ileo-Cæcal Valve.

*Experiment 23.* While completely under the influence of ether an incision was made through the linea alba of a cat, sufficiently long to render the ileo-cæcal region readily accessible to sight. An incision was made into the ileum just above the valve, and by gently retracting the margins of the

wound, the valve could be distinctly seen; water was then injected per rectum, and as the cæcum became well distended, it could be readily seen that the valve became tense and appeared like a circular curtain preventing effectually the escape of even a drop of fluid into the ileum. The competency of the valve was only overcome by *over-distention* of the cæcum which mechanically separated its margins, which allowed a fine stream of water to escape into the ileum. The insufficiency of the valve was clearly caused by great distention of the cæcum. That such a degree of distention is attended by no inconsiderable danger was proved by this experiment, as the cat was immediately killed, and on examination of the colon and rectum a number of longitudinal rents of the peritoneal coat were found.

*Experiment 24.* In this experiment, a cat was fully narcotized with ether and while the body was inverted water was injected per rectum in sufficient quantity, and adequate force by means of an elastic syringe, to ascertain the force required to overcome the resistance offered by the ileo-cæcal valve. Great distention of the cæcum could be clearly mapped out by percussion and palpation before any fluid passed into the ileum. As soon as the competency of the valve was overcome, the water rushed through the small intestines, and having traversed the entire alimentary canal issued from the mouth. About a quart of water was forced through in this manner. The animal was killed and the gastro-intestinal canal carefully examined for injuries. Two longitudinal lacerations of the peritoneal surface of the rectum, over an inch in length, were found on opposite sides of the bowel.

*Experiment 25.* This experiment was conducted in the same way as the foregoing, only that the cat was not etherized. More than a quart of water was forced through the entire alimentary canal from anus to mouth. The animal was not killed, and lived for eight days, but suffered the whole time with symptoms of ileo-colitis. A post-mortem examination was not made in this case, although the symptoms manifested during life leave no doubt that they resulted from injuries inflicted by the injection. It will thus be seen that in the three cases where fluid was forced beyond the ileo-cæcal valve, in two of them the post-mortem examination revealed multiple lacerations of the peritoneal coat of the large intestines, while the third animal sickened immediately after the experiment was made, and died from the effects of the injuries inflicted eight days later. The injection of water beyond the ileo-cæcal valve in the treatment of intestinal obstruction must therefore be looked upon in the light of a dangerous expedient and should never be resorted to.

## II. Enterectomy.

It still remains an open question to what extent resection of the small intestines can be performed with impunity. It is true that Koeberlé, Kocher and Baum have successfully removed respectively 205 cm., 160 cm., and 137 cm. of the small intestine in the human subject; but while two of the patients do not appear to have suffered any ill effects in consequence of the removal of such a large surface

for digestion and absorption, in Baum's case death, which supervened six months after the operation, was attributable clearly to marasmus, brought about by the extensive intestinal resection. As in a number of pathological conditions of the intestinal canal, where the wounds are large and in close proximity, such as multiple strictures, gangrene, and multiple gunshot wounds, it may be necessary to resort to extensive resection, it becomes an important matter for the surgeon to know how much of the intestinal tract can be removed without any immediate or remote ill consequences.

The immediate danger attending such an operation is the traumatism, which of course, will be proportionate to the length of the piece of intestine removed; while the remote consequences are due to impairment of the functions of digestion and absorption caused by the shortening of the intestinal canal. With the view of obtaining additional light on these important questions the following experiments were undertaken:

*Experiment 26.* Dog, weight twenty-two pounds. Mesentery divided into four portions and tied with catgut, and thirty inches of the ileum from near the ileo-cæcal region upwards excised, and ends sutured together by Czerny-Lembert sutures. Abdominal wound failed to unite, and a copious sero-sanguinolent discharge escaped from it the last day. Death on fifth day from peritonitis. Peritoneal adhesions in abdominal wound only partial; omentum adherent to wound. Intestines firmly adherent to omental stump. Circumscribed gangrene of bowel on convex side at site of operation. Recent diffuse peritonitis caused by perforation.

*Experiment 27.* In a cat, twelve inches were removed from the middle of the ileum, and the ends united by a double row of sutures; mesenteric vessels tied *en masse* with one catgut suture. The animal never rallied from the operation, and died of the shock the same night.

*Experiment 28.* Dog, weight thirty-six pounds. Mesentery tied in several sections with catgut ligatures; ileum divided just above the ileo-cæcal valve and six feet of the small intestines excised, and the ends united by Czerny-Lembert sutures. On the third day the fæcal discharges were bloody. Although the appetite remained good, and the dog was allowed to eat as much as he desired, he lost several pounds in weight during the first week. On the third day the abdominal wound opened as the sutures had cut through and required re-suturing. After this time the wound healed kindly. Three or four fluid fæcal discharges during twenty-four hours. The character of the discharges remained the same, and several microscopic examinations made at different times revealed the presence of free undigested fat. The dog was kept busy eating most of the time, and although the most nourishing food was furnished, he emaciated to a skeleton. He was killed one hundred and sixty-one days after the operation. Marasmus extreme, hardly a trace of fat could be found any-

where in the tissues. Stomach enlarged to three or four times its normal size, and distended with food. A slight thickening of the wall of the gut indicated externally the site of suturing, and the lumen of the bowel at this point was slightly diminished in size. At point of operation a loop of intestine was found adherent and somewhat contracted. The remaining portions of the small intestines, only forty-five inches in length, seemed to have undergone compensatory hypertrophy, as the coats were much thickened and exceedingly vascular. At the seat of suturing, the mucous membrane presented a slight circular prominence. Pancreas, liver and spleen were normal in size and appearance.

*Experiment 29.* Medium-sized, adult dog. Mesentery tied in several sections, and eight feet and two inches of the small intestines from ileo-cæcal region upwards excised and ends sutured in the usual manner. On the following day the dog vomited, and blood was seen to escape from the abdominal wound. Death three days after operation. The abdominal cavity was filled with fluid and coagulated blood, which on closer inspection was found to have escaped from one of the stumps of the mesentery, where the catgut ligature had slipped off.

*Experiment 30.* Scotch terrier, weight ten pounds. Mesentery ligated in part with catgut ligatures, the ileum divided four inches above the ileo-cæcal region, and fifty inches of the small intestines excised, and the continuity of the intestinal canal restored by the usual method of suturing. Some difficulty was experienced in suturing, as the lumen of the upper end was considerably larger than that of the lower. Until four weeks after the operation the dog, although eating well, seemed to become more and more emaciated. After this time he gained somewhat in weight until killed forty-seven days after the resection. During the whole time the fæces were either fluid or only semi-solid, and at different times contained free, undigested fat. Appetite most of the time voracious. No adhesions to abdominal wound. Omentum adherent to visceral wound and to bowel. The site of operation was indicated by a slight depression on the surface of the bowel. On palpation a ring-like thickening was felt corresponding to the united ends of the bowel. Bowel above seat of resection somewhat enlarged. On cutting into the bowel the point of union was indicated by a circular prominence of mucous membrane. Nine of the deep sutures were found still attached to the mucous membrane. The entire tract of the small intestines which remained measured only two feet and ten inches in length.

*Experiment 31.* Adult Maltese cat. The mesentery was tied in five sections with catgut ligatures corresponding to twenty-nine inches of the ileum which was excised. Previous experience in circular enterorrhaphy had satisfied me that perforation is most likely to take place on the mesenteric side of the bowel, where, on account of the triangular place made by the reflections of the peritoneum, the muscular coat is not covered by serous membrane. To obviate this difficulty I secured a continuity of the serous covering of the ends of the bowel before suturing, by drawing the peritoneum over this raw surface by a fine catgut suture. The mesentery was detached

only to a sufficient extent to apply the second row of sutures. The fine catgut suture to approximate the edges of the peritoneum was applied near the margin of the divided end of the bowel, so that the knot did not interfere with the accurate coaptation of the serous surface between the deep and superficial row of sutures. This modification of circular suturing was adopted for the first time in this case. Although the animal manifested no untoward symptoms, and the appetite remained good, the marasmus was progressive until the time of killing, twelve days after the excision. Abdominal wound not completely united. Intestinal wound, which was two inches above the ileo-cæcal region, completely healed. The sutured surface was adherent to a loop of bowel which caused a sharp flexion. Intestine above this point somewhat dilated and partially distended with fæcal accumulation. Slight contraction of the lumen of bowel by circular bulging of mucous membrane, in which most of the deep sutures remained fixed. The post-mortem appearance pointed to partial obstruction at point of flexion; remaining portion of small intestines measured only twenty-one inches in length.

*Experiment 32.* Medium-sized Maltese cat. Mesentery tied in sections, and thirty-four inches of the small intestines excised and the divided ends united in the same manner as in the last case, special care being taken to secure an uninterrupted peritoneal surface for divided ends before suturing. Appetite remained good, but progressive marasmus, which appeared at once, continued and proved the direct cause of death twenty-one days after the excision. Abdominal wound firmly united. No peritonitis. Visceral wound completely united; intestine at site of operation covered with adherent omentum.

## I. Excision of Colon.

*Experiment 33.* Large, black cat. The meso-colon was divided in numerous sections, and each part separately tied with a catgut ligature. As the meso-colon was very short, a number of the ligatures slipped off and had to be replaced by fine silk ligatures. The entire colon and about two inches of the lower end of the ileum were excised. As it was found impossible to unite the bowel on account of the deep location of the rectal end, it became necessary to close the distal or rectal end by inverting its margins and applying a continuous suture. An artificial anus was established by stretching the iliac or proximal end into the abdominal wound. Death from shock a few hours after the operation.

*Experiment 34.* Medium-sized dog. Resection of entire colon and three inches of ileum. Meso-colon divided into sections and ligated with silk ligatures. In order to enable circular enterorrhaphy it was found necessary to excise a triangular piece from large distal end, so as to make its lumen correspond to that of the divided ileum. After this was done and the lateral wound closed by two rows of sutures, the ends of the bowel were united in the usual manner. Death from shock six hours after operation.

*Experiment 35.* Excision of entire colon and two inches of ileum in a cat. Excision of triangular piece from distal end, to narrow the bowel suffi-

ciently so that its lumen should correspond to that of the ileum. The ileum and rectum were then united by Czerny-Lembert sutures. The animal never rallied from the prolonged operation, and died of shock two hours later.

Remarks.—The results of these experiments speak for themselves. In all cases of extensive resection of the small intestines where the resected portion exceeded one-half of the length of this portion of the intestinal tract, where the animals survived the operation, marasmus followed as a constant result, although the animals consumed large quantities of food. In all of these cases defective digestion and absorption could be directly attributed to a degree of shortening of the digestive canal imcompatible with normal digestion and absorption. Only one of these animals (experiment No. 27) died from shock a few hours after operation. Another death resulted from the trauma, in experiment No. 29, where fatal hæmorrhage occurred from one of the mesenteric vessels, where the catgut ligature became displaced from shrinkage of the included mesenteric tissues. When the vessels of the omentum or mesentery are tied *en masse* there is always danger from this source, and to prevent this accident it becomes necessary not to include too much tissue, and to tie firmly with fine threads of aseptic silk. After I commenced to tie in this manner, I encountered no further difficulty in arresting and preventing hæmorrhage in operations requiring incision of these tissues. Although the large artery running parallel with the bowel where the mesentery is attached was excised in every case with the intestine, gangrene and perforation occurred only in experiment No. 26. The post-mortem appearances after extensive enterectomies indicated that the portion of bowel which remained underwent compensatory hypertrophy, but that as a rule the increased functional activity was not adequate to make up for the great anatomical loss. In all instances where the animal recovered from the operation, the discharges from the bowels were frequent, fluid or semi-fluid, and contained undigested food, among other substances, free undigested fat, showing that the intestinal secretions play an important role in the digestion of fat. As an approximate estimate the statement can be ventured that in dogs and cats, the excision of more than one-third of the length of the small intestines is dangerous to life, as it is followed by marasmus, which sooner or later results in death. As all three cases of excision of the colon proved fatal from shock in from two to six hours, it can be safely

asserted that this operation is impracticable, and is invariably followed by death from the immediate results of the trauma.

## 2. Physiological Exclusion.

As extensive resections of the intestines are always attended by great risks to life from the trauma, I concluded to study the subject of sudden deprivation of the system of a great surface for digestion and absorption, by eliminating or diminishing the cause of death from this source by leaving the intestine, but by excluding permanently a certain portion from participating in the functions of digestion and absorption; in other words, by resorting to physiological exclusion. These experiments were also made to determine the tissue changes which would take place in the bowel thus excluded, and to learn if under such circumstances accumulation of intestinal contents would become a source of danger, as had been feared by the older surgeons. The complete interruption of passage of intestinal contents either by section and closure of the bowel, or by making an intestinal obstruction of some kind, and the restoration of the continuity of the physiologically active portion of the intestinal canal, was established by suturing the proximal end of the high section with the distal end of the lower section, or by implanting the proximal end into the bowel lower down, the intervening portion of the intestinal tract in either case thus becoming the excluded portion.

*Experiment 36.* Large cat, weight nine pounds. Double division of small intestines, upper section made about eight inches below the pylorus, and the lower three feet lower down; the portion of bowel between these circular sections was closed at both ends, and the continuity of the intestinal canal restored by suturing the open ends in the usual manner. In this way three feet of the small intestines were isolated and completely excluded from the digestive canal. The intervening portion was emptied of its contents as completely as possible before its ends were closed by suturing. The animal died on the fourth day after the operation. A small perforation of the sutured bowel on the mesenteric side was found, otherwise the visceral wound was found well united. The perforation had given rise to diffuse peritonitis which was the immediate cause of death.

*Experiment 37.* Dog, weight thirty-two pounds. The jejunum was divided four feet above the ileo-cæcal region, and the distal end closed. Jejuno-colostomy was made by implanting the proximal end into a slit made in the convex side of the ascending colon, large enough to correspond to the circumference of the jejunum. The implanted end was fixed in its position by two rows of sutures. The animal never appeared to rally from the effects of the operation, and died at the end of the next day. The abdominal cavity

was found filled with blood, which must have escaped from a mesenteric vessel, from which probably the catgut ligature had slipped. The excluded portion, that is, that portion intervening between the circular section and the point of implantation, was found quite empty of intestinal contents, but slightly distended with gas. Implanted end perfectly retained by sutures, and slight adhesions between serous surfaces had already taken place. Death in this case was the result of secondary hæmorrhage.

*Experiment 38.* Dog, weight thirty-five pounds. Divided the ileum just above the ileo-cæcal region, and closed both ends of the bowel. Ileo-colostomy was done by making an incision about an inch and a half in length on concave side of ileum, forty-four inches above the division, and a similar slit on convex side of ascending colon, and uniting these wounds by Czerny-Lembert sutures, thus excluding from the intestinal circulation forty four inches of the bowel. The day after the operation the fæces contained blood. During the progress of the case it was frequently noted that the stools were thin, sometimes liquid. Appetite remained good, and the animal was well nourished at the time of killing, twenty-five days after operation. Abdominal wall well united. The omentum and a few intestinal loops adherent to inner surface of wound. The excluded portion contracted to more than one-half of its usual size, atrophic, and not nearly as vascular as remaining portion of intestinal canal, the two blind ends adherent to each other and to adjacent loops. The excluded portion contained in its blind end a few sharp fragments of bone. The new opening between the ileum and colon, about the capacity of the lumen of the ileum, surrounded by a prominent margin of mucous membrane, which somewhat resembled the ileo-cæcal valve to which still remained attached about ten of the deep sutures. The coats of both bowels at points of approximation thickened by inflammatory exudation.

*Experiment 39.* Young cat. The ileum was divided about thirty inches above the ileo-cæcal region; the distal end closed and proximal end laterally implanted into the convex side of the transverse colon, where it was fixed by a double row of sutures. Before implantation, the continuity of the peritoneal surface was procured by drawing the peritoneum with a fine catgut suture over the denuded space left after detachment of the mesentery. Although the animal partook freely of food, progressive marasmus set in, to which the cat succumbed eleven days after the operation. Abdominal wound completely healed. Union of implanted ileum with colon perfect. No peritonitis. Excluded portion empty. Bowel above implantation somewhat dilated.

*Experiment 40.* Young, but full-grown cat. Physiological exclusion of two-thirds of the small intestines and the entire colon, by division of the small intestines at the junction of the upper with the middle third. Closure of distal end, and restoration of continuity of the shortened intestinal tract by making a jejuno-rectostomy. The implantation was made into the upper portion of the rectum at a point opposite the meso-rectum. Previous to section and suturing, the portion of bowel to be excluded was emptied of its contents. Animal died two days after operation. No peritonitis. Slight adhesions between the serous surfaces of rectum and implanted jejunum; excluded portion empty.

*Experiment 41.* The entire ileum was excluded, in a cat, by dividing the intestine at its junction with the jejunum, closure of distal end and making a jejuno-colostomy by implantation of the proximal end into a slit of the transverse colon at a point opposite the meso-colon. The cat remained in good condition until killed fifteen days after operation. No vomiting, and movements from bowels normal. Abdominal wound completely closed; no peritonitis; jejunum at point of implantation firmly united; new opening in colon the size of the lumen of the ileum. Excluded portion empty, contracted and anæmic.

*Experiment 42.* Large mastiff. The small intestine was divided six and a half feet above the ileo-cæcal region, the distal end closed, and the proximal end implanted into an incision of the transverse colon large enough to receive it at a point opposite the meso-colon. Suturing was done exclusively with fine silk. For three weeks the dog appeared quite well, ate well, and the discharges from the bowels were normal. From this time the emaciation, which commenced soon after the operation was done, began to increase rapidly, the animal began to refuse food, and died of marasmus thirty-two days after operation. No peritonitis. Excluded portion empty, and reduced one-half in size; the coats of the bowels very much attenuated, and the vessels hardly half the normal size. Only three feet and five inches of the small intestine remained for physiological action. New opening in colon sufficiently large to permit the introduction of the index finger as far as the first point. On slitting open the colon, the point of juncture with the jejunum upon the inner surface was marked by a slight ridge of mucous membrane, which bore a faint resemblance to the ileo-cæcal valve.

Remarks.—For some reason which I am unable to explain satisfactorily, in animals where the same length of intestine was physiologically excluded, as in the resection experiments, the appetite never became so voracious, and the remaining portion of intestine did not undergo the same degree of compensatory hypertrophy as in the excision experiments. Theoretically, two explanations might be advanced: first, in shortening the intestinal canal by resection, an extensive vascular district is cut off by ligation of the mesentery, and it is only reasonable to assume that the circulation in the remaining branches of the mesenteric artery would be increased, and consequently the functional activity of the organs supplied by them augmented; second, in cases of physiological exclusion by lateral apposition, it is possible that at least some of the fluid contents reached the excluded portion from which a certain amount might still have become absorbed. The exclusion was complete or nearly so, hence we must conclude from the post-mortem appearances, that in nearly every instance, the excluded portion presented an atrophic, contracted condition, and was only sparingly

supplied with blood-vessels. From a practical standpoint these experiments teach us that a limited portion of the intestinal canal can be permanently excluded from the processes of digestion and absorption in proper cases, by operative measures without incurring any risk of fæcal accumulation in the excluded part. These experiments demonstrate also that physiological exclusion of a certain portion of the intestinal tract is a less dangerous operation than excision, and that in certain cases of intestinal obstruction, where excision has been heretofore practiced, it can be resorted to as a substitute for this operation in cases where excision is impracticable, or where the pathological conditions which have caused the obstruction do not in themselves constitute an intrinsic source of immediate or remote danger to life. The post-mortem appearances of the specimens of these experiments tend to prove that as long as any of the contents of the intestines reach the excluded portion, the peristaltic or anti-peristaltic action in that part is effective in forcing it back into the active current of the intestinal circulation.

## III. Circular Enterorrhaphy.

During my experimental work I became convinced that circular enterorrhaphy as it is now commonly performed is attended by three great sources of danger: 1. Perforation at the junction not covered with peritoneum ; 2. Length of time required in performing the operation; 3. The number of sutures required.

To obviate the danger of perforation at the junction of the bowel not covered by serous membrane, I resorted to peritoneal suturing before uniting the bowel, by drawing the peritoneum over the denuded space caused by the limited detachment of the mesentery, by a fine catgut suture applied near the free margin of the bowel as described before. This requires but little time, and secures for the whole circumference of the bowel a peritoneal covering, so that after the bowel has been sutured the great rule inaugurated by Lembert (serosa against serosa) has been carried out to perfection. The results showed that this little modification of the ordinary method of suturing yielded more satisfactory results, and should therefore be adopted in all cases where circular enterorrhaphy is done with Czerny-Lembert or Lembert's sutures. Time plays an important part in determining the results of all operations requiring abdominal section; and this is especially true in all operations for intestinal

obstruction, as this class of patients is usually greatly exhausted before consent to an operation can be obtained. With a patient exhausted from an acute attack of obstruction of the bowels, it becomes exceedingly important to consume as little time as possible in the operation, as the shock incident to a long operation may itself determine a fatal result. Even after I had acquired a fair degree of manual dexterity in suturing the bowel, I seldom spent less than an hour in making a circular enterorrhaphy with a double row of sutures. In opening the abdomen for intestinal obstruction, a considerable length of time is usually spent in finding the obstruction; and when this is found and the patient manifests symptoms of collapse, a radical operation, which for its performance requires an hour or more, is often abandoned and the operation finished by making an artificial anus, which at the present time must be looked upon as a reproach upon good surgery.

The last objection to the Czerny-Lembert method of suturing requires no argument. Any surgeon who hastily transfixes the bowel with a needle from thirty to forty times in applying the Lembert suture is liable to perforate the whole thickness of its walls once or more; and if silk is used as suturing material, the puncture may become the seat of a perforation, and the direct cause of a fatal peritonitis. This is more particularly the case in operating on the bowel in cases of intestinal obstruction, as under such circumstances the walls of the bowel have become greatly attenuated from overdistention, and consequently more liable to become perforated by the needle. But the use of so many sutures, from thirty to forty as recommended, brings with it another source of danger—gangrene of the inverted margin of the bowel. The second row of sutures applied in such close proximity must materially affect the blood supply to the inverted margin of the bowel, which in some instances must terminate in gangrene. Such a result is the more likely to ensue as the inner surface of the bowel is exposed to all dangers incident to infection from the intestinal canal; in other words, an aseptic condition for one side of the wound cannot be secured, consequently the gangrene is of a septic character, which is prone to extend beyond the primary cause which produced it.

To obviate some of these dangers I experimented with a modification of Jobert's invagination suture. According to Madelung, the ingenious method of circular suturing devised by Jobert was practiced

only in four cases, and two of the patients are known to have recovered. A number of years ago, I was forced to resort to resection of a part of the small intestine in a very complicated case of ovariotomy and resorted to this method, and although the patient died forty-eight hours after the operation from causes outside of this complication, the bowel was found permeable and quite firmly united, and had the patient lived I have no doubt the result of the resection and suturing would have been satisfactory. In Jobert's method the invagination sutures must be looked upon as a source of danger, as they were made to traverse the entire thickness of the wall of the bowel, and the material used was silk. It has been claimed that in this method the invaginated portion of the bowel becomes gangrenous as in cases of invagination from pathological causes. This claim has arisen from a theoretical, and not from an experimental standpoint. In cases of invagination the intussusceptum carries with it the mesenteric vessels intact in the form of an arch, which by constriction at the neck of the intussuscipiens is prone to become strangulated, an event which is followed by œdema and inflammatory swelling of the invaginated portion, which rapidly tends to complete venous stasis and gangrene. In circular suturing by Jobert's method the intussusceptum has no vascular connection with the intussuscipiens. The vascular arch is interrupted and consequently the danger arising from venous obstruction is almost completely obviated. My experiments will show that gangrene of the invaginated portion as a rule does not occur. My modification of Jobert's method consists essentially in the use of a thin elastic rubber ring for lining the intussusceptum to prevent ectropium of the mucous membrane, to protect the mucous membrane of the bowel against injurious pressure from the suture, to keep the lumen of the bowel patent during the inflammatory stage, and to assist in maintaining coaptation of the serous surfaces, and finally the substitution of catgut for silk as invagination sutures.

My method of proceeding is as follows: The upper end of the bowel which is to become the intussusceptum is lined with a soft pliable rubber ring made of a rubber band, transformed into a ring by fastening the ends together with two catgut sutures. This ring must be the length of the intussusceptum, from one-third to half an inch; the lower margin is stitched by a continuous catgut suture to the lower end of the bowel which effectually prevents the

bulging of the mucous membrane, a condition which is always difficult to overcome in circular suturing. After the ring is fastened in its place the end of the bowel presents a tapering appearance which materially facilitates the process of invagination. Two well-prepared fine juniper catgut sutures are threaded each with two needles. The needles are passed from within outwards, transfixing the upper portion of the rubber ring and the entire thickness of the wall of the bowel and always equidistant from each other; the first suture being passed in such a manner that each needle is brought out a short distance from the mesenteric attachment, and the second suture on the opposite convex side of the bowel. During this time an assistant keeps the opposite end of the bowel compressed to prevent contraction and bulging of the mucous membrane. The needles next are passed through the peritoneal, muscular and connective tissue coats at corresponding points about one-third of an inch from the margins of the opposite end of the bowel, and when all the needles have been passed, an assistant makes equal traction on the four strings, and the operator assists the invagination by turning in the margins of the lower end evenly with a director, and by gently pushing the rubber ring completely into the intussuscipiens. The invagination accurately made, the two catgut sutures are tied only with sufficient firmness to prevent disinvagination should violent peristalsis follow the operation. This is their only function.

The invagination itself effects accurate, almost hermetical sealing of the visceral wound. The intestinal contents pass freely through the lumen of the rubber ring from above downwards, and escape from below is impossible, as the free end of the intussuscipiens secures accurate valvular closure. After a few days the rubber ring becomes detached, and by giving way of the catgut sutures is again transformed into a flat band, which readily passes off with the discharges through the bowels. The invagination sutures of catgut are gradually removed by substitution on the part of the tissues, hence the punctures in the bowel remain closed either by the catgut or by the products of local tissue-proliferation; and thus extravasation is prevented. In my first experiments I used three invagination sutures, but found by experience that two are just as efficient in making and retaining the invagination. No superficial or peritoneal sutures were used in any of the cases, sole reliance being placed upon the invagi-

nation to maintain approximation and coaptation. The mesenteric attachment, both of the intussusceptum and intussuscipiens, was separated only a few lines to enable invagination without too much narrowing of the lumen of the intussuscipiens.

*Experiment 43.* Dog, weight fifteen pounds. Three invagination sutures were used. The ileum was cut completely across at a point about three feet above the ileo-cæcal region. Depth of invagination one inch. For two days after operation a slight rise in temperature; no symptoms of obstruction during the whole time. Animal in good condition when killed two weeks after operation. Omentum adherent at point of operation as well as on adjacent loop of intestine. Union between intussusceptum and intussuscipiens firm, no signs of gangrene. Narrowest portion of lumen of bowel was large enough to pass the little finger to second joint. An enterolith composed of fragments of wood, bone, etc., in the centre of which the straight rubber band which had been the rubber ring, was found just above the seat of operation. No distention of the bowel above this point. Bowel considerably flexed at seat of invagination, this condition being evidently brought about by inflammatory adhesions.

*Experiment 44.* Dog, weight twenty pounds. Section of bowel and invagination with rubber ring the same as in the foregoing experiment. In subsequent history no mention is made of any symptom of obstruction, but for the last few weeks it was noticed that the dog began to emaciate. He died suddenly eighty-one days after the operation. Diarrhœa was a prominent symptom toward the last. No adhesions and no peritonitis. An enormous enterolith composed of all kinds of crude material, and again holding in its centre the rubber band, was found just above the invagination. Bowel at this place considerably dilated. Intussusceptum firmly adherent, a false passage admitting the tip of the little finger had been made on one side between it and the intussuscipiens. Death in this case was evidently produced by the enterolith. In this, as in the last case, the invagination was made at least an inch in length, and the collection around the detached rubber ring of the crude, indigestible material, which the dog must have eaten in large quantities, gave rise to the enterolith. The wall of the bowel surrounding the foreign body was not only dilated, but also greatly thickened. It is a well known fact that even a moderate degree of stenosis of the bowel in dogs is liable to give rise to the formation of an enterolith, as the crude material which these animals swallow becomes arrested, and by constant accretions of the same kind of material, the enterolith forms and continues to increase in size, until its presence causes catarrhal inflammation and finally intestinal obstruction.

It is quite possible that the lower end of the intussusceptum became impermeable during the inflammatory stage, and that the false passage was formed on this account by perforation on one side of the intussusceptum, an accident which was plainly traceable to too deep invagination.

*Experiment 45.* Dog, weight forty pounds. This experiment is interesting only from the fact that it shows that it is possible to make a mistake in

the direction of the invagination, even after the operation has determined with accuracy which is the ascending and descending end of the gut, and to show the disastrous consequences which must necessarily follow such a technical mistake. The invagination was made in the usual manner with rubber ring and three catgut sutures. The animal appeared to be quite ill the day following the operation, and on the next day the thermometer showed a rise in temperature to 104.2°F. On the third day the dog died with well marked symptoms of perforative peritonitis. Recent peritonitis with some agglutinations of intestines. Considerable quantity of sero-sanguinolent fluid in the peritoneal cavity. To my utter astonishment, I found that an ascending invagination had been made. Circular gangrene of intussusceptum and complete separation of ends was found. The rubber ring remained *in situ* still attached to the intussuscipiens by the catgut sutures, which had become somewhat softened. The invagination had decreased considerably by the traction caused by the peristalsis and by the pressure of the intestinal contents from above the obstruction, and the extensive gangrene of the bowel was undoubtedly determined to a great extent by these causes.

*Experiment 46.* This experiment illustrates another source of danger due to faulty technique. Medium-sized dog. Circular enterorrhaphy was done with the rubber ring two feet above the ileo-cæcal valve. In making the invagination it was noticed that the ring was too large, as it was seen that it caused too much pressure. Thinking that the parts might adapt themselves to this pressure, the bowel was replaced and the abdominal wound closed. The dog died thirty-six hours after the operation. Abdominal wound not united; omentum and intestines adherent to each other, and at point of operation. The circumscribed gangrene of the intussuscipiens was evidently entirely due to pressure on the part of the rubber ring. The intussuscipiens was much swollen, a condition which materially aggravated the pressure caused by the rubber ring. With the following experiment two new departures were inaugurated, viz.: Instead of three invagination sutures only two were used, a change which still further shortened the time for performing the operation, and Nothnagel's test was employed to determine the direction in which the invagination should be done. In all of the remaining experiments of circular enterorrhaphy which were made, only two catgut sutures were used. Until this time it was necessary to find one of the extremities of the small intestines for the purpose of determining which was the afferent and which the efferent end of the tube, so as to make the invagination in the right direction; a procedure which often required considerable time, and brought additional risk by increasing the shock of the operation and the danger of traumatic infection.

## 1. Nothnagel's Test.

In experimenting upon animals for the purpose of studying the functions of the intestinal canal in health and disease, Nothnagel made the discovery that when the salts of potash are brought in contact with the serous surface of the bowel, circular constriction

takes place, and when the peritoneal surface is touched with a crystal of common salt, ascending peristalsis is produced. The sodic chloride test I applied in sixteen cases, and found Nothnagel's observations corroborated in fifteen cases, by subsequent anatomical examination. In the remaining case where a wrong conclusion was drawn, the error might have been due to a faulty observation, or else the observation was not continued for a sufficient length of time. If, in the human subject, these observations could be verified, it would be of great practical importance to surgeons in operations on the intestinal canal whenever it becomes necessary to determine which is the ascending or descending part of the bowel.

*Experiment 47.* Dog, weight thirty pounds. Circular section of ileum and immediate enterorrhaphy by invagination with rubber ring and two catgut sutures. Intussusceptum invaginated not more that a quarter of an inch. A few days after the operation stools mixed with blood, no other unfavorable symptoms. Animal killed fourteen days after operation. Wound united firmly. A number of omental and intestinal adhesions. A small abscess in mesentery at point of operation. No obstruction of any kind. On opening the bowel the walls at site of operation were very thick, corresponding to the three intestinal coats, which had become considerably attenuated. The inner surface showed the point of junction of the intussusceptum with the intussuscipiens in the shape of a circular ring of mucous membrane. The most contracted portion was large enough to admit the little finger.

*Experiment 48.* Dog, weight fifteen pounds. Section of ileum and circular enterorrhaphy with rubber ring and two catgut sutures. Depth of invagination one-third of an inch. No unfavorable symptoms after operation. Animal killed after seven days. Wound completely united. Firm union of visceral wound; no gangrene of intussusceptum. Rubber ring retained *in situ* by catgut sutures, which were easily torn. Upper end of rubber ring matted with hair. No obstruction. Lumen of bowel somewhat contracted by a circular ridge of mucous membrane, which indicated the junction of the two invaginated ends of the bowel.

## 2. Transplantation of Omental Flap.

In almost all post-mortem examinations of specimens from operations on the intestines, I observed that the omemtum was adherent over a greater or less surface at the seat of suturing. I also observed that perforations never occurred where this additional protection to the peritoneal cavity had formed. To anticipate nature in protecting the peritoneal cavity in this manner, I commenced to transplant an omental flap about an inch in width and sufficiently long to reach around the bowel, over the neck of the intussuscipiens,

where it was fastened on the mesenteric side by two catgut sutures. The flap was taken either from the margin of the omentum or from its middle, care being taken to take some portions supplied with a vessel of considerable size. Its base was left attached to the omentum; all bleeding points were carefully tied with catgut ligatures. The two catgut stitches used for its fixation were passed twice through the flap, its base and free end and the mesentery, in such a way that when tied the direction of the suture corresponded to the course of the mesenteric vessel, so that after tying they would not interfere with the vascular supply of the bowel. When the flap was taken from the middle of the omentum, the lateral halves were united with one or two catgut sutures before closing the abdominal wound.

*Experiment 49.* Dog, weight forty pounds. Ileum divided eighteen inches above ileo-cæcal region, and the ends united by invagination with rubber ring, and two catgut sutures. Transplantation of omental flap one inch in width around the whole circumference of the bowel over neck of intussuscipiens, fixation with two catgut sutures on mesenteric side. Invagination one-third of an inch in depth. Animal killed two weeks after operation. Abdominal wound perfectly healed. Omental flap firmly adherent to bowel over neck of intussuscipiens. Bowel at seat of operation much thickened; rubber ring gone; lumen of bowel at its most contracted point large enough for the passage of the little finger.

*Experiment 50.* Dog, weight twenty pounds. Complete division of ileum and immediate union of divided ends by invagination with rubber ring and two catgut sutures. Transplantation of omental flap two inches in width over the neck of the intussuscipiens. On third day stools mixed with blood. Died on the fifth day. Wound not united; omental flap firmly adherent except at a small point on the mesenteric side where a minute perforation had taken place from circumscribed gangrene of the intussusceptum. Rubber ring only loosely held by one of the sutures. Lumen in invaginated portion quite narrow, but permeable.

*Experiment 51.* Dog, weight fifteen pounds. Complete section of ileum and union of divided ends by invagination. The rubber ring was only one-third of an inch wide, while formerly none were used less than half an inch in width. Neck of intussuscipiens protected by an omental flap two inches wide. The dog remained perfectly well, and was killed twenty-five days after operation. Abdominal wound completely healed, covered on the inner side by adherent omentum. Rubber ring gone. Lumen of bowel at most contracted point readily admits the little finger. No signs of obstruction. Omental flap adherent throughout.

*Experiment 52.* Dog, weight twenty-two pounds. Division of ileum and suturing in usual manner by invagination with rubber ring and two catgut sutures; transplantation of omental flap. The dog remained perfectly well and was killed twenty-three days after operation. A number of intestinal

adhesions had produced several flexions. Point of operation four feet above the ileo-cæcal region. Omental flap firmly adherent to bowel throughout. Rubber ring gone. Lumen of bowel in invaginated portion quite large. The invaginated portion so atrophic and retracted that it appeared in the shape of a firm ring and was indicated in the interior by a circular prominence of the mucous membrane. No evidence of obstruction.

*Experiment 53.* Dog, weight fifteen pounds. Complete division of the ileum and reunion of ends by invagination. Transplantation of omental flap two inches in width over neck of intussuscipiens, two catgut fixation sutures. Second day after operation stools bloody. After this time all functions normal. Animal killed forty-four days after operation. Point of operation four feet below the pylorus. The invaginated portion atrophied and retracted to such an extent that the bowel at this point only presented a thickened ring with its lumen but slightly narrowed by a circular ridge of mucous membrane. Omental flap firmly adherent all around and greatly atrophied.

Remarks.—In circular enterorrhaphy, as in cases of intestinal wounds of any kind, the ideal of any operation should be to bring in continuous, uninterrupted apposition a large surface of serous membrane, without, at the same time, interfering with the vascular supply of the parts which it is intended to bring together for permanent union by cicatrization. If in employing the Czerny-Lembert sutures more than a few lines of the margins of the bowel are inverted and included between the two rows of sutures, there is great danger of causing primary traumatic stenosis by the projecting circular ring in the lumen of the bowel. The narrowing of the lumen of the bowel must be as great, if not greater, than after invagination. That the second row of sutures has often been the cause of gangrene of the inverted margin of the bowel would not be difficult to prove by many post-mortem records and specimens. By invaginating to the depth of a quarter or third of an inch, accurate coaptation is secured of the corresponding serous surfaces between the intussusceptum and intussuscipiens, which is made more secure and effective by the elastic pressure exerted by the rubber ring. This method of coaptation furnishes a large peritoneal surface of peritoneum for immediate union by cicatrization.

With perhaps one exception, all of my experiments have shown that when catgut was used for invagination sutures none of the failures were attributable to their presence. On the inner side of the bowel the rubber ring is drawn against the puncture, and would thus furnish a mechanical protection against the escape of fluids along these minute canals ; besides, the swelling of the catgut where it

becomes softened by the fluids of the tissues, would most effectually plug the punctures until a permanent plug is furnished by the granulations, which in time completely remove the catgut by substitution and close the punctures permanently by a minute cicatrix. One great advantage of the rubber ring consists in its furnishing absolute protection to the bowel against pressure by the invagination sutures during the invagination, and subsequent traction from peristaltic contraction should the latter cause tension of the sutures, an occurrence which is not likely to arise if the invagination has been properly done. A circular enterorrhaphy as described above can be done in fifteen minutes, which certainly compares very favorably with any other procedure, as far as time is concerned. In the description of a number of the specimens, it has been distinctly stated that the injurious results followed the stenosis caused by the invagination, and this might be urged as an argument against the safety and applicability of the operation.

As compared with the human subject the dog is an unfavorable animal for circular enterorrhaphy by invagination. In the first place, the walls of the bowel are much thicker in proportion to its lumen than in man, a condition which of necessity seriously affects the lumen of the intussusceptum. Again, the dogs were allowed to eat what they desired before and after the operation, and the quantity was not limited; consequently a great deal of indigestible substances, often of the coarsest kind, as straw, fragments of wood, or bone, hair, etc., found their way into the intestinal canal, and in a number of cases were arrested at the point of narrowing in the bowel, where they gave rise to the formation of an enterolith. In one instance death resulted clearly from intestinal obstruction from such a cause. In men the coats of the bowel being thinner, and the lumen correspondingly larger, invagination is done with greater ease, and the danger from stenosis could hardly come into question, as the fluid contents of the small intestines would pass readily through the rubber tube. Some of the older specimens prove that the traumatic stenosis caused by the invagination gradually diminishes by atrophy of the invaginated portions, which finally only appear as a prominent ridge of mucous membrane on the inner surface of the bowel, the remaining coats having completely or nearly disappeared by retrograde metamorphosis and absorption. In the healing of all wounds one important condition for an ideal result is rest. The

rubber ring in the intussusceptum secures this important condition for the invaginated portion, as the elastic pressure must overcome peristaltic action and secure for this segment of the bowel, as near as possible, absolute physiological rest. The danger of stenosis after invagination is greatest as soon as inflammatory swelling makes its appearance, a day or two after the operation, and the rubber ring is again in the right place to prevent any undue swelling by affording a gentle support for the invaginated portion, which cannot fail in preventing undue venous engorgement and œdema, which would otherwise follow the invagination. It serves both the purpose of a splint and an elastic bandage. After union of the bowel by invagination with a rubber ring peritoneal sutures are superfluous, as the invagination itself most effectually prevents any escape of intestinal contents by the valvular action of the invaginated portion; at the same time the serous surfaces are kept in permanent and uninterrupted contact by the elastic pressure on the part of the rubber ring.

Although the experiments have demonstrated the safety of the catgut invagination sutures in operating upon dogs, the same innocuity might not attend operations after intestinal resections for obstruction, as in such cases the coats of the bowel are almost without exception very much attenuated, and consequently the danger of extravasation along the needle punctures would be increased. Very recent trials have satisfied me that invagination after circular resection can be done with the rubber ring with facility, and probably greater safety, by dispensing with the invagination sutures and adopting the following plan: The lower end of the intussusceptum is lined with a soft rubber ring about one-quarter to one-third of an inch in width, and its lumen of sufficient size to afford free transit to the intestinal contents. The lower margin of the ring is stitched to the end of the intussusceptum by a continued fine catgut suture. The ends of the bowel are now brought in contact and fastened together with four catgut sutures which are placed equidistant from each other. Invagination is now made by gently pushing the ends of the bowel in opposite directions, being careful to push the ring sufficiently deep so that its upper margin is grasped by the neck of the intussuscipiens. A few superficial sutures are applied simply for the purpose of preventing disinvagination; the four catgut sutures act as invagination sutures, and at the same time prevent

ectropium of the mucous membrane of the lower end of the bowel during and after invagination. With proper facilities and good assistance, a circular enterorrhaphy can be made in this manner without using invagination sutures, in ten minutes; and by using not more than four retention sutures, the blood supply to the inverted portions is not impaired, and at the same time the two ends of the bowel have been joined together by a large surface of peritoneum, which is held in accurate contact for rapid union by granulation and cicatrization.

The advantages that are derived from covering a sutured intestinal wound by an omental flap are self-evident. The procedure is simply an imitation of nature's process in protecting the peritoneal cavity against perforation, and in hastening the healing of the visceral wound. An adherent omentum secures rest for the part to which it has become attached. As the omental flap becomes firmly adherent before definitive healing of the visceral wound has taken place, it furnishes additional protection, and in the event of a small perforation it guards against perforative peritonitis by mechanically preventing the entrance of pus into the peritoneal cavity. Should pus reach the omental flap after it has become firmly adherent it is not very probable that perforation would take place through the two layers of peritoneum furnished by the adherent omental flap, and the subsequent healing of the perforation of the bowel would be most likely to take place. I shall again refer to this subject under the head of "Omental Grafting."

## IV. Intestinal Anastomosis.

By an intestinal anastomosis we understand a condition of the intestinal canal where on account of an obstruction or complete occlusion, the intestinal contents are directed into a segment of the bowel below the seat of obstruction or occlusion, through a fistulous opening between the bowel above and below the seat of partial or complete occlusion. The idea of establishing such a communication between the bowel above and below the seat of obstruction originated with Maisonneuve, who, without testing the new procedure first on animals, operated on two cases, but as the result in each case was fatal, he seems to have become discouraged and abandoned the operation, and never published the communication on this subject which he had in preparation. In the Surgical Society of Paris, his

proposition met with violent opposition from his contemporaries, who argued that the excluded portion of the intestine would become the seat of fæcal accumulation, which, even if the operation were a success, would subsequently destroy the life of the patient. The subject was revived in 1863 by Hacken, who under the directions of Adelmann made some experiments on dogs. For a long time the operation was completely forgotten until E. Hahn, of Berlin, very recently alluded to it again in commenting on his two cases of excision of the colon where circular enterorrhaphy could not be performed, and where an artificial anus was established. Both patients recovered from the operation, but all attempts to close the preternatural opening proved futile.

The results of my experiments have shown conclusively that the fear of accumulation of fæces in the excluded portion of the intestine, that is, the intervening portion containing the seat of obstruction and extending on each side as far as the new opening by which the anastomosis has been established, is unfounded. If this objection can be laid aside, it becomes evident that the operation of establishing intestinal anastomosis has a great future, and will soon become an established procedure in the treatment of intestinal obstruction, and as a substitute for circular suturing in some forms of injuries of the intestines, which require excision. When I first made my experiments for establishing intestinal anastomosis, I made the operation by making an incision an inch and a half to two inches in length through the convex surface of each bowel, and sutured the wounds together by Czerny-Lembert sutures the same as in making a circular enterorrhaphy. The results soon showed that the operation was attended by the same dangers as suturing after circular resection, that is, gangrene of the margins of the bowel, and perforation.

Dr. M. E. Connel, Superintendent of the Milwaukee County Hospital, suggested the use of perforated plates for making the lateral apposition, in place of suturing. A few crude experiments were made with perforated discs of lead, wood, gutta-percha, and leather, and the results soon satisfied us of the expediency and greater safety of uniting the intestines in this manner. Although the first experiments were very imperfect, and faulty in technique, almost every animal recovered. In the first experiments no needles were used. Around the oval perforation four catgut or silk sutures were tied; a slit was made in the bowel on the convex side parallel with its

axis and large enough to permit the passage of a plate about an inch in width and about two and a half inches in length. After making the incision, and introducing the plate above and below the seat of obstruction, the two wounds were brought into apposition, and the corresponding strings tied together with sufficient firmness to bring the flattened surfaces into accurate coaptation. The threads were cut short and the ends pushed inward out of sight. Experience showed that although the apposition was good, a tendency was observed on the part of the margins of the wound to evert on account of the bulging of the mucous membrane. I consequently modified the operation by arming the lateral threads with a needle with which the margin of the incision about the middle of the wound was transfixed. This proved a step in the right direction, as the lateral sutures completely prevented eversions of the margins of the wound, at the same time they fixed the plates in their position, and lastly, at once transformed the longitudinal slit into an oval foramen of sufficient size for the free passage of intestinal contents. After many trials with different kinds of materials for the plates, I came to the conclusion that decalcified or partially decalcified bone plates, preserved after the decalcification in pure alcohol, served the best purpose.

### Directions for Preparing Bone Plates.

The compact layer of an ox's femur or tibia is cut with a fine saw into oval plates, one-fourth of an inch in thickness, two and one-half to three inches in length, and an inch in width. The plates are then decalcified in a ten per cent. solution of hydrochloric acid, changed every twenty-four hours until they have become sufficiently soft so that they can be bent in any direction without fracturing. After decalcification they are washed by letting water flow over them from three to six hours so as to remove the acid. The plates are then covered with porous paper and compressed between two pieces of tin until they are perfectly dry. If during the process of drying the plates are not compressed between two smooth surfaces they become distorted by warping. The hardened plates are next drilled several times in a straight line in the centre, and the openings enlarged and connected with a file, until the perforation is five-eighths of an inch in length and about one-eighth to one-sixth of an inch in width. The sharp margins of the plate and perforations are

removed with a file. With a fine drill the four perforations for the sutures are made near the margin of the oblong perforation, one at each end and one at each side. For preservation the plates are kept in absolute alcohol. When the plates are to be used they are washed in a two per cent. carbolic acid solution, and the threads or sutures attached by threading two fine sewing needles, each with a piece of aseptic silk, twenty-four inches in length, which are tied together. The threads are then fastened to the surface of the plate by another thread passing through the perforations in the shape of a loop and fastened at the back.

Instead of describing the experiments in their chronological order, I will enumerate them according to the part of the intestine operated upon, commencing with the upper portion of the intestinal tract.

## 1. Gastro-Enterostomy.

As gastro-enterostomy is an operation which establishes an anastomosis between the stomach and the upper portion of the intestinal canal, with exclusion of the duodenum, and sometimes a portion of the jejunum, and is performed in cases of obstruction in the pylorus or duodenum, it comes within the legitimate sphere of this article. Gastro-enterostomy, as heretofore described and performed, is an operation attended by many difficulties, and requires even in the hands of an expert an hour or more for its execution. As this operation is only done in cases greatly debilitated by disease and long suffering, anything which will simplify the technique and shorten the time must be looked upon as an improvement. An operation that can be done in ten minutes instead of an hour or two, and which furnishes even better conditions for the healing of the visceral wounds, must take the place of the more complicated procedures which so far have only been practiced in the hands of the most experienced surgeons.

*Eperiment 54.* Dog, weight twenty-five pounds. Incision made through linea alba from xiphoid cartilage to near umbilicus. Omentum pushed to one side, and the stomach drawn forward into the wound; near the middle of its anterior surface a longitudinal incision was made, two inches in length, and a perforated gutta-percha plate, to which four medium-sized juniper catgut sutures were attached, was introduced. The lateral sutures, armed with needles, were passed through the entire thickness of the walls of the stomach, half way between the angles of the wound. A similar incision was made into

the intestine at the junction of the duodenum with the jejunum; the same kind of plate introduced, and the margins of the wound punctured by the lateral armed sutures, when the two wounds were brought *vis-a-vis* and the corresponding sutures tied. In tying the sutures, the lower lateral suture was tied first and the threads cut short; next the sutures corresponding to each angle of the wound were tied, and lastly the upper lateral. The serous surfaces of the stomach and intestine over an area corresponding to the size of the plates were brought into accurate permanent contact by the tying of the sutures. The stomach was replaced and the abdominal wound closed. The animal was allowed to eat immediately after the operation, manifested no signs of illness or pain, and was killed seven days after operation. Abdominal wound healed. Omentum adherent to its inner surface. Union between stomach and bowel firm over the entire surface of approximation. Plates detached, the one in the bowel had passed, while the other was found loose in the stomach. The new opening large enough to admit the index finger.

*Experiment 55.* Dog, weight fifty pounds. The operation was performed in the same manner as in the previous experiment, but great difficulty was experienced in bringing the stomach forward, as this organ was distended to its utmost with an enormous quantity of solid food. Evacuation was effected through the incision, aided by attempts of the animal to vomit, the violent contractions of the stomach forcing the food toward the opening, from which it was removed with fingers and spoon. After the stomach was emptied it was washed out with warm water. For the stomach a bone plate, only partially decalcified, was used, while the approximation plate in the bowel was fully decalcified. The four approximation sutures were of catgut. Several portions of omentum, which were soiled during the emptying of the stomach, were excised. The abdominal cavity was thoroughly irrigated with warm water before the wound was closed. The animal died the next day, and on opening the abdomen it was ascertained that the immediate cause of death was hæmorrhage, as the peritoneal cavity was filled with blood. The bleeding undoubtedly took place from the omentum, by slipping or loosening of one of the catgut ligatures.

*Experiment 56.* Medium-sized dog. Operation performed in the same manner with decalcified bone plates and catgut sutures. The first two days the animal had several attacks of vomiting, subsequently showed no signs of suffering. Appetite good and stools regular. Killed thirty-four days after operation. Omentum adherent to inner surface of abdominal wound. At point of operation stomach was contracted, so that the organ presented an hour-glass appearance. Interior of the organ contained a large mass of hay and fragments of bone. New opening large enough to pass index finger. Union between stomach and bowel over entire surface of approximation. Water passed into the stomach flowed through the pyloric orifice and the new opening, in a stream of equal size.

*Experiment 57.* Large bull-dog. Approximation of anterior surface of stomach with bowel by perforated gutta-percha plates, and four catgut sutures.

Length of visceral incisions, two inches. The day after operation animal vomited his dinner, subsequently no unfavorable symptoms. Animal killed fourteen days after operation. Abdominal wound well united. Omentum adherent to wound, duodenum, liver and at point of operation. Firm adhesions between stomach and bowel. Water passed into the stomach only passed through the pyloric orifice. On opening the stomach, it was found that the wound in the stomach and intestine had completely healed, the site of incisions being marked by a narrow firm cicatrix. The failure of obtaining an anastomotic opening between the stomach and intestine could only be attributed to one of two causes, viz.: either the perforations in the plates were too narrow, or the needles of the lateral sutures included too much tissue. Either cause would bring about approximation of the margin of the wounds and permanent closure of the opening by granulation and cicatrization.

Remarks.—All of the animals recovered, except in case of experiment 55, without any untoward symptoms, although they were allowed to eat immediately after the operation, and the diet was not selected or restricted at any time. In the fatal case death was caused from complications which had no connection with the gastro-intestinal opening. In all of the specimens examined, the mucous membrane of the stomach and intestine which had been interposed between the approximation plates, presented a healthy appearance, showing that the pressure of the plates had exercised no injurious effect on this structure. More recent experience with this operation on animals has revealed the fact that in the stomach a completely decalcified bone plate is almost entirely digested in thirty-six to forty-eight hours. It would therefore, appear advisable to use only partially decalcified bone which remains for a longer time, so that in case of delayed union the approximation would be maintained for a sufficient length of time. As the animals subjected to the operation recovered promptly, and under the most unfavorable conditions, we have every reason to believe that this operation will be attended by the same favorable results when done for pyloric or duodenal stenosis in man, where a careful preparatory and after treatment cannot fail to facilitate the operation and to improve the conditions for the formation of early adhesions and a speedy definitive healing of the wound. I have no hesitation in recommending it as a substitute for the more time-consuming and less certain operation by the tedious and difficult method of double suturing which is now generally practiced.

## 2. Jejuno-Ileostomy.

In this operation some form of intestinal obstruction was made; either complete, by division of the bowel and closure of both ends, or partial, by making a volvulus, invagination or flexion in the vicinity of the juncture of the jejunum with the ileum, followed by establishing a communication between the bowel above and below the obstruction. Before I made use of the perforated approximation discs, this was accomplished by making an incision an inch and a half or two inches in length through the convex surface of the bowel above and below the obstruction, and uniting the wounds by a double row of sutures. An operation of this kind usually lasted over an hour, while the rapid operation of coaptation by perforated discs seldom took more than fifteen minutes.

### a. Jejuno-Ileostomy by Suturing.

*Experiment 58.* Large cat. Invagination of ileum into ileum in a downward direction, and fixation of intussusceptum to neck of intussuscipiens by two fine catgut sutures to prevent spontaneous reduction. Intestinal anastomosis by establishing an opening an inch in length, suturing by Czerny-Lembert method. The animal never recovered from the shock of the operation, and died in less than twenty-four hours. Length of intussusceptum two inches, which, after the removal of the sutures, could not be reached by traction, as the bowel was firmly constricted by the neck of the intussuscipiens, and recent adhesions had formed. No peritonitis; suturing found perfect.

*Experiment 59.* Dog, weight sixty-five pounds. Intestinal obstruction by making acute flexions in upper portion of ileum; fixation of loops of intestine by fine catgut sutures. Intestinal anastomosis between jejunum and ileum by incision and double suturing. The animal died on third day with symptoms of perforative peritonitis. On close examination, one of the superficial approximation sutures had been passed through the whole thickness of the wall of the bowel, and it was here that perforation had taken place. Recent diffuse general peritonitis.

*Experiment 60.* Dog, weight seventeen pounds. Descending invagination of ileum into ileum, length of intussusceptum three inches, fixation by two catgut sutures. Formation of intestinal anastomosis between the bowel above and below the invagination by incision and double suturing. Animal died on third day with symptoms of perforative peritonitis. Abdominal wound not united. Adhesions at point of operation quite firm. Diffuse general peritonitis from a perforation which had been made by a sharp fragment of bone above the new opening. Intussusceptum not gangrenous.

*Experiment 61.* Dog, weight twenty-three pounds. Intestinal obstruction was made by producing a volvulus in the upper part of the ileum. Restoration of continuity of intestinal canal by making a jejuno-ileostomy by lateral

apposition and double suturing. Day after operation intestinal discharges were bloody; after this time normal. Animal in perfect health when killed sixty-seven days after operation. The volvulus was found in same condition as after operation; the intestinal loop empty, atrophied and adherent to adjacent loops of intestine. Bowel above seat of obstruction and as far as the new opening empty. Intestinal tract above and below the obstruction presented no indication of the presence of an obstruction. New opening oval in shape and as large as the lumen of the bowel at that point.

*Experiment 62.* Large Maltese cat. Intestinal obstruction by making two flexions in ileum, about eighteen inches apart, after this portion had been cleared of its contents. Flexions made by doubling the bowel toward its convex side, and fixing it in this position by fine catgut sutures. Jejuno-ileostomy by lateral apposition and suturing. Vomiting day after operation; stools scanty the first few days, and later complete obstruction. Died nineteen days after operation. Wound completely united; no general peritonitis; flexions remained; bowel between them contained a slight amount of fæcal matter. Bowel some distance above the new opening very much dilated, pointing to obstruction above new opening. On tracing the intestinal canal from above downward, this obstruction was seen to consist in acute flexion of the bowel by firm and extensive adhesions. New opening sufficiently large to admit the tip of the index finger, around the margins of which most of the deep sutures remained attached.

*Experiment 63.* Large cat. Obstruction made by two flexions in the ileum, the apices of which were united by catgut sutures. Intestinal anastomosis made by a jejuno-ileostomy. For eleven days the animal remained in good condition, when symptoms of perforative peritonitis manifested themselves, and death ensued two days later. External portion of wound not united. Numerous omental and intestinal adhesions. Flexions retained and their apices adherent to each other by firm band of adhesion. Excluded portions above and below the obstruction empty. Two small perforations at point of suturing on anterior surface of bowel; remaining portion of wound firmly united. New opening sufficiently large to admit tip of index finger. Death from perforative peritonitis.

*Experiment 64.* Large, Newfoundland dog. Descending invagination of ileum into ileum to the extent of six inches; fixation of intussusceptum by two catgut sutures. Permeability of intestinal canal restored by making a jejuno-ileostomy; wounds united by a double row of sutures. Intestinal discharges normal throughout. No rise in temperature. General condition as good as before operation, when killed on the twentieth day. Abdominal wound completely united; no peritonitis; omentum adherent at site of operation. Invagination had reduced itself, and its location was marked by an acute flexion caused by extensive adhesions. No accumulation of intestinal contents in excluded portions. The new opening at least two inches in length; a few of the deep sutures remained attached to its margins. This opening was partially obstructed by a mass of hair and fragments of bone. On passing a stream of water from above downward, the fluid passed through an opening in

the centre of this mass into the lower portion of the ileum, but not through the portion that was invaginated. After this mass was removed, the fluid was found to pass through the portion that was invaginated, as well as through the new opening.

The many failures which attended jejuno-ileostomy and ileo-ileostomy by lateral apposition and suturing, led to the use of perforated approximation discs. A great contrast was observed in the animals operated upon by these two methods. The operation by suturing required usually more than an hour, and almost all of the animals showed more or less symptoms of shock after its completion, and not a few succumbed to its immediate effects; while the operation by approximation plates could always be finished within twenty minutes, consequently the animals never suffered seriously from the immediate effects of the operation. The first experiments were made somewhat carelessly and with crude material, and yet it was observed that the healing process progressed more favorably and was accomplished in a shorter time than after suturing. The approximation discs brought into uninterrupted contact large serous surfaces without impairing the vascular supply; at the same time they secured for the parts destined to become united an essential condition for rapid wound healing—rest—by serving the useful purpose of splints.

*Experiment 65.* Dog, weight fifteen pounds. Ileum was completely divided at its junction with the jejunum and both ends of the bowel closed by invagination, and three stitches of the continued suture. An incision was made on convex side of bowel about two inches from the closed ends, and a heavy perforated lead plate to which six catgut sutures were fastened around the oval perforation, was introduced into the lumen of the bowel of each closed end, all of the catgut sutures being brought out through the incision. The two wounds were brought opposite each other and the six sutures tied. The serous surfaces of the two intestines over a surface corresponding to the size of the lead discs were thus brought into accurate apposition. The sutures were cut short and the ends buried as deeply as possible. The condition of the animal remained excellent until the time of killing, seventy-five days after operation. Omentum adherent to wound; large intestines distended with normal fæces. Bowel above and below point of operation normal in size and structure. New opening between ileum and jejunum large enough to admit the little finger to second joint. Bowels firmly united by a broad surface. Above the communicating opening a double flexion of the bowel was found which apparently had done no harm.

*Experiment 66.* Dog, weight eighteen pounds. Operation done in the same manner as in the last experiment, only that instead of lead the discs were made of sole leather, and the sutures used were linen in place of catgut.

For a few days the temperature was higher than normal and appetite diminished. After fourth day the animal appeared to be in excellent condition and remained so for three weeks, when the appetite failed and occasional attacks of vomiting set in. The symptoms remained more or less prominent until the time of killing, thirty-nine days after operation. Omentum adherent to abdominal wound; extensive intestinal adhesions at site of operation; union between intestines perfect. On incising the bowel it was found that the plates had sloughed through, and had passed along the distal portion of the bowel, leaving an opening the size of the plates, the margins of which had almost completely cicatrized. The two leather plates, still held together by the linen sutures, were found three feet lower down in the ileum, where they had become embedded in a mass of hair, straw and fæcal matter, and quite firmly impacted, causing complete obstruction of the bowel. The intestine above the seat of obstruction was enormously dilated, while below the seat of impaction it was empty and contracted. Large intestines likewise empty and contracted. The cause of the illness was evidently due to intestinal obstruction produced by the impaction of the large enterolith, in the center of which the leather discs were found.

*Experiment 67.* Dog, weight ten pounds. In this instance the bowel was divided near the junction of the jejunum with the ileum, both ends closed, and its continuity established by incising the convex surface of both ends, and approximating the wounds by two perforated bone plates tied together by silk ligatures. The animal died fourteen days after operation. During the last few days symptoms of intestinal obstruction were present. Abdominal wound completely united. Numerous intestinal adhesions at site of operation. Bone plates still *in situ* and firmly fixed. On proximal side, perforation of bone plates completely closed by hair and fragments of bone, giving rise to complete intestinal obstruction. The bowel above this point was greatly dilated, while on distal side it was empty and contracted. Firm adhesions between the two intestinal surfaces included by the bone plates. Intestinal obstruction by a mechanical arrest of portion of the intestinal contents above the proximal plate had caused death before a more efficient communication could be established by sloughing through of the bone plates.

*Experiment 68.* Dog, weight thirty pounds. Ileo-ileostomy by dividing the ileum near its centre, closing both sides, and after incising both ends on convex surface, bringing wounds in apposition by perforated plates of cross-grained walnut wood, which were tied together with silk sutures. The dog remained in perfect health and was killed eighteen days after operation. External wound completely united. Plates had become detached, leaving a communicating opening two inches in length. Blind ends of bowel empty; no trace of plates could be found.

*Experiment 69.* Dog, weight twenty-four pounds. Double ileo-ileostomy. Ileum divided transversely five inches above ileo-cæcal region, and both ends closed by invagination and three stitches of the continued suture. Lower and upper end of bowel were again brought into communication by incision on convex side, and lateral apposition of wounds by means of perforated

approximation plates of decalcified bone, hardened in alcohol. The plates were fastened together by four silk sutures, all of the threads being brought out of the incision, tied and cut short. Above this point a loop of the ileum was made by bringing the convex surfaces into apposition after incision at two points, and introducing perforated gutta-percha plates, which were retained in place by four silk sutures. No fever or symptoms of obstruction followed the operation. Animal killed thirteen days later. External wound firmly united. No evidences of peritonitis or intestinal obstruction. First operation left a communicating opening large enough to admit the little finger in one of its margins. The silk ligatures which had become detached from the plates had embedded themselves. The decalcified bone plates had disappeared and no trace of them could be found in any portion of the intestinal canal lower down. The second operation was thirty inches higher up. Gutta-percha plates remained *in situ*, although somewhat loosened by the gradual disappearance of the intervening tissues by pressure atrophy. Adhesions between the two surfaces of the bowel firm, and extending a little beyond the line of approximation. The perforation in the proximal plate almost completely closed by an accumulation of hair. The entire ileum normal in size and appearance.

*Experiment 70.* Dog, weight fifty-four pounds. Transverse section of ileum thirty inches above ileo-cæcal region and closure of both ends in the usual manner. The two closed ends were overlapped four inches and brought into communication by two longitudinal openings, which were approximated by being buttoned together with a shuttle-shaped button, nearly one and a half inches in length, the sides being lead plates and the shaft a rubber tube through which the anastomosis was established at once. As the margins of the intestinal wounds showed a tendency to evert, a fine catgut suture was inserted on each side embracing only the peritoneal coat. Only for two or three days after the operation did the dog not appear to be well. Killed twenty-three days after operation. Omentum adherent to abdominal wound which was firmly united. Omental adhesions to intestine at site of operation. Intestinal anastomosis thirty inches above the ileo-cæcal valve. Proximal blind end of bowel five inches in length adherent to distal end, considerably dilated and contained fragments of bone and other crude substances. Approximation button *in situ* and quite firmly fixed. A fragment of bone partly filled the lumen of the rubber tube. Coaptated peritoneal surfaces firmly adherent. The obstruction of the communicating tube had given rise to dilatation of the bowel above the point to twice its natural size, while below the seat of partial obstruction the intestine appeared empty and contracted.

*Experiment 71.* Small dog. In this experiment the ileo-ileostomy was made by lateral apposition by perforated approximation plates of partially decalcified bone tied together by four catgut sutures. The lateral sutures were passed through the margins of the wound near its border, a modification of the usual procedure, which not only fixed the plates firmly in their places, but also prevented ectropium of the mucous membrane, and ensured free patency of the new opening by retracting the margins of the wound, so that the longi-

tudinal slit was at once transformed into an oval shape. The animal showed no unfavorable symptoms and was killed twenty-nine days after operation. Dog well nourished. External wound united. Omentum adherent to wound and intestines. The proximal blind end of bowel contained one of the bone plates which showed signs of softening and disintegration. The bone plate in the distal end had been passed with fæces previously. The new opening perfect and sufficiently large to equal in size the lumen of the bowel.

*Experiment 72.* Dog, weight twelve pounds. Made ileo-ileostomy the same as in the last experiment, using decalcified perforated bone plates, which were tied together with four catgut sutures, the lateral ones being passed through the margins of the wound. An omental flap was used to cover the sides of the bowel where approximation had been made. This flap was retained by two fine catgut sutures. No unfavorable symptoms. Animal killed twenty-three days after operation. Omentum adherent to distal blind end. Omental flap in position and firmly adherent. Site of operation fourteen inches above ileo-cæcal region. Both bone plates had disappeared and no trace of them could be found. Some hair had collected in the blind proximal end. New opening large enough to admit the index finger.

Remarks. — Jejuno-ileostomy or ileo-ileostomy by internal apposition with decalcified perforated bone plates in cases of complete obstruction of the bowel artificially produced, is an operation almost devoid of danger. Partially or completely decalcified bone plates hardened in alcohol remain firm for a sufficient length of time to answer the purpose of retentive measures, until firm adhesions have formed between the serous surfaces held by them in approximation. Until it was ascertained by experiment that the plates would undergo softening and disintegration in the course of a few days, catgut sutures were used to hold them in place with the expectation that the plates would become detached and escape with the intestinal contents as soon as the sutures would give way. Experience, however, has shown that aseptic silk threads are preferable to catgut, as they can be tied with greater accuracy and the knots will never become loosened, while the approximation discs disppear completely by softening and disintegration in a few days. Approximation plates of inabsorbable material as lead, wood, leather, bone, and gutta-percha, fastened together by silk or linen sutures, remain *in situ* until the interposed tissues disappear by pressure atrophy, and the opening that results corresponds in size to the dimensions of the plates. In the first experiments the plates were tied together by six sutures, but it was found that four sutures answered the same purpose. As a rule the plates were about two

and a half inches in length, and their width corresponded to one-third of the circumference of the bowel. The greatest advantage to be found in the method of restoring the continuity of the intestinal canal by lateral apposition by approximation discs, consists in the fact that the point of contact is always made on the convex surface of the intestines, so that the means employed to secure coaptation do not interfere with the blood supply from the mesenteric vessels. As this method requires much less time than any form of circular enterorrhaphy, and has been followed almost without exception by recovery, it recommends itself strongly as a substitute for the latter procedure in many cases where loss of time constitutes an important factor in the issue of the case, or where from other causes circular suturing appears impossible or impracticable.

## 3. Ileo-Colostomy.

As the ileo-cæcal region is frequently the seat of intestinal obstruction, it becomes desirable to devise some definite plan of operative treatment in cases where the cause of obstruction is not amenable to removal, with a view of establishing the continuity of the intestinal canal, thus avoiding the necessity of resorting to the formation of an artificial anus. To accomplish this object two distinct methods were followed: 1. Division of the ileum with closure of distal and implantation of proximal end into colon. 2. Division of ileum, closure of both ends and lateral apposition of proximal end with colon, and the formation of an intestinal anastomosis by suturing or approximation discs.

### a. Ileo-Colostomy by Implantation.

*Experiment 73.* Dog, weight thirty-eight pounds. Intestinal anastomosis by implantation of ileum into colon. The ileum was divided transversely just above the ileo-cæcal region, and the distal end closed by invagination and three stitches of the continued suture, and dropped back into the abdominal cavity. A longitudinal incision, in size corresponding to the lumen of the ileum, was made in the ascending colon at a point directly opposite the mesentric attachment, and the proximal end of the ileum was then fixed in this opening by Czerny-Lembert sutures. Only slight febrile reaction followed the operation. The appetite remained good and the discharges from the bowels were normal. The animal was in excellent condition when killed, thirty-three days after operation. Few circumscribed omental adhesions to abdominal wound, which was completely closed. Peripheral portion of ileum presented a conical appearance, and was found adherent to, and of the same length as the appendix vermiformis. Implantation had been done about the

middle of the colon. Union at point of suturing perfect, apparently no interruption of continuity of peritoneal surface. The new opening into colon a little smaller than the lumen of the ileum. Around the margins of this opening, which somewhat resembled the ileo-cæcal valve, six of the deep silk sutures remained attached. Above the new opening the colon and cæcum were found empty and somewhat atrophic. Lower portion of the ileum and colon below the new opening appeared normal in size and structure.

Remarks.—In the remaining experiments the implantation was made by lining the proximal end of the ileum with a narrow flexible rubber ring, which was retained in place by a continued catgut suture, embracing the free margin of the bowel and the lower margin of the rubber ring. The implantation was made by two catgut sutures, threaded each by two needles and passed at opposite points from within outwards through the upper margin of the ring and the entire thickness of the bowel, while the needles were only passed through the serous and muscular coats of the colon. After both sutures were in place gentle traction upon all of the ends brought the end of the ileum into the incision in the colon, and the walls of the colon were drawn over the end of the ileum to the points where the needles emerged from the ileum, making really a limited invagination. When in proper position, the serous surfaces of the colon and ileum over a surface corresponding to the width of the rubber ring were in accurate coaptation, after the two sutures were tied. Only in exceptional cases was it found necessary to apply one or two additional superficial coaptation sutures. As in circular enterorrhaphy, so in these cases, the elastic pressure on the part of the rubber ring rendered material assistance in maintaining accurate coaptation, while at the same time it secured rest for the sutured parts, and kept the new opening freely patent for the escape of intestinal contents into the colon. This operation did not require one-fourth of the time consumed in making an implantation by Czerny-Lembert sutures.

*Experiment 74.* Dog, weight fifty pounds. Division of ileum eight inches above ileo-cæcal region, distal end closed by invagination, and three stitches of the continued suture. Proximal end lined with rubber ring and implanted into incision of ascending colon by two catgut invagination sutures. The dog did not appear to do well after the operation, and died on the fifth day. Abdominal wound not united. Partial separation of implanted bowel and diffuse septic peritonitis from perforation.

*Experiment 75.* Dog, weight thirty-five pounds. Ileum divided twelve inches above ileo-cæcal region, distal end closed and proximal end lined with flexible rubber ring and implanted into an incision in the transverse colon,

and retained by two invagination sutures of catgut. An omental flap an inch and a half in width was placed over the junction of the two intestines and fixed in its place by two catgut sutures. No unfavorable symptoms after operation. Animal when killed eighteen days later, in excellent condition. Omentum adherent to abdominal wound which was firmly united. Omental flap adherent all round. Colon above new opening ten inches in length, completely empty, contracted and atrophic. New opening oval in outline and as large as the lumen of the ileum.

*Experiment 76.* Dog, weight sixteen pounds. Division of ileum, closure of distal end and implantation of proximal into an incision of the colon by rubber ring and two invagination sutures of catgut. As the inverted portions of the colon showed a tendency to evert, two additional retaining sutures of fine catgut were used, which secured perfect coaptation throughout. An omental flap was laid over the junction of the intestines and fixed in its place by one catgut suture. The dog remained in good condition, appetite unimpaired, and discharges from bowels normal. Killed thirteen days after operation. Abdominal wound firmly united. Omentum adherent to wound. A number of adhesions between coils of intestine. Ileum somewhat dilated above the new opening. Omental flap in place and adherent. Union between ileum and colon perfect. A long, sharp fragment of bone was found lodged just above the new opening, the lower end partially occluding its lumen. The dilatation of the lower portion of the ileum was evidently due to partial obstruction from the presence of the foreign body in the new opening.

*Experiment 77.* Dog, medium size. Section of ileum two feet above the ileo-cæcal region, closure of distal end in the usual manner, implantation of proximal end into colon by rubber ring and two invagination sutures of catgut. No omental flap. Animal remained well and was killed forty-three days after operation. Omentum adherent to abdominal wound. Distal end of ileum conical in shape, the extremity presenting a cup-shaped depression, which was filled with cicatricial material. Omentum adherent at ileo-cæcal region and at site of operation. Union between the bowels perfect and their serous surfaces appeared to be continuous over the line of junction. The new opening from the colon admitted the little finger, and was surrounded by a prominent ridge of mucous membrane, which resembled the ileo-cæcal valve.

*Experiment 78.* Dog, weight fourteen pounds. Division of ileum a few inches above ileo-cæcal valve, distal end closed by invagination, and three stitches of continued suture. Implantation of proximal end into colon by rubber ring and two catgut invagination sutures. Over the junction of the two intestines an omental flap was placed which was retained by a catgut suture. The animal showed no unfavorable symptoms and was killed twenty-three days after operation. Omental flap retained and firmly adherent throughout. Point of implantation three inches above cæcum; union between the two intestines firm throughout. New opening corresponded in size to the lumen of the ileum, and was surrounded by a prominent ridge of mucous membrane which appeared to be derived from the invaginated portion of the ileum.

*Experiment 79.* Ileum divided a few inches above ileo-cæcal region, and after closure of the distal, the proximal end was implanted into the colon in the usual manner by a rubber ring and two invagination sutures of catgut. Animal died on third day after operation. Wound partially united; a considerable quantity of sero-sanguinolent fluid in the abdominal cavity. Ileum almost completely separated from colon, and the portion which had been invaginated showed signs of gangrene. Rubber ring had disappeared; death from perforative peritonitis. In this case we have reason to believe that the rubber ring which was used was too large, and that the gangrene and separation was due to injurious pressure.

### b. Ileo-Colostomy by Lateral Apposition.

Anastomosis by this method was made after producing an intestinal obstruction of some kind at or near the ileo-cæcal region, and then by bringing the ileum above the seat of obstruction in communication with the colon below the point of obstruction, by making an incision an inch and a half to two inches in length in both intestines at a point opposite the mesenteric attachments, and uniting the wounds either by a double row of sutures or perforated decalcified bone discs. The first experiments were all made by suturing but, as in circular enterorrhaphy, it was found by experience that perforation not infrequently occurred along the track of one of the sutures, in some instances several days after the operation, at a time when union had taken place by firm adhesions. These unfavorable results led to the use of the approximation discs.

*Experiment 80.* Dog, weight twenty-five pounds. The ileum was withdrawn from the abdomen through an incision in the linea alba, and having emptied a loop of its contents, acute flexion was made just above the ileo-cæcal region by approximating the serous surfaces of the convex side for a inch and a half by five catgut sutures. Two longitudinal incisions of equal size were made, one in the ileum six inches above the flexion, and the other in the ascending colon three inches above the cæcum. The visceral wounds were carefully united by Czerny-Lembert sutures, using silk for the deep interrupted sutures, and fine catgut for the superficial continued sutures. No untoward symptoms were observed after the operation; appetite remained unimpaired, and fæcal discharges were normal. The dog was killed thirty-seven days after operation. Animal well nourished. No evidences of peritonitis. Bowel above point of obstruction nearly empty, and somewhat contracted as far as the new opening. Flexion permeable to a stream of water. Slight omental adhesions to bowel at site of operation; union firm throughout. Lumina of non-excluded portion of bowel normal in size above and below the flexion. Serous surfaces at point of junction appeared perfect and continuous. On slitting open the colon opposite the new opening, its outlines were seen to be marked by a prominent ridge of mucous membrane to which a number of the deep sutures

remained attached. The opening was large enough to admit the tip of the middle finger. The excluded portion of the colon and the cæcum were somewhat contracted and atrophic, and contained only a very small quantity of fæcal matter.

*Experiment 81.* Medium-sized cat. About two inches of the ileum were invaginated into the colon through the ileo-cæcal valve, and the intussusceptum stitched to the neck of the intussuscipiens by two fine catgut sutures. Continuity of the intestinal canal restored by incising the ileum above the obstruction, and the ascending colon below the free extremity of the intussusceptum, and uniting the wounds by a double row of sutures. The invagination caused no serious disturbance, and the animal remained in good health and was in excellent condition at the time of killing, one-hundred and sixty-two days after operation. A number of adhesions between the folds of the intestines near the site of operation. At point of juncture of the two intestines the peritoneal surface presented a glistening and continuous surface. New opening an inch and a half in length, oval in outline and located five inches above the ileo-cæcal region. Two inches below the opening the invagination remained in the shape of a circular thickening of the bowel with a narrowing of its lumen to more than one-half of its normal size. A close inspection of the specimen showed that no gangrene had occurred, but that the intussusceptum had undergone atrophy. A stream of water passing along the ileum in a downward direction escaped through the invaginated portion and through the new opening, the stream from the latter being at least three times larger than the one through the intussusceptum. Excluded portion of ileum and colon empty and very much atrophied and contracted. Below the new opening the colon and rectum contained normal fæces in considerable quantity.

*Experiment 82.* Young cat. Ileo-cæcal invagination; length of intussusceptum four inches. In order to prevent spontaneous disinvagination the bowel was fixed in its position by two fine catgut sutures. Ileo-colostomy below the lower end of the intussusceptum by lateral apposition and suturing. Animal died on the fourth day after operation. Abdominal wound united. Diffuse peritonitis from perforation at site of suturing. Length of intussusceptum reduced from four inches to two inches and a half. It was found impossible to effect reduction by traction on account of firm adhesions at neck of intussuscipiens. No gangrene.

*Experiment 83.* Adult, large dog. Intestinal obstruction was produced by making two sharp flexions near the ileo-cæcal region by folding the bowel on its side and fixing it in this position by fine catgut sutures; the apices of the flexions were sutured together so as to render the obstruction more complete. Intestinal anastomosis was established by lateral apposition and suturing. Physical condition of dog remained good throughout; appetite and evacuations normal. Killed thirty-one days after operation. No peritonitis; a number of omental adhesions at point of operation. Flexions quite sharp, rendering the bowel nearly, if not completely, impermeable at this point. Perfect union between bowels, with some thickening of their walls by inflammatory exudation. New opening oval in shape, an inch and a half in length,

a few of the deep sutures still remaining attached to its margins. Excluded portion of bowel empty and somewhat atrophic.

*Experiment 84.* Dog, weight thirteen pounds. Obstruction of the bowels made by an acute flexion four inches above the ileo-cæcal region, retained by four catgut sutures. Intestinal anastomosis by an opening an inch and a half in length, which brought into communication the ileum above the obstruction and the descending colon. The animal showed no untoward symptoms, and was killed forty-one days after operation. A number of intestinal folds agglutinated by adhesions; no evidences of diffuse peritonitis. Where the flexion had been made the loop of intestine was connected by a broad band of adhesion which gave to the bowel a horse-shoe shaped appearance. Intestine below the seat of flexion contained a small amount of hardened fæces. Colon and cæcum above the new opening nearly empty and greatly contracted. Line of suturing somewhat thickened. New opening oval in outline and about an inch in length, surrounded by a corrugated elevation of mucous membrane. A stream of water passed through the bowel from above downward readily escaped through the new opening, while only a small stream could be forced through the flexion.

*Experiment 85.* Dog, weight twenty-seven pounds. A volvulus was made six inches above the ileo-cæcal region by rotating an empty loop of the intestine once around its axis, and fixing it in this position by three catgut sutures. Intestinal anastomosis between the ileum above the volvulus and the descending colon by lateral apposition and suturing. For four days after the operation the evacuations from the bowels contained blood; after this time the stools were normal. Dog in excellent condition when killed thirty-one days after operation. No signs of diffuse peritonitis. The portion of bowel which constituted the volvulus adherent, contracted and empty. Water could be readily forced through this part of the bowel. Cæcum and colon above new opening empty and contracted. Size of new opening larger than the lumen of the ileum, its margins surrounded by a prominent ridge of mucous membrane to which a few of the deep sutures still remained attached. In this experiment nearly the entire colon was excluded, consequently the fæcal discharges were quite frequent and fluid or semi-fluid in consistence.

*Experiment 86.* Dog, weight seventeen pounds. Two inches of the ileum were invaginated into the cæcum. Ileo-colostomy by uniting the ileum with the transverse colon by suturing. The animal appeared quite ill after the operation and died on the fifth day after having manifested well-marked symptoms of perforative peritonitis. Abdominal wound not united. Only partial union between the intestines at point of junction. Diffuse septic peritonitis from perforation.

Remarks.—In at least two experiments which are not here reported, the animals died of shock a few hours after operation. In a number of other experiments the operation was followed by more or less shock, but the animals, without receiving any special treatment, rallied after six to twelve hours. The symptoms referable to

the immediate effects of the operation were due to the length of time required in applying a double row of sutures in uniting the visceral wounds, a step in the operation which always required from thirty minutes to an hour. These experiments only corroborate the statement previously made that the excluded portion of the intestinal canal, including the obstruction, does not become the seat of fæcal accumulation, but undergoes atrophy after free intestinal anastomosis has been established between the intestine above and below the seat of obstruction. Experiments Nos. 70 and 71 furnish most striking proof that the danger of gangrene in cases of invagination is greatly diminished by establishing an early intestinal anastomosis, as when this is done the violent peristalsis is promptly arrested by furnishing a new outlet to the intestinal contents ; at the same time, the serious consequences resulting from pressure and distention above the obstruction are likewise promptly averted. In cases of intestinal anastomosis where nearly the entire colon has been excluded, the fluid contents of the small intestines reach the rectum at once, and cause frequent fluid fæcal discharges, an occurrence which does not appear to impair the general health of the animal. The new opening should be made of adequate size, so that its lumen will at least correspond to the lumen of the bowel above the obstruction.

### c. Ileo-Colostomy by Perforated Approximation Discs.

*Experiment 87.* Dog, weight twenty pounds. The ileum was completely divided three inches above the ileo-cæcal region, both ends closed by invagination and three stitches of the continued suture. A communication was established between the proximal extremity and the colon, by making an incision into the ileum on convex side near the closed end and introducing through this opening a perforated decalcified bone plate. A similar opening was made into the ascending colon opposite its mesenteric attachment, through which a perforated plate of wood was introduced. To each plate were tied four catgut sutures. The lateral sutures were passed through the margins of the wound. After the plates and sutures were in place the wounds were brought in contact and the four sutures tied, which coaptated the serous surfaces of both bowels over an area corresponding to the size of the plates. The animal remained apparently well for two days, when symptoms of peritonitis set in and death occurred five days after operation. Diffuse peritonitis. Union at point of operation incomplete, which resulted in a perforation. Discs had disappeared. As the catgut sutures were quite fine it is more than probable that partial separation of the plates occurred before adhesions had taken place between the serous surfaces of the coaptated bowels, which resulted in perforation and death from diffuse septic peritonitis.

*Experiment 88.* Dog, weight fifteen pounds. Invagination of colon into colon to the extent of two inches. Intestinal anastomosis by making an ileo-colostomy by lateral apposition of the ileum to colon below invagination, using perforated hard rubber plates which were tied together by four catgut sutures, the lateral sutures being passed through the margins of the wound. After tying the sutures it was found that at one point the margins of the wound showed a tendency to evert, consequently a fine catgut suture was passed through the peritoneum only and tied. The animal did not appear bright the day after the operation, but subsequently showed no signs of suffering; killed twenty-four days after operation. Abdominal wound firmly united. Omentum adherent to wound and at point of operation. The invagination was partially reduced. The bowel at this point was curved in the shape of a horse-shoe, but permeable to a stream of water. Excluded portion of colon tortuous and atrophic. Cæcum contained a small quantity of fluid fæces. Plates could not be found. New opening sufficiently large for free passage of intestinal contents.

*Experiment 89.* Dog, weight fifteen pounds. Ileum divided transversely fifteen inches above the ileo-cæcal region; both ends closed in the usual manner. Ileum and colon approximated by decalcified perforated bone plates which were tied together by four catgut sutures, the lateral ones transfixing the margins of the wound. On the second day the evacuation from the bowels contained traces of blood. Animal killed eighteen days after operation. Abdominal wound completely healed. Omentum adherent to wound. Numerous adhesions between the intestinal folds. Proximal blind end of ileum had been changed into a pouch-like form and contained a mass of hair and fragments of bone. One very sharp spiculum of bone had nearly perforated the intestine. New opening corresponded in size to the lumen of the ileum.

Remarks.—The operations of lateral apposition of ileum to colon by perforated approximation discs, have shown that it is unsafe to rely upon catgut as a suturing material, as when fine catgut is used coaptation is not maintained for a sufficient length of time for adhesions to take place, and coarse catgut when tied interferes with accurate approximation, as the knots after tying mechanically separate the serous surfaces. It is advisable to use removable plates and to tie with silk. The results of ileo-colostomy made by approximation discs have not been as favorable as after jejuno-ileostomy or ileo-ileostomy, and in repeating the operation on man it would be indicated, after bringing the intestines in apposition by tying the four sutures, to apply a number of superficial sutures for the purpose of still further guarding against the escape of gas or fluid contents into the peritoneal cavity. The plates when properly fixed in their places and tied together with sufficient firmness, not only

coaptate an extensive area of serous surfaces, but they at the same time secure perfect rest for the parts which it is intended to unite, until firm adhesions have formed.

## 4. Ileo-Rectostomy.

In cases of intestinal obstruction due to inoperable conditions low down in the colon, it becomes necessary to establish an intestinal anastomosis between the ileum and the rectum, in order to avert the necessity of making an artificial anus; in other words, to make an ileo-rectostomy. The operation can be made in the same way as establishing a communication between the ileum and the colon by lateral implantation, by lateral apposition and double suturing, or by lateral apposition by perforated decalcified bone plates. The operation is, however, more difficult because the rectum is not as accessible as the colon, and from the greater vascularity of the gut, the incision is more liable to give rise to troublesome hæmorrhage. While the slight hæmorrhage from an incision into the small intestines and the colon is usually promptly arrested by suturing, or compression by the approximation discs, the bleeding from a wound of the upper portion of the rectum not infrequently requires the application of one or more catgut ligatures before it is safe to unite the wounds. During the operation traction must be made upon the rectum in an upward direction so as to lift the upper portion of the bowel out of the pelvis. In both of the experiments described below, the wounds were united by Czerny-Lembert sutures.

*Experiment 90.* **Dog, weight ninety pounds. Invagination of colon into colon for two inches and suturing of intussusceptum to neck of intussuscipiens by four fine silk sutures to prevent spontaneous disinvagination. Ileum incised in a parallel direction for an inch and a half on convex side, and this wound united with a similar incision in the rectum on its anterior surface by a double row of sutures. For the purpose of immobilizing the sutured intestines an additional fine catgut suture was applied above and below the place of suturing, embracing only the peritoneal and muscular coats of the intestines. On the third, fourth, and fifth days the fæcal discharges contained blood and mucus. On the sixth day the abdominal wound partially opened, and a considerable quantity of sero-purulent fluid escaped. Death seven days after operation. Abdominal wound not united. Diffuse purulent peritonitis. Numerous intestinal adhesions. Invagination retained; adhesions between the intussusceptum and intussuscipiens; no gangrene; perforation at point of operation.**

*Experiment 91.* **Cat, weight seven pounds. Ileo-rectostomy by lateral implantation. The ileum was cut across transversely an inch above the ileo-**

cæcal valve, and the distal end closed by invagination and three stitches of the continued suture. The proximal end was transplanted into a longitudinal incision on the anterior surface of the upper portion of the rectum by Czerny-Lembert sutures. With the exception of an occasional slight rise in temperature no serious disturbances were observed during the progress of the case. The evacuation of the small intestines directly into the rectum appeared to increase the peristaltic action of the rectum, as the fæcal discharges were fluid and frequent. Animal killed twenty days after operation. Abdominal wound completely united. No peritonitis. A few folds of the small intestines and the omentum adherent to the wound. Insertion of ileum into rectum in an oblique direction; union at point of junction complete throughout; intestinal coats at this point somewhat thickened. Peritoneal surface smooth and continuous from one bowel to the other. New ileo-rectal opening corresponded in size to the lumen of the ileum; margins of this opening consisted of a ridge of mucous membrane to which a row of the deep sutures remained attached. Excluded portion of large intestine empty and contracted. Rectum contained a small quantity of fluid fæces.

## 5. Colo-Rectostomy.

Among the many possibilities in the operative treatment of intestinal obstruction, a condition might be met with where the seat of obstruction is located low down in the colon, perhaps in the sigmoid flexure, and where it might be impossible or impracticable to remove the cause of obstruction, and where it becomes necessary to restore the continuity of the intestinal canal by establishing a communication between the permeable portion of the colon and the rectum. Such an anastomosis can be made, as in ileo-colostomy, by lateral implantation, lateral apposition by perforated approximation plates, or by double suturing. For want of time only one experiment was made, and although the animal died from the immediate effects of the operation, the local conditions at the site of operation found after death showed that colo-rectostomy in selected cases is not only a justifiable and feasible operation, but whenever it can be done, that it is always preferable to the formation of an artificial anus. As the operation by lateral apposition requires much less time than lateral implantation, it should be preferred to the latter procedure, and should be done by perforated approximation discs and a few superficial sutures.

*Experiment 92.* Medium-sized cat. Incision through the linea alba; colon cut transversely in the middle third and the distal portion, and the rectum cleared of its contents by injecting a stream of warm water from the cut end downward, a procedure which could only be well accomplished after forcible

dilatation of the sphincter ani muscles. The distal end was closed in the usual manner. The rectum was drawn upward and an incision made into its anterior wall large enough to correspond with the lumen of the colon. Into this opening the proximal end of the colon was implanted by two rows of sutures. During the latter part of the operation, which lasted over an hour, the animal was seized by convulsions which continued for several hours, and finally subsided under the administration of whisky given hypodermically. The symptoms of shock, however, continued and death occurred thirty-six hours after operation. Numerous omental adhesions; closed end of bowel congested; peritoneal surfaces adherent; colon and rectum at point of implantation adherent.

Remarks.—In cases where the obstruction is located some distance from the rectum, where it would be impossible to approximate the permeable portion of the colon with the rectum, the entire colon must be excluded and the continuity of the intestinal canal restored by ileo-colostomy or ileo-rectostomy. In all cases of intestinal anastomosis where the communication is made in the lower portion of the colon or the rectum, the sphincters of the anus should be rendered temporarily incompetent by stretching, for the purpose of guarding against over-distention of this part of the bowel during the time required for the healing process between the united intestines.

## V. Adhesion Experiments.

In works on abdominal surgery we invariably meet with the assertion that serous surfaces brought into apposition by suturing unite after a few hours. Isolated experiments and the results of post-mortem examinations have given rise to the general belief that serous surfaces so united will become firmly adherent in a very short time; but the question concerning the exact time for adhesion to take place, and for the definitive healing to be complete, can only be determined by experiments made for this special purpose. The following experiments were made with a view of ascertaining the exact time which is requisite for adhesions and definitive healing between approximated serous surfaces to take place, and likewise to study the effects of local conditions which would hasten or retard these processes. It is quite important to make a distinction between the terms "adhesion" and "healing." Adhesion precedes the process of definitive healing, but implies simply the presence of an adhesive or cement substance between the serous surfaces, which mechanically agglutinates the parts; while definitive healing includes

all the processes which take place during cicatrization. In intestinal surgery this distinction has an important practical bearing, as perforation may take place as long as the serous surfaces are simply held together by adhesions, while such an occurrence is beyond the reach of all possibilities after the approximated surfaces have become united by living organized tissue. Adhesions between serous surfaces take place by the exudation of plastic lymph, which acts the part of a cement material; while on the other hand, the process of definitive healing is initiated by cell-proliferation from the pre-existing endothelial and connective tissue cells, and the formation of a network of new blood-vessels springing from each of the coaptated granulating surfaces. The processes are the same as we observe within blood-vessels during cicatrization after ligature. In suturing an intestinal wound, or in making a circular enterorrhaphy, it has always heretofore been deemed necessary not to injure the peritoneum unnecessarily, for fear that such injuries would result deleteriously by interfering with the prompt union between the sutured surfaces.

It is a well known fact in surgery that approximation of intact serous surfaces does not result in the formation of adhesions. When the surgeon desires to secure union between serous surfaces he resorts to mechanical irritation for the purpose of inducing a circumscribed plastic peritonitis, which invariably results in adhesions and the obliteration of the serous space. Reasoning from this analogy, I was induced to study the effects of traumatic and chemical irritation in hastening adhesions and cicatrization between apposed serous surfaces. In most of these experiments the serous surfaces in the different operations were held in contact by perforated approximation plates, and in case artificial means were employed to expedite the healing process, the fact is mentioned, and the result of such modification noted. The animals operated on were all dogs.

## 1. Traumatic Irritation of Serous Surfaces.

TIME, SIX HOURS.

*Experiment 93.* The ileum was divided near the middle, and both ends closed by invagination and the continued suture. Ileo-ileostomy was made at two points, making two openings of communication. No suturing. Parts kept in apposition by perforated decalcified bone plates. To compare the effect of traumatic irritation of the peritoneum in the reparative process

with the intact serous surface, the peritoneal surfaces at one point of operation designated as the upper, were scarified with the point of a needle over an area corresponding to the size of the bone discs, the scratches being made sufficiently deep to penetrate the entire thickness of the peritoneum. The scarifications were made in a longitudinal and transverse direction, mapping out the serous surfaces into small squares. Only slight oozing followed this procedure. The serous surfaces between the plates at No. 1, where no scarification was made, was found slightly adherent by a scanty deposit of plastic lymph. At No. 2, where scarifications had been done, the amount of plastic lymph was greater and stained by blood, and the adhesions much firmer.

TIME, TWELVE HOURS.

*Experiment 94.* In this experiment the bowel was not interrupted by division, but two adjacent coils of the ileum were united by making an ileo-ileostomy by perforated decalcified bone plates, the plates holding the parts perfectly in apposition; a slight tumefaction of the intestinal walls made the coaptation more secure. Coaptated serous surfaces very vascular, covered with a thin layer of plastic lymph which had agglutinated the folds of the intestine brought in contact.

*Experiment 95.* Bowel not divided, but two adjoining loops of the ileum united by making a double ileo-ileostomy by perforated approximation discs, the two communicating openings about six inches apart. At one point of operation, designated as No. 2, serous surfaces freely scarified. At both points the adhesions were perfect throughout, but where scarification was made they were notably firmer.

*Experiment 96.* In this experiment a gastro-enterostomy and an ileo-ileostomy were made at the same time and on the same animal. In both operations the parts were coaptated by perforated decalcified bone plates. Scarification of peritoneal surfaces at both places. The adhesions between the anterior surface of the stomach and upper portion of jejunum were uniform throughout, over the whole surface, kept in contact by the plates. There was no leakage on distending the stomach and intestine forcibly by water. The adhesions between the folds of the ileum at point of approximation were, if anything, firmer than between stomach and jejunum. The decalcified bone plate in the interior of the stomach was softened more than those in the intestine.

TIME, EIGHTEEN HOURS.

*Experiment 97.* Gastro-enterostomy by perforated decalcified bone plates; communication made between stomach and upper portion of jejunum; no scarification. Agglutination quite firm, so that forcible distention of stomach and bowel caused no leakage. New opening sufficiently large to admit middle finger, and apparently lined throughout by mucous membrane. Plate in stomach very much softened and on the verge of becoming detached. On forcibly separating the adhesions the serous surfaces were found to be cemented together by a thin layer of plastic lymph, and after scraping this away they appeared vascular and rough, as though completely deprived of the endothelial covering.

TIME, TWENTY-FOUR HOURS.

*Experiment 98.* Triple ileo-ileostomy without division of the bowel; the operations were numbered 1, 2, 3, respectively. Coaptation by approximation discs of decalcified bone. Communicating openings about six inches apart. In No. 1 no scarification. No. 2, scarification of one loop only. No. 3, scarification of both serous surfaces. After twenty-four hours the result was as follows:

No. 1. Lymph scanty; adhesions not very firm.

No. 2. Lymph more plentiful; adhesions firmer.

No. 3. Lymph more abundant than in No. 2, and mixed with a fine stratum of coagulated blood; adhesions also firmer. The adhesions increase in firmness in the order 1, 2, 3.

*Experiment 99.* Double gastro-enterostomy by perforated decalcified bone plates. The communicating openings, one near the pyloric, and the other near the cardiac extremity of the stomach, were made between the anterior surface of the stomach, and the upper portion of the jejunum. In operation No. 1, the intact serous surfaces near the pylorus were brought in contact, while in the second operation both the stomach and bowel were scarified. At the post-mortem, it was found that the adhesions at both places were of sufficient firmness to prevent leakage under pressure. In No. 2, adhesions firmer and the inflammatory infiltration more marked than in No. 1. Plates in stomach much softened, but remain *in situ*. Openings lined throughout by mucous membrane and sufficiently large to admit the index finger.

*Experiment 100.* Ileo-colostomy by lateral apposition and fixation by perforated approximation discs. Lower portion of ileum united with the ascending colon. No scarification; bowels lightly agglutinated throughout by a very thin layer of plastic lymph; adhesions, however, could be easily separated, and where this is done the peritoneal surface appeared denuded of endothelial cells, and very vascular with new vessels along the outer margin of the surface of approximation.

TIME, FORTY-EIGHT HOURS.

*Experiment 101.* Double gastro-enterostomy. The communicating openings were between the anterior surface of the stomach and the duodenum, and the posterior surface of the stomach and the upper portion of the jejunum. In the posterior operation the intact serous surfaces were brought in contact, while in the anterior, the peritoneal surfaces of the stomach and duodenum were scarified. In both operations perforated decalcified bone plates were used. Adhesions between posterior surface of stomach and bowel uniform throughout, but easily broken down; the peritoneal surfaces injected and apparently deprived of their endothelial covering. The anterior operation resulted in the formation of firm adhesions, the products of exudation and tissue proliferation being supplied with new vessels, the circumscribed plastic peritonitis being much more advanced than at the site of the posterior operation.

*Experiment 102.* Double ileo-colostomy by perforated approximation plates. The anastomosis between the lower portion of the ileum and the colon just above the cæcum was made without scarification, while in the second operation about six inches higher up in the colon and ileum, both serous surfaces were freely scarified. Omentum adherent at point of operation. Plates swollen, softened and pliable, but still efficient in maintaining coaptation and fixation. Adhesions at both places quite firm, but more so in the upper portion where scarification had been done.

*Experiment 103.* Ileo-colostomy by approximation discs. The ileum was divided a few inches above the ileo-cæcal region, and both ends closed by invagination and three stitches of the continued suture. An anastomosis was made between the proximal end and the ascending colon by lateral apposition. No scarification. Intestines agglutinated at point of operation, but the adhesions gave way when the bowel was forcibly distended under hydrant pressure.

## 2. Chemical Irritation of Serous Surfaces.

In these experiments it was aimed to study the effect of chemical irritation of the peritoneum in the reparative process after intestinal operations. Iodine has been used for a long time in producing plastic inflammation of serous surfaces for the purpose of obliterating serous cavities, consequently this substance was used in the first experiments. To study the effects of the diffuse application of tincture of iron to the intact peritoneal cavity, the following experiments were made:

*Experiment 104.* Medium-sized dog. The needle of a hypodermic syringe was thoroughly disinfected, and a drachm of the tincture of iodine injected into the peritoneal cavity. Immediately after the injection the animal evinced great pain, which, however, appeared to subside after a short time, and subsequently no unfavorable symptoms were observed. Three days after the injection the urine was examined and showed the presence of iodine. Dog killed nine days after the injection. Circumscribed plastic peritonitis over a space four inches square, corresponding to the point where the puncture was made. At this place the omentum was much thickened, very vascular and adherent to the parietal peritoneum and the adjoining folds of the intestines.

*Experiment 105.* Medium-sized dog. A fluid drachm of the tincture of muriate of iron was thrown into the peritoneal cavity by means of a well-disinfected hypodermic syringe. The pain immediately after the injection was intense, and the animal appeared to be very ill two days after the injection, and died with well-marked symptoms of peritonitis on the sixth day. Diffuse plastic peritonitis was found to be the cause of death. The omentum was adherent everywhere, and the intestines were matted together by numerous adhesions. The abdominal cavity contained a considerable quantity of serous fluid.

Remarks.—Both experiments prove that when tincture of iodine and tincture of iron are brought in contact with the peritoneum, a plastic inflammation ensues; and it was reasonable to expect that if either of these substances could be applied to the serous surfaces which it was intended to unite, the reparative process would be hastened.

*Experiment 106.* Triple ileo-ileostomy by perforated decalcified bone plates. Three internal fistulæ were made between the adjacent loops of the ileum, about six inches apart. In operation No. 1, approximation of intact serous surfaces; in operation No. 2, the serous surfaces were painted with tincture of iron over an area corresponding to the size of the plates; in operation No. 3, the serous surfaces over the same extent were brushed with pure tincture of iodine. The animal was killed forty-eight hours after operation, and the following conditions were noted: No general peritonitis. All the plates firmly in place coaptating the serous surfaces accurately, the swelling of the tunics of the bowel only serving to enhance their efficiency. At No. 1, adhesions quite firm, flexion of bowel and marked injection of serous surfaces. At No. 2, no adhesions between serous surfaces. The peritoneal surfaces to which the tincture of iron had been applied appeared stained, almost black, and at some points the serous coat was destroyed. At No. 3, peritoneal surfaces stained dark brown; adhesions firm, and an abundance of plastic lymph even beyond the margin of the plates.

*Experiment 107.* Double ileo-ileostomy by approximation plates and omental grafting. Operation No. 1, approximation of ileum to ileum by perforated decalcified bone plates; serous surfaces intact. Operation No. 2, similar operation six inches higher up uniting the same loops, but painting the serous surfaces with pure tincture of iodine. Operation 3, cutting off a piece of omentum two inches wide and sufficiently long to encircle the entire bowel. After scarifying the bowel and the omental graft on one side, the scarified surfaces were brought in contact, and the graft fixed in its place by two fine catgut sutures passed through the mesentery and both ends of the graft. Animal killed forty-eight hours after operation. All plates firmly in place. At No. 1, adhesions firm. At No. 2, dark-brown discoloration of surface to which the iodine had been applied; agglutination over the whole surface. Under hydrostatic pressure the adhesions first gave way between the two plates where the iodine had been applied; showing conclusively that chemical irritation of serous surfaces does not hasten the adhesive process, while it may, and probably does, expedite the definitive healing. At No. 3, omental graft firmly adherent to the entire circumference of the bowel, and beginning vascularization of the graft around its margins.

Remarks.—In all of these experiments the post-mortem examinations showed no evidences of diffuse peritonitis. In most of the cases the inflammatory process was limited to the portion of the bowel interposed between the plates. Without exception the

adhesions formed were firmest and the definitive healing was initiated first where scarification was performed; results which clearly demonstrate the fact that the reparative process between serous surfaces which it is intended to unite, is hastened by traumatic irritation. Traumatic irritation by scarification of the peritoneal surface with the point of an aseptic needle, is the most potent means to provoke a circumscribed plastic peritonitis, and is followed within a few hours by a copious exudation of plastic lymph, which, like a cement substance, mechanically agglutinates the coaptated serous surfaces. The same measure, by destroying the continuity of the non-vascular layer of the peritoneum, brings at once in contact the vascular network of both sides of the bowel, and opens up a direct route for the new vessels, an important element in the rapid healing of the visceral wounds. Chemical irritants by destroying the endothelial layer of the peritoneum rather retard, than favor, early adhesion and union between the coaptated bowels, and should therefore not be resorted to in intestinal surgery, to hasten the reparative process.

## 3. Omental Grafting.

Under the head of circular enterorrhaphy, mention is made of transplantation of omental flaps after uniting the two ends of the bowel by suturing or invagination, with a view of securing an additional safeguard against perforation during the process of repair. A number of experiments are described where the procedure was practiced with satisfactory results. After a few days the omental flaps were found firmly adherent and vascular around the whole circumference of the bowel, constituting a ring of living tissue outside the line of suturing. In all these cases the proximal end of the flap remained in connection with the omentum, and care was taken to cut the flap in such a manner that some vessel of considerable size should furnish the necessary vascular supply. I was well aware that plausible objections could be entered against this method, in that the connecting bridge between the bowel and the omentum might become subsequently a cause of intestinal obstruction by making traction upon the bowel, thus causing a flexion, or, by becoming a band of constriction for some loop of intestine.

For the purpose of obviating such remote consequences I resorted to another procedure which I have designated as omental grafting. I was familiar with the fact that implantations of aseptic

substances into the peritoneal cavity had frequently been done without any immediate or remote ill-effects, and I had every reason to expect that a large, completely detached, aseptic, omental graft, in an aseptic abdominal cavity, would be well tolerated, and would soon become adherent to the subjacent peritoneal surface, and thus afford an additional safeguard against perforation and the disastrous consecutive result, namely: perforative peritonitis during the time required for the healing of the intestinal wound. In the following experiments the grafts used were from one and a half to two inches in width, and of sufficient length to completely encircle the bowel. The free ends were made to project a few lines beyond the mesenteric attachment, and were fixed by two fine catgut sutures, each of which embraced the corresponding angles of the graft and the mesentery. The stitches were made in the direction of the mesenteric vessels, so that in tying, no vessels should be included in the suture. In these experiments dogs were used exclusively.

*Experiment 108.* Three pieces of omentum, two inches wide and sufficiently long to encircle the bowel, were completely detached and grafted as follows:

1. Graft simply laid over the bowel corresponding to the lower portion of the ileum, and fastened in its place on mesenteric side by two fine catgut sutures.

2. Serous surface of bowel about six inches higher up scarified, and graft applied to this surface and fixed in the same manner.

3. Bowel treated in the same way about six inches still higher up, and one of the serous surfaces of the graft also freely scarified.

The graft was scarified on the side which was to be brought in contact with the bowel. Fixation of graft by two catgut sutures on mesenteric side. Animal killed thirty-six hours after operation. All the grafts adherent, slightly contracting the bowel at the three different places. On separating the adhesions the subjacent serous surface very vascular and denuded of its endothelial layer. Firmness of adhesions increased in proportion to the extent of scarification done, being least firm at No. 1, firmer at No. 2, and firmest at No. 3, where both coaptated serous surfaces had been scarified. At Nos. 2 and 3, the plastic lymph was freely supplied with new blood-vessels. The vascularization was most conspicuous on the mesenteric side.

*Experiment 109.* Two omental grafts planted around the ileum in the same manner as described above. At No. 1, both the bowel and the inner side of the graft were scarified; at No. 2, only the serous surface of the bowel. Animal killed forty-three hours after operation. Stump of omentum adherent to abdominal wound and intestines. No peritonitis. At No. 1, graft firmly adherent over the entire extent. A slight extravasation of blood between the graft and the bowel. Beginning vascularization of interposed plastic lymph.

At No. 2, also firm adhesions and beginning vascularization of the plastic exudation. Both of the grafts appear to be stained with the coloring material of the blood.

*Experiment 110.* Planting of two omental grafts around the ileum about eight inches apart. At No. 1, both the bowel and one side of the omental graft were scarified. At No. 2, only the serous surface of the bowel was treated in this manner. Animal killed six days after the operation. Both grafts firmly adherent throughout and freely supplied with blood-vessels, the largest of the new vessels being on the mesenteric side. The omental stump adherent to the portion of bowel between the grafts where a flexion had been made from this cause.

*Experiment 111.* In this experiment omental grafting was done at two points around the lower portion of the ileum. At one point the serous surfaces were left intact, at the other, both the peritoneal surface of the bowel and the omental graft were freely scarified. Animal remained perfectly well and was killed eight days after operation. No signs of peritonitis. Both grafts formed a thin vascular layer around the entire circumference of the bowel, and firmly and evenly united throughout. Vascularization was more marked where scarification had been done. On attempting to separate the grafts it was difficult to find and define the line of union between the omentum and the underlying bowel, as the union was very intimate and firm.

Remarks.—In all of these experiments the grafts retained their vitality, and in a few hours became firmly adherent to the intestinal surface with which they had been brought in contact. Scarification of the serous surface has also been found in these experiments, an exceedingly valuable measure in hastening the processes of adhesion, granulation and vascularization. By planting grafts side by side, with and without scarification, I was enabled to determine with accuracy the beneficial influence exerted by this procedure in favoring the reparative process, and without a single exception, observed that where scarification was done the adhesions were firmer and vascularization more advanced. The post-mortem examinations appeared to demonstrate that the firmness of the adhesions and the degree of vascularization were in direct proportion to the extent of traumatic irritation of the peritoneum, being always most marked in cases where both the bowel and the under surface of the graft were scarified, and least where intact peritoneal surfaces were brought into apposition.

As soon as the omental grafts were cut off from the omentum they were placed in a 1-2000 solution of corrosive sublimate, kept at the temperature of the body, in order to secure for the graft a perfectly aseptic condition until everything was in readiness for

the transfer of the graft to its new location. Before planting the graft it was carefully dried by pressing it between gauze or sponges wrung out of the same solution. The scarifications of the serous surfaces should only be made sufficiently deep to give rise to a very slight oozing, as when hæmorrhage is more profuse, there is danger of the formation of a clot between the graft and the bowel, which, if it does not ultimately prevent union between the coaptated surfaces, must necessarily interfere with the formation of early and firm adhesions.

Omental grafting cannot fail to become an established procedure in many abdominal operations. After suturing a large wound of the stomach or intestines, a strip of omentum should be laid over the wound and fastened in its place by a few catgut sutures. After circular enterorrhaphy, the operation should be finished by covering the circular wound by an omental graft about two inches wide, which should be fixed in its place by two catgut sutures passed through both ends of the graft and the mesentery. Omental grafting should also be resorted to in repairing peritoneal defects in visceral injuries of the abdominal organs, and in covering large stumps after ovariotomy or hysterectomy, where the pedicle is treated by the intra-abdominal method.

## VI. Conclusions.

In conclusion I beg leave to submit the following propositions for further discussion :

1. Traumatic stenosis from partial enterectomy and longitudinal suturing of the wound becomes a source of danger from obstruction or perforation, in all cases where the lumen of the bowel is reduced more than one-half in size.

2. Longitudinal suturing of wounds on the mesenteric side of the intestine should never be practiced, as such a procedure is invariably followed by gangrene and perforation by intercepting the vascular supply to the portion of bowel which corresponds to the mesenteric defect.

3. The immediate cause of gangrene in circular constriction of a loop of intestine is due to obstruction of the venous circulation, and takes place first in the majority of cases at a point most remote from the cause of the obstruction.

4. On the convex surface of the bowel a defect an inch in width, from injury or operation, can be closed by transverse suturing without causing obstruction by flexion. In such cases the stenosis is subsequently corrected by a compensating bulging or dilatation of the mesenteric side of the bowel.

5. Closing a wound of such dimensions on the mesenteric side of the bowel by transverse suturing may give rise to intestinal obstruction by flexion, and to gangrene and perforation by seriously impairing the arterial supply to, and venous return from, the portion of bowel corresponding with the mesenteric defect.

6. Flexion caused by inflammatory and other extrinsic causes gives rise to intestinal obstruction only in case the functional capacity of the flexed portion of the bowel has been impaired or suspended by the causes which have produced the flexion, or by subsequent pathological conditions which have occurred independently of the flexion.

7. As in flexion, a volvulus gives rise to symptoms of obstruction, when the causes which have given rise to a rotation upon its axis of a loop of bowel have at the same time produced an impairment or suspension of peristalsis in the portion of bowel which constitutes the volvulus; or when a diminution or suspension of peristalsis follows in consequence of the degree or extent of the rotation.

8. Accumulation of intestinal contents above the seat of invagination is one of the most important factors which prevents spontaneous reduction, and which determines gangrene of the intussusceptum and perforation of the bowel.

9. Spontaneous disinvagination is not more frequent in ascending than descending invagination.

10. The immediate or direct cause of gangrene of the intussusceptum is obstruction to the return of venous blood by constriction at the neck of the intussuscipiens.

11. Ileo-cæcal invagination, when recent, can frequently be reduced by distention of the colon and rectum with water; but this method of reduction must be practiced with the greatest caution and gentleness, as over-distention of the colon and rectum is productive of multiple longitudinal lacerations of the peritoneal coat, an accident which is followed by the gravest consequences.

12. The competency of the ileo-cæcal valve can only be overcome by over-distention of the cæcum, and is effected by a mechanical separation of the margins of the valve; consequently it is imprudent to attempt the treatment of intestinal obstruction beyond the ileo-cæcal region by injections per rectum.

13. Resection of more than six feet of the small intestine in dogs is uniformly fatal; the cause of death in such cases is always attributable to the immediate effects of the trauma.

14. Resection of more than four feet of the small intestine in dogs is incompatible with normal digestion, absorption and nutrition, and often results in death from marasmus.

15. In cases of extensive intestinal resection, the remaining portion of the intestinal tract undergoes compensatory hypertrophy, which microscopically is apparent by thickening of the intestinal coats and increased vascularization.

16. Physiological exclusion of an extensive portion of the intestinal tract does not impair digestion, absorption and nutrition as seriously as the removal of a similar portion by resection.

17. Fæcal accumulation does not take place in the excluded portion of the intestinal canal.

18. The excluded portion of the bowel undergoes progressive atrophy.

19. A modification of Jobert's invagination suture by lining the intussusceptum with a thin flexible rubber ring, and the substitution of catgut for silk sutures is preferable to circular enterorrhaphy by the Czerny-Lembert suture.

20. The line of suturing, or neck of intussuscipiens, should be covered by a flap or graft of omentum in all cases of circular resection, as this procedure furnishes an additional protection against perforation.

21. In circular enterorrhaphy, the continuity of the peritoneal surface of the ends of the bowel to be united should be procured where the mesentery is detached, by uniting the peritoneum with a fine catgut suture before the bowel is sutured, as this modification of the ordinary method furnishes a better security against perforation on the mesenteric side.

22. In cases of complete division of an intestine, if it is deemed advisable not to resort to circular enterorrhaphy, one or both

ends of the bowel should be closed by invagination to the depth of an inch, and three stitches of the continued suture embracing only the peritoneal and muscular coats.

23. The formation of a fistulous communication between the bowel above and below the seat of the obstruction should take the place of resection and circular enterorrhaphy in all cases where it is impossible or impracticable to remove the cause of obstruction, or where after excision it would be impossible to restore the continuity of the intestinal canal by suturing, or where the pathological conditions which gave rise to the obstruction do not constitute an intrinsic source of danger.

24. The formation of an artificial anus in the treatment of intestinal obstructions should be practiced only in cases where continuity of the intestinal canal cannot be restored by making an intestinal anastomosis.

25. Gastro-enterostomy, jejuno-ileostomy and ileo-ileostomy should always be made by lateral apposition with partially or completely decalcified perforated bone plates.

26. In making an intestinal anastomosis for obstruction in the cæcum, or colon, the communication above and below the seat of obstruction can be established by lateral apposition with perforated approximation plates, or by lateral implantation of the ileum into the colon or rectum.

27. An ileo-colostomy, or ileo-rectostomy by approximation with decalcified perforated bone plates, or by lateral implantation, should be done in all cases of irreducible ileo-cæcal invagination, where the local signs do not indicate the existence of gangrene or impending perforation.

28. In all cases of impending gangrene or perforation, the invaginated portion should be excised, both ends of the bowel permanently closed, and the continuity of the intestinal canal restored by making an ileo-colostomy or ileo-rectostomy.

29. The restoration of the continuity of the intestinal canal by perforated approximation plates, or by lateral implantation, should be resorted to in all cases where circular enterorrhaphy is impossible on account of the difference in size of the lumina of the two ends of the bowel.

30. In cases of multiple gunshot wounds of the intestines involving the lateral or convex side of the bowel, the formation of intestinal anastomosis by perforated decalcified bone plates should be preferred to suturing, as this procedure is equally, if not more safe, and requires less time.

31. Definitive healing of the intestinal wound is only initiated after the formation of a network of new vessels in the product of tissue proliferation from the approximated serous surfaces.

32. Under favorable circumstances quite firm adhesions are found within the peritoneal surfaces in six to twelve hours, which effectually resist the pressure from within outward.

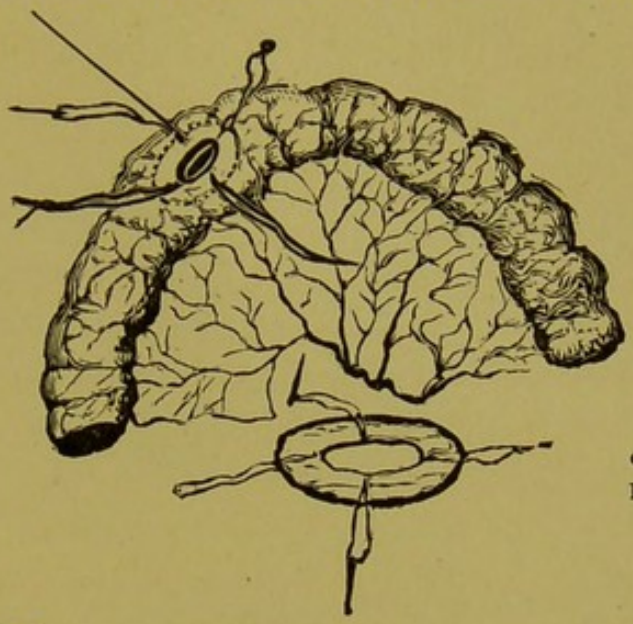
33. Scarification of the peritoneum at the seat of coaptation hastens the formation of adhesions and the definitive healing of the intestinal wound.

34. Omental grafts, from one to two inches in width, and sufficiently long to completely encircle the bowel, retain their vitality, become firmly adherent in from twelve to eighteen hours, and are freely supplied with blood-vessels in from eighteen to forty-eight hours.

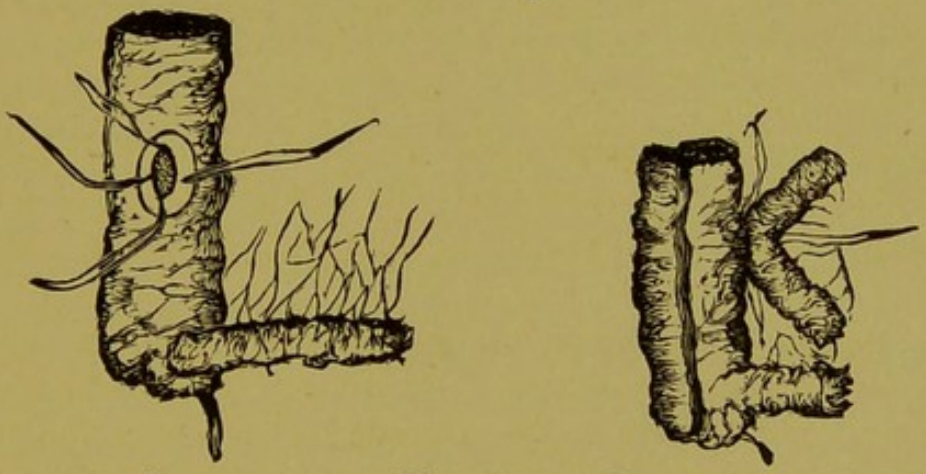
35. Omental transplantation, or omental grafting, should be done in every circular resection or suturing of large wounds of the stomach or intestines, as this procedure favors healing of the visceral wound, and affords an additional protection against perforation.

# Methods of Intestinal Anastomosis.

Plate within the intestine above seat of obstruction.



Perforated decalcified bone-plate.

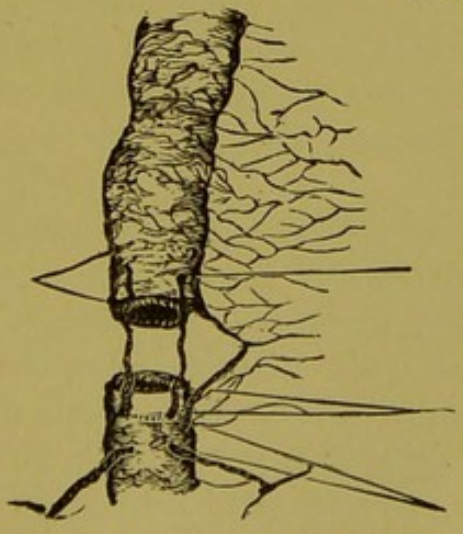


INTESTINAL ANASTOMOSIS BY PERFORATED DECALCIFIED BONE-PLATES.

Plate within colon below seat of obstruction.

Approximation of intestine by tying of sutures.

Rubber ring within bowel fixed by continuous catgut sutures.



Needles passed from within outward through entire wall of bowel and ring.

Part to be invaginated.

Needles passed through serous and muscular coats.

AUTHOR'S MODIFICATION OF JOBERT'S SUTURE.

# RECTAL INSUFFLATION OF HYDROGEN GAS AN INFALLIBLE TEST IN THE DIAGNOSIS OF VISCERAL INJURY OF THE GASTRO-INTESTINAL CANAL IN PENETRATING WOUNDS OF THE ABDOMEN.

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The operative treatment of penetrating wounds of the abdomen complicated by visceral injury of the gastro-intestinal canal is now sanctioned by the best surgical authorities, and may be considered as a well-established procedure, based as it is upon the results of experimentation and clinical experience. A visceral wound of the stomach or any portion of the intestinal canal sufficient in size to give rise to extravasation into the peritoneal cavity, must be looked upon as a mortal injury unless promptly treated by abdominal section. A number of well authenticated cases are on record where a wound in the stomach or the large intestine healed, and the patients recovered without the intervention of surgery, but these instances are so few that, practically, the force of the preceding statement remains unimpaired. After a careful study of an immense amount of clinical material Otis came to the important conclusion that gunshot injuries of the small intestines under the old expectant treatment, without exception resulted in death; and that is a sufficiently cogent argument in favor of their treatment by laparotomy as affording the only chance of recovery.

The great difficulty that presents itself to the surgeon in the absence of positive symptoms, is the differential diagnosis between a simple penetrating wound and a penetrating wound complicated by injury of the gastro-intestinal canal. While the existence of serious intra-abdominal hæmorrhage can usually be readily recognized by well marked physical signs and a complexus of symptoms which points to sudden diminution of intra-arterial pressure, and thus furnishes one of the positive indications for treatment by laparotomy,

the well-known fact remains that a visceral injury of the stomach or intestines seldom gives rise to symptoms upon which the surgeon could rely in making a positive diagnosis.

In the treatment of penetrating wounds of the abdomen laparotomy is resorted to either (1) for the purpose of arresting dangerous hæmorrhage, or (2) for the detection and treatment of a wound or wounds of its hollow viscera. The first indication is readily recognized, and the diagnosis not only justifies the operation, but imposes it as a stern duty upon the surgeon, from which he should never shrink. The recognition of the second indication offers greater difficulties, and the uncertainty of diagnosis which surrounds such cases is used as a sufficient argument by many in opposing the adoption of timely and efficient surgical treatment, and is responsible for the loss of many lives which otherwise might have been saved. The uncertainty of diagnosis must remain in the way of a more general adoption of laparotomy in the treatment of penetrating wounds of the abdomen, in the case of timid surgeons, and the same cause may lead to most unpleasant medico-legal complications in the practice of bolder and more aggressive operators.

Clinical experience and statistics have demonstrated the importance of making a distinction between punctured and gunshot wounds in the abdomen, both in reference to diagnosis and treatment. It is well known that penetrating stab-wounds are less likely to be complicated by visceral injury than bullet wounds, consequently this class of injuries offers a more favorable prognosis and does not call so uniformly for treatment by abdominal section. That penetrating gunshot wounds of the abdomen do not always implicate the gastro-intestinal canal has been well demonstrated by experiment and clinical observation. During the last two years three cases of bullet wounds of the abdomen came under my observation where no doubt could be entertained that penetration had taken place, and yet all the patients recovered without operation. In all three cases the bullet had taken an antero-posterior direction. As in private practice the treatment of penetrating wounds of the abdomen usually involves great medico-legal responsibilities, it becomes of the greatest importance to arrive at positive conclusions in reference to the character of the injury, before the patient is subjected to the additional risks to life incident to an abdominal section.

We will suppose a case. In a quarrel a man is shot in the abdomen. The assailant is placed under arrest. The surgeon who is called establishes the fact that the bullet has entered the abdominal cavity, and from the point of entrance and its probable direction, he has reason to believe that it has wounded some part of the gastro-intestinal canal, and he concludes to verify his diagnosis by an exploratory laparotomy; the operation is performed, and the most careful examination made, but no visceral wound is found. The wound is closed and the patient dies on the third or fourth day of septic peritonitis. The attorney for the state charges the defendant with murder.

The defense will very naturally raise the questions: "Did the man die of the injury, or the operation?" "Shall the defendant be tried for assault and battery, or for murder?" During the trial the attending surgeon is made the target for a volley of a medley of scientific and unscientific questions by the cunning attorney for the defense in his attempt to save his client from the gallows or state prison for life, at the expense of the reputation of the surgeon and the respect and good name of the art and science of surgery. This picture is not overdrawn. Such cases have happened and will happen again. It is apparent that if some infallible diagnostic test could be applied in cases of penetrating wounds of the abdomen which would indicate to the surgeon the presence or absence of visceral lesions of the gastro-intestinal canal, the indication for aggressive treatment would become clear and the medico-legal responsibility of the operator would be reduced to a minimum.

As we can never expect by a study of symptoms or by the ordinary physical examination to fill this gap, I was induced to search for some reliable test which in such cases should prove that the penetrating bullet or instrument had injured the gastro-intestinal canal. It occurred to me that a wound in the stomach or intestine should be sought for in some such way as the plumber locates a leak in a gas-pipe. The first object to be accomplished was to prove the permeability of the entire gastro-intestinal canal to inflation of air, and the next step was to find some innocuous gas which, when inflated, would escape from the intestinal wound into the peritoneal cavity, and from there through the external wound, where its presence could be proved by some infallible test.

## I. Permeability of the Ileo-Cæcal Valve to Rectal Insufflation of Air or Gas.

A great deal has been said and written in reference to the permeability of the ileo-cæcal valve to injections of fluids into the rectum, or to the insufflation of air or gases. The majority of those who have studied this subject clinically or by experiment make the positive assertion that the ileo-cæcal valve is perfectly competent, and effectually guards the ileum against the entrance of both fluids and gases forced into the rectum, while others insist that it is permeable only in exceptional cases, and only a few claim that its resistance can be overcome by a moderate degree of pressure. Heschl[1] made a number of experiments and satisfied himself that the ileo-cæcal valve serves as a safe and perfect barrier against the entrance of fluids from below. In testing the resisting power of the coats of the intestine he found that the serous coat of the colon gave way first to overdistention, while the remaining tunics yielded subsequently to a somewhat slighter pressure. The small intestine of a child on being subjected to overdistention ruptured first on the mesenteric side, the place where acquired diverticula are found.

Bull[2] has found that in the adult one litre of water injected by the rectum will reach the cæcum, but that the entire capacity of the large intestine is from four to five litres. He is of the opinion that in the living body, fluid cannot be forced beyond the ileo-cæcal valve, although ancient and modern experimenters claim to have succeeded in the cadaver. He affirms that when the rectum is distended by air, the ileo-cæcal valve is rendered incompetent and the air passes into the small intestines.

Cantani[3] is a firm believer in the permeability of the ileo-cæcal valve to fluid rectal injections. In one instance he treated a case of coprostasis by an injection of a litre and a half of oil per rectum, and an hour later a part of the oil was ejected by vomiting. He advises that the intestinal tract above the ileo-cæcal valve should be utilized as an absorbing surface in cases requiring rectal alimenta-

[1] Zur Mechanik diastaltischen Darmperforationen. Wiener Med. Wochenschrift, No. 1, 1881.

[2] Virchow's Jahresbericht, B. 11, 1878, S. 205.

[3] Virchow's Jahresbericht, B. 11, 1879, S. 180.

tion, and that when in a diseased condition it should be treated by topical applications.

Behrens[1] concluded from his experiments that it required the insufflation per rectum of one and one-eighth litres of air to reach the ileum through the ileo-cæcal valve. In his experiments he had no difficulty in overcoming the competency of the ileo-cæcal valve by rectal insufflation of air.

Debierre[2] made numerous experiments on the cadaver to test the permeability of the ileo-cæcal valve to rectal injections of fluids or inflation of air. The results which he obtained were not constant. In some subjects the valve proved only permeable to air, in others, to both air and water, while in some no air or fluids could be forced into the ileum by any degree of force. When the intestine was left *in situ* the valve was found less permeable than when the intestine had been removed from the body. He attributed the different degrees of competency of the valve to variations in the anatomical construction of the valve. If both lips of the valve were equal in length, or if the lower lip was longer the valve was found impermeable. It proved permeable in cases where the lower lip was shorter, contracted, and smaller than the upper. In the last instance, the advancing volume of fluid or air lifted the upper valve, while in the former structure of the valve, the margins of the lips of the valve were pressed against each other, perfectly shutting off all communication between the colon and the ileum.

Mr. Lucas[3] enumerates the following objections against forcible rectal injections of water as a means of reducing invagination:

1. Owing to its weight it exerts much too strong lateral pressure for the intestine safely to bear, and he has found it easy to rupture the bowel after death by forcing in water.

2. Should reduction have been accomplished, the contact of a large quantity of water with the large bowel is apt to increase the tendency to diarrhœa. He claims very properly, that air, on the other hand, is a natural occupant of the intestinal canal, and whilst

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[1] Ueber den Werth der Künstlichen Auftreibung des Dickdarmes mit Gasen u. Flüssigkeiten. Göttingen. Dissertation. 1886.

[2] La valvule de Bauhin considérée comme barrière des apothicaires. Lyon Médicale, No. 45, 1885.

[3] On Inversion with Inflation in the Cure of Intussusception. The Lancet, January 16, 1886.

its pressure is of the gentlest its presence excites no unnatural peristaltic action. He administers an anæsthetic to the point of relaxation before the inflation is attempted.

Dawson[1] made a number of experiments on the cadaver and came to the conclusion that when the ileo-cæcal valve is in a normal condition it effectually guards the small intestine against the ingress of fluids from below. Illoway[2] has devised a force-pump which he strongly recommends for the purpose of forcing water beyond the ileo-cæcal valve, in case the seat of an intestinal obstruction is located above that point. He reports four cases of intestinal obstruction treated by this method, three of which recovered. Battey[3] asserts the permeability of the entire alimentary canal by enema, and verifies his statement by the recital of his own clinical experience and experiments upon the cadaver.

Ziemssen recommends inflation of the rectum for diagnostic and therapeutic purposes and proceeds as follows: A rectal tube about six inches long is carried into the anus and fixed by pressing together the nates, the patient lying on the back. A funnel is then connected with the rectal tube by means of rubber tubing. For complete inflation of the large intestine three drams of bicarbonate of soda and four and a half drams of tartaric acid are separately dissolved in water and portions of either solution alternately added. To prevent sudden overdistention of the bowel it is advised to add the solutions at intervals of several minutes. A very important use of this method is to diagnosticate the position of contractions, strictures, or occlusion of the intestine in cases in which it is desirable to operate, and also to show the position of peritoneal adhesions. The result of his observations has led him to believe that, as a rule, the small intestine is completely closed to the entrance of substances from the colon, by the ileo-cæcal valve. Under the influence of deep chloroform narcosis, however, this resistance is lessened, and fluids can be thrown into the small intestine.

Since this work has gone to press my attention has been called by Dr. Eastman, of Indianapolis, to a paper on "Fifty Laparotomies," etc., which he published in Progress, for January, 1888, in which

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[1] Lancet and Clinic, Feb. 21, 1885.

[2] American Journal Medical Sciences, Vol. 41, p. 168.

[3] Transactions of the American Medical Association, 1878.

he describes a case of pelvic abscess where he resorted to Bergeon's method of rectal insufflation of sulphuretted hydrogen gas after the abscess was opened, to determine whether it communicated with the large intestine. In the same paper appears a case of resection of the colon where the same test was used after suturing, to prove the efficiency of the sutures.

In my paper read at the last International Medical Congress[1] the following experiments appear, which illustrate the difficulty in overcoming the resistance of the ileo-cæcal valve by rectal injections of water:

*Experiment 23.* While completely under the influence of ether, an incision was made through the linea alba of a cat, sufficiently long to render the ileo-cæcal region readily accessible to light. An incision was made into the ileum just above the valve and by gently retracting the margins of the wound, the valve could be distinctly seen. Water was then injected into the rectum, and as the cæcum became well distended it could be readily seen that the valve became tense and appeared like a circular curtain, preventing effectually the escape even of a drop of fluid into the ileum. The competency of the valve was only overcome by overdistention of the cæcum, which mechanically separated its margins, allowing a fine stream of water to escape into the ileum. The insufficiency of the valve was clearly caused by great distention of the cæcum. That such a degree of distention is attended by no inconsiderable danger, was proved by this experiment, as the cat was immediately killed, and on examination of the colon and rectum, a number of longitudinal rents of the peritoneal coat was found.

*Experiment 24.* In this experiment a cat was fully narcotized with ether and while the body was inverted, water was injected per rectum in sufficient quantity and adequate force, by means of an elastic syringe, to ascertain the force required to overcome the resistance offered by the ileo-cæcal valve. Great distention of the cæcum could be clearly mapped out by percussion and palpation before any fluid passed into the ileum. As soon as the obstruction at the valve was overcome, the water rushed through the small intestines, and having traversed the entire alimentary canal, issued from the mouth. About a quart of water was forced through in this manner. The animal was killed and the gastro-intestinal canal carefully examined for injuries. Two longitudinal lacerations of the peritoneal surface of the rectum, over an inch in length, were found on opposite sides of the bowel.

*Experiment 25.* This experiment was conducted in the same manner as the foregoing, only that the cat was not etherized. More than a quart of water was forced through the entire alimentary canal from anus to mouth. The animal lived for eight days, but suffered during the whole time with

[1] An Experimental Contribution to Intestinal Surgery with Special Reference to the Treatment of Intestinal Obstruction.

symptoms of ileo-colitis. A post-mortem examination was not made, although the symptoms manifested during life leave no doubt that they resulted from injuries inflicted by the injection.

It will thus be seen that in the three cases where fluid was forced beyond the ileo-cæcal valve, in two of them the post-mortem revealed multiple lacerations of the peritoneal coat of the large intestines, while the third animal sickened immediately after the experiment was made, and died eight days later from the effects of the injuries inflicted. These experiments combined with clinical experience leave no further doubt that, practically, the ileo-cæcal valve is not permeable to fluids from below, and that for diagnostic and therapeutic uses it is unsafe and unjustifiable to attempt to force fluids beyond the ileo-cæcal valve. We should *a priori* expect that air and gases, on account of their less weight and greater elasticity than water, could be forced along the intestinal canal with less force, and for that reason alone, if for no other, should be preferred to water in cases where it appears desirable to distend the intestine above the ileo-cæcal valve. The results obtained by experimental research in the past speak in favor of rectal inflation by air or gas in all cases where for diagnostic or therapeutic purposes it becomes necessary to dilate the entire or a portion of the gastro-intestinal canal.

## 1. Rectal Insufflation of Air.

*Experiment 1.*[1] Dog, weight seventy-five pounds. The animal was profoundly anæsthetized, and by means of an ordinary elastic syringe, air was forced through the rectum until the whole abdomen became distended and tympanitic. The abdominal cavity was opened in the median line, and the whole intestinal canal was found distended. An incision about an inch in length was made about the middle of the small intestines, when air escaped, and about one foot of the intestine on either side of the wound collapsed. The remaining portion of the intestines remained unaffected by the incision. The animal was killed, and every part of the entire gastro-intestinal canal carefully examined for injuries. The ileo-cæcal valve remained intact, and no evidence of rupture of any of the coats of the intestines could be detected.

*Experiment 2.* Dog, weight twelve pounds. Under full anæsthesia the gastro-intestinal canal was inflated in the same manner as in the preceding experiment, and the inflation was carried to the same extent. On opening the

[1] These experiments were made at the County Hospital, and my thanks are due to Dr. M. E. Connel, superintendent of the hospital, and his assistants, and Dr. Wm. Mackie of Milwaukee, for valuable assistance.

abdomen in the median line the distended loops of the intestines protruded from the wound, and partial exventration was allowed to take place for the purpose of examining the intestine for injuries. The closest inspection failed to detect evidences of partial or complete rupture of any of the tunics. One of the distended coils of intestine was incised at opposite points on the lateral aspect, the incisions being an inch in length. Only a limited segment of the bowel on each side of the wounds collapsed, and although the peristalsis was active, more remote portions were emptied very slowly. The wounds were united transversely for the purpose of making an artificial diverticulum. The animal recovered without any untoward symptoms.

*Experiment 3.* Dog, weight thirteen pounds. Animal profoundly etherized, and air inflated as in former experiments. The distended colon could be clearly mapped out by percussion before a gurgling sound in the region of the ileo-cæcal valve indicated that the air had entered the ileum. After this had occurred the middle of the abdomen became prominent and tympanitic. As soon as the resistance offered by the ileo-cæcal valve had been overcome, it required less force to distend the remaining portion of the gastro-intestinal canal. The inflation was carried to the extent of distending the stomach, an event which was easily recognized by a considerable prominence in the epigastric region which was tympanitic on percussion. At this time an elastic tube was inserted into the stomach, and its free end immersed under water. Bubbles of air escaped freely, and the abdominal distention was materially diminished. As the inflation was continued the air would escape through the stomach-tube, showing that a moving current of air existed between the rectal tube and the stomach tube. The abdominal distention which remained after the experiment had completely disappeared after eighteen hours, and the animal never manifested pain or any other symptoms of disease.

*Experiment 4.* Dog, weight fifteen pounds. In this experiment inflation was practiced without anæsthesia. The rigidity of the abdominal muscles greatly interfered with the distention of the colon to a requisite degree to overcome the competency of the ileo-cæcal valve. The passage of air from the cæcum into the ileum through the ileo-cæcal valve was announced by an audible gurgling sound which was repeated at intervals, as the cæcum, after partial collapse, was again distended by renewing the inflation. The insufflation was continued until the stomach became distended by air, which caused vomiting and copious eructations of air. The dog remained in perfect health after the inflation.

These experiments prove the feasibility of forcing air through the entire alimentary canal from below upwards. In not a single experiment could any structural changes be found in the walls of the intestine, and all animals not killed immediately after the experiment recovered. The results of these experiments contrast strongly with those by rectal injections with water where the same objects were in

view. In the latter experiments the force requisite to overcome the ileo-cæcal valve invariably produced lacerations of the peritoneal coat of the bowel, which in themselves would constitute a grave source of danger.

It now became necessary for me to prove that the ileo-cæcal region in man in so far resembled that of the dog, that the ileo-cæcal valve could be rendered more readily incompetent by inflation of air than by injections of fluids. The following two experiments were made for this purpose:

*Experiment 5.* A young man, twenty-five years of age, a patient in the Milwaukee Hospital, under treatment for a tumor in the epigastric region, was subjected to the experiment. He was placed flat on the back. On percussion the whole umbilical region was found flat and the abdominal wall retracted. No anæsthesia. With an ordinary elastic syringe air was injected slowly into the rectum. As inflation progressed the outlines of the entire colon could be clearly seen and accurately mapped out by percussion. The cæcal region especially became very prominent. The inflation was continued very slowly, and as soon as the air passed through the ileo-cæcal valve, the hypogastric and umbilical regions began to rise and resonance replaced the former dullness on percussion. The arrival of air in the stomach was indicated by distention of the epigastric region, disappearance of the contour of the tumor and resonance on percussion. During the whole process of inflation the patient only complained of a slight pain in the splenic flexure of the colon, and a sensation of fullness in the abdomen. As soon as it became apparent that the stomach was distended by air, a stomach-tube was introduced and its free end placed under water. As the inflation was continued, bubbles of air continued to escape. On assuming the erect position the patient complained of colicky pains in the umbilical region, which were undoubtedly caused by an exaggerated peristalsis. The pain, however, soon disappeared, and on the following day he was as well as usual.

*Experiment 6.* Adult male, suffering from neurasthenia. Experiment and result the same as in No. 5, only that in this case the pain due to distention of the colon was referred to the ileo-cæcal region, and the colicky pain in the umbilical region persisted for a longer time. The air was again forced from anus to mouth without causing any injury whatever and only moderate degree of pain for a short time.

The foregoing experiments demonstrate conclusively that in the human subject by a moderate degree of force, short of producing any injury of the tunics of the intestines, air can be forced along the entire alimentary tract, and that this procedure can be resorted to with perfect safety for diagnostic and therapeutic purposes in all cases where the tissues of the intestinal wall have not suffered too much loss of resistance from antecedent pathological changes.

## 2. Inflation of Alimentary Canal through Stomach Tube.

We should naturally expect that the alimentary canal could be inflated with more ease and with a less degree of force by following the normal peristaltic wave. That this is not the case will be seen from the following experiments:

*Experiment 7.* Dog, weight forty pounds (18 kilograms). After complete anæsthesia was effected a flexible rubber tube was introduced into the stomach, and the free end of the tube connected with a four-gallon rubber balloon containing hydrogen gas, by means of a rubber tube. Between the gas reservoir and the stomach-tube a manometer was interposed, registering accurately the force used in making the inflation. The inflation was made by compressing the rubber bag. A tube was introduced into the rectum to facilitate the escape of gas that might reach this portion of the intestinal tract. Under a pressure of one pound and a half the stomach dilated rapidly, and later the entire abdomen became distended and resonant on percussion, but no gas escaped per rectum. When the pressure was increased to two pounds (.9 kilogram), no further distention of the abdomen took place, as the gas escaped along the side of the stomach tube. At this time respiration became greatly embarrassed, but was relieved on allowing gas to escape through the stomach-tube. On compressing the abdomen firmly the distention disappeared almost completely; at the same time a large quantity of gas continued to escape through the stomach-tube. Inflation was renewed, and under a pressure of one pound and a half, the abdomen again became uniformly distended. When the pressure was increased to two pounds (.9 kilogram) the dog suddenly died, and all efforts at resuscitation failed. On opening the abdomen the stomach was found enormously distended, reaching three inches below the umbilicus, occupying almost the entire abdominal cavity. The upper half of the small intestines was distended; numerous points of sharp flexions were found among the different distended coils. The distended stomach had evidently encroached so much upon the abdominal space as to render the greater part of the intestinal canal impermeable by pressure.

*Experiment 8.* Dog, weight fifteen pounds. After the animal was placed fully under the influence of ether, the abdomen was opened and the cæcum and lower portion of ileum drawn forward into the wound, and a large aspirator needle inserted into the ileum just above the ileo-cæcal valve. Through a rubber tube hydrogen gas was forced into the stomach. Under one pound (.45 kilogram) of pressure, the stomach and upper portion of the intestines dilated readily. When the force was increased, the gas returned through the œsophagus along the sides of the stomach-tube.

*Experiment 9.* Dog, medium size. This animal was killed to ascertain the results of an experiment made for another purpose. Rubber balloon containing hydrogen gas, and manometer were used for making the inflation. The tube through which the inflation was made was tied in the œsophagus. The abdomen was distended enormously, and on increasing the pressure to

three and three-fourths pounds (1.7 kilograms), still no gas escaped through the rectal tube. The abdomen was then opened, when the stomach was found so enormously distended that it filled almost the entire abdominal cavity. About one-fourth of the length of the small intestines was found distended, and among the distended loops numerous acute flexions could be seen. After the abdomen was opened, under long and continuous distention, the peritoneal covering of the stomach gave way, when the manometer registered only one pound and a half of pressure.

*Experiment 10.* Dog, weight eighteen pounds (8 kilograms). Immediately after death the œsophagus was isolated and the tube of the hydrogen gas inflator securely tied in, and a glass tube was inserted into the rectum. Under a pressure of two and three-fourths pounds (1.2 kilograms), registered by the manometer, the gas first dilated the stomach and then passed along the intestines until it escaped in a steady stream through the rectal tube, where it was ignited. On opening the abdomen the stomach was found greatly distended, while the distention of the intestines was a great deal less marked. None of the tunics of the stomach or intestines were injured.

*Experiment 11.* Dog, weight twenty pounds (9 kilograms). Animal etherized and a flexible tube connected with the gas inflator introduced into the stomach, and a glass tube into the rectum. On inflation the stomach became gradually distended, and when the pressure had reached one pound and a half (.7 kilogram), the dog vomited and a good deal of gas escaped at the same time. Inflation was again commenced and was followed by uniform distention and tympanites over the entire abdomen; when the pressure reached two pounds and a half (1.1 kilograms), the gas escaped from the rectum, and when ignited burned with a steady blue flame. The experiment was followed by no unfavorable symptoms.

*Experiment 12.* Dog, weight twelve pounds (5.4 kilograms). Under the influence of ether inflation with hydrogen gas in the same manner as in last experiment. As soon as the stomach became well distended, and the manometer registered one pound and a half of pressure, vomiting occurred, attended by a free escape of gas, which was followed by collapse of the distended epigastric region. When inflation was resumed, it was noted that any increase of pressure over one pound (.45 kilogram) was followed by regurgitation of gas, and on this account it was found impossible to inflate the lower portion of the intestinal tract. No unfavorable symptoms followed the experiment.

*Experiment 13.* Dog, weight twenty-eight pounds (12.7 kilograms). Under the influence of ether inflation of hydrogen gas through the stomach tube. As soon as the pressure was increased to more than one pound (.45 kilogram) the gas escaped along the sides of the tube through the œsophagus; consequently only the upper portion of the abdomen could be distended, and the inflation evidently did not extend much beyond the stomach. The experiment was repeated several times with the same result. The animal remained perfectly well after the experiment.

*Experiment 14.* Dog, weight twelve pounds (5.4 kilograms). Inflation of stomach by hydrogen gas under full anæsthesia. The effect of the infla-

tion was the same as in the last experiment; only the stomach and upper portion of the small intestines could be distended and further inflation was impossible, as the gas escaped from the stomach as soon as the pressure exceeded one pound (.45 kilogram). A large aspirator needle was pushed through the linea alba into the stomach, and the gas which escaped through it, on being lighted, burned with the characteristic blue flame. After the needle was withdrawn, the inflation was continued to ascertain if the puncture in the stomach would allow the escape of gas into the peritoneal cavity. The inflation was continued until the entire abdomen was distended by the gas. That the distention and tympanites was due to the presence of gas in the peritoneal cavity became evident, as it remained after the stomach had been emptied of its gas, and on percussion it was ascertained that the entire liver dullness had disappeared. The dog recovered without symptoms of peritonitis or any other ill-effects from the experiment.

These experiments demonstrate conclusively that it is more difficult to inflate the alimentary canal from above downwards than from below upwards, as in the living animal I succeeded only in one instance in forcing hydrogen gas from mouth to anus, while in others a degree of force sufficient to rupture the peritoneal coat of the stomach, only effected distention of the stomach and upper portion of intestinal canal. It is evident that great distention of the stomach constitutes an important factor in causing or aggravating intestinal obstruction, as it effects compression which causes impermeability of the intestines, or aggravates conditions arising from an antecedent partial permeability, by producing sharp flexions among the distended coils of the intestines. For diagnostic and surgical purposes the stomach can be readily inflated almost to any extent through a stomach tube, and when it becomes necessary to ascertain the presence of a visceral wound or perforation of this organ, this method of inflation may be resorted to with advantage.

## 3. Experiments to Determine the Degree of Force which is Necessary to Overcome the Resistance Offered by the Ileo-Cæcal Valve.

Accurate experiments to determine the force required to render the ileo-cæcal valve incompetent by insufflation of air or gas having not heretofore been made, as it is exceedingly important to obtain some accurate information on this subject, the following experiments were made. In all experiments air or hydrogen gas was used. The inflation was made with a rubber balloon. The pressure was esti-

mated either with a mercury gauge or with a manometer, as used by gas-fitters and plumbers. The manometer or mercury gauge was connected by means of rubber tubing with the rectal tube on one side and the rubber balloon on the other. The rubber balloon in which the hydrogen gas was collected held four gallons, and numerous experiments showed that when the gas was forced through the opening of a stopcock, the lumen of which was about the size of a knitting needle, a compression equal to two hundred pounds (91 kilograms) would never register more than three pounds (1.4 kilograms) of pressure. In the living subject the escape of air or gas from the rectum was prevented by an assistant pressing the margins of the anus firmly against the rectal tube.

*Experiment 15.* Dog, weight thirty-five pounds (16 kilograms). Immediately after death the lower portion of the rectum was isolated and the rectal tube inserted and fixed in its place by tying a string firmly around the rectum. The abdomen was opened and the intestines left *in situ*. The ileum was cut transversely six inches above the ileo-cæcal valve and a glass tube inserted into the distal end, which was also tied in. Hydrogen gas was inflated from a rubber balloon. Under a pressure of three-quarters of a pound (.3 kilogram) the cæcum was dilated, and a moment later the gas escaped from the glass tube and was ignited; the flame remained steady under a pressure of from one-half to three-quarters of a pound (.2 to .3 kilogram).

*Experiment 16.* Dog, weight twenty pounds (9 kilograms). Same as in the preceding experiment, only that the resistance of the ileo-cæcal valve was overcome under a pressure of one-half pound (.2 kilogram). The distention of colon and cæcum was moderate, and signs of injury to the tunics could not be found in either experiment.

*Experiment 17.* Dog, weight twenty-three pounds (10 kilograms). In this experiment the abdomen was opened immediately after death, and a large hypodermic needle inserted into the ileum a short distance above the ileo-cæcal valve before the inflation of hydrogen gas was made. A pressure of three-quarters of a pound (.3 kilogram) was sufficient to force the gas through the ileo-cæcal valve and through the needle; the valve remained open under a steady pressure of one-half pound (.2 kilogram).

Having determined that air and gas could be forced beyond the ileo-cæcal valve in dogs under very low pressure, varying from one-half to three-quarters of a pound, I proceeded to test the degree of resistance of the ileo-cæcal valve in the human subject.

*Experiment 18.* Strong, healthy young man. The subject was placed flat upon his back and hydrogen gas was inflated from a rubber balloon. At first the gas was forced in very slowly under a pressure of one pound and a half

(.7 kilogram), which distended the colon visibly as far as the cæcum. As the distention appeared to remain the same, the pressure was increased to two pounds (.9 kilogram), when suddenly the indicator of the manometer receded to one pound (.45 kilogram), and the umbilical region became prominent and resonant, showing conclusively that the ileo-cæcal valve had been passed and the small intestines were filling rapidly with gas. As soon as the whole abdomen had become distended and tympanitic, the manometer again registered one pound and a half (.7 kilogram) of pressure, and remained at this figure for some time after further inflation was discontinued by turning the stopcock.

*Experiment 19.* Young man, in good health. Experiment conducted in the same manner as before. After the colon and cæcum had been well dilated the manometer registered two and one-quarter pounds (1 kilogram), and the umbilical region became prominent and resonant. As the inflation advanced the average pressure was one pound and three-quarters (.8 kilogram), and twice it was increased to two and a half pounds (1.1 kilograms), when the patient complained of pain in the umbilical region. As soon as the stopcock was turned the pressure sank to three-quarters of a pound (.3 kilogram).

These two experiments prove that in a normal condition the ileo-cæcal valve in a healthy adult person is overcome by rectal inflation under a pressure of one and a half to two and a quarter pounds (.7 to 1.1 kilograms). This amount of pressure is not sufficient to injure the tunics of a healthy intestine, and in both instances the subjects of the experiments complained but little of the immediate or remote effects of the experiments. As the result of numerous observations, I can state that when the inflation is made slowly and continuously there is less danger of injuring the intestines than when the inflation is made rapidly, or with interruptions. Slow and gradual distention of the cæcum is best adapted to overcome the competency of the ileo-cæcal valve, by effecting diastasis of the margins of the valve. A rubber balloon holding from two to four gallons (10 to 20 litres) recommends itself as the most efficient and safest instrument for making rectal insufflation for therapeutic or diagnostic purposes.

The following experiments were made to determine:

## 4. The Amount of Pressure Necessary to Force Hydrogen Gas Through the Entire Alimentary Canal by Rectal Inflation.

*Experiment 20.* Dog, weight thirty-five pounds (16 kilograms). Immediately after death rectal inflation of hydrogen gas was made, and a pressure of one pound (.45 kilogram) sufficed to distend the entire abdominal cavity, and

when a tube was introduced into the stomach and a burning taper applied to its end, a blue flame at once appeared and continued as long as the inflation was kept up under the same pressure.

*Experiment 21.* Dog, weight twelve pounds (5.4 kilograms). Under ether narcosis rectal inflation of hydrogen gas from rubber balloon. The ileo-cæcal valve offered very little resistance, and as soon as the manometer registered one pound and a half (.7 kilogram) of pressure the gas escaped through the stomach tube which had been introduced previously, and on applying a lighted taper it burned with a continuous flame as long as the inflation was continued.

*Experiment 22.* Dog, weight twenty pounds (9 kilograms). Experiment and result same as in last; the pressure never exceeded one pound and a half (.7 kilogram).

*Experiment 23.* Dog, weight nineteen pounds (8.6 kilograms). In this experiment no anæsthetic was used, and in consequence the pressure had to be increased to three pounds (1.4 kilograms) before the gas escaped through the stomach tube. On account of the violent contractions of the abdominal muscles the escape of gas was intermittent, the flame being frequently extinguished by an absence of the gas.

*Experiment 24.* Dog, weight twenty-one pounds (9.5 kilograms). The animal being completely under the influence of ether the abdomen was opened in the median line, and the ileo-cæcal region made accessible to sight. Hydrogen gas was inflated per rectum, and under a pressure of three-quarters of a pound (.3 kilogram) readily passed the ileo-cæcal valve, and under one pound of pressure it ascended the intestinal canal, and in a few seconds reached the stomach. A tube was introduced into the stomach, and as the gas escaped it was ignited and burned with a steady flame.

*Experiment 25.* Dog, weight eighteen pounds (8 kilograms). Rectal insufflation of hydrogen gas, the dog being fully under the influence of an anæsthetic. The colon and cæcum were only slightly distended when the gas, under one-quarter of a pound (.1 kilogram) of pressure, passed the ileo-cæcal valve. Under one pound (.45 kilogram) of pressure, the abdomen became uniformly distended and tympanitic, and when a tube was introduced into the stomach the escaping gas was ignited and burned with a steady flame as long as the pressure was continued.

*Experiment 26.* Dog, weight twenty pounds (9 kilograms). Animal etherized, and when completely relaxed hydrogen gas was inflated per rectum, and passed the ileo-cæcal valve under a pressure of half a pound (.2 kilogram). The stomach became distended under a pressure of one pound and a half (.7 kilogram), and on the introduction of a tube the escaping gas was ignited and burned with a continuous flame as long as the manometer registered half a pound (.2 kilogram) of pressure.

In all animals where the insufflation was not complicated by abdominal section, no unpleasant symptoms followed the experiments. All of the animals recovered as rapidly as after an ordinary ether narcosis. In all of the experiments the pressure fell rapidly after the

ileo-cæcal valve had been opened, but the pressure had again to be increased before the gas reached the stomach. It usually required one-half to one pound more pressure to force gas through the entire alimentary canal than when it was forced only through the ileo-cæcal valve. Whenever it becomes desirable to conduct the hydrogen gas a considerable distance along the intestines, or through the entire alimentary canal, it is exceedingly important to proceed slowly with the inflation, as under slow distention half a pound (.2 kilogram) of pressure will accomplish in time a greater degree of distention than four times this amount of pressure if the force is applied quickly, and only for a short time, and is attended by much less risk of injury to the coats of the intestines. I am quite convinced that in the dog, rectal insufflation of hydrogen gas made under a pressure of one-quarter of a pound, if made very slowly, the abdominal walls being completely relaxed by an anæsthetic, will not only overcome the resistance offered by the ileo-cæcal valve, but will prove sufficient to force the gas through the whole length of the alimentary canal.

I have already sufficiently demonstrated the permeability of the ileo-cæcal valve and the entire alimentary canal in animals and man to rectal insufflation of air and gas, and I shall now endeavor to establish the safety of this procedure as a diagnostic and therapeutic measure by showing:

## II. The Resistance of Different Portions of the Gastro-Intestinal Canal to Diastaltic Force.

### 1. Stomach.

*Experiment 27.* Large, healthy, adult dog. Experiment made immediately after death. Stomach *in situ*. Œsophagus tied and distention made with a force pump from pyloric orifice, the organ being rapidly dilated with air. When the manometer registered eight and one-half pounds (3.9 kilograms) of pressure, the stomach was distended at least eight times its normal size, when a rent in the peritoneal covering an inch and a half in length parallel to, and near the omental attachment, occurred.

*Experiment 28.* Middle-aged man, died of sepsis. The whole gastro-intestinal canal showed marked evidences of septic gastro-entero-colitis, the mucous membrane being softened, very vascular, and dotted with numerous hæmorrhagic infarcts. Organ *in situ* inflated with air in the same manner as in last experiment. Longitudinal rupture of peritoneal coat along anterior surface under two and one-half pounds of pressure (1.1 kilograms), and when it was increased to three pounds (1.4 kilograms), the whole thickness of the wall at the lesser curvature ruptured.

## 2. Small Intestines.

*Experiment 29.* Subject same as in experiment 28. Lower portion of ileum under five pounds (2.3 kilograms) of pressure, became emphysematous along mesenteric attachment, and ruptured completely as soon as the manometer registered five and three-fourths pounds (2.6 kilograms) of pressure.

*Experiment 30.* Dog, weight twenty pounds (9 kilograms). Immediately after death the lower part of the ileum, with mesenteric attachment intact, was gradually distended and remained intact until a pressure of ten pounds (4.5 kilograms) was reached, when air escaped between the two serous layers of the mesentery, showing that minute ruptures at numerous points had taken place. When the distention had reached its maximum, the segment of bowel inflated was elongated twice its normal length.

*Experiment 31.* Upper portion of ileum of same animal when distended to its utmost gave way under a pressure of eight pounds (3.6 kilograms), the peritoneal coat on convex side rupturing to the extent of two inches (51 mm.) parallel to the axis of the bowel.

*Experiment 32.* The middle portion of the small intestines, when subjected to a pressure of eight pounds (3.6 kilograms), sustained a longitudinal rupture of the peritoneum on convex surface, and the remaining tunics gave way when the pressure was increased to nine pounds (4.1 kilograms).

## 3. Colon.

*Experiment 33.* Subject same as experiments 28 and 29. Experiment was made twenty-four hours after death. Colon and cæcum apparently very much softened and mucous membrane in a state of inflammation. One foot (30 cm.) of the transverse colon isolated and gradually distended, when the peritoneal coat along the border of one of the longitudinal bands ruptured under a pressure of two pounds and a half (1.1 kilograms). The peritoneal laceration became very extensive before the remaining tunics ruptured under a pressure of four pounds (1.8 kilograms).

*Experiment 34.* Dog, weight eighteen pounds (8.2 kilograms). Immediately after death the ileum was tied just above the cæcum, and the inflation made per rectum. Air was pumped in gradually with a force-pump and when the pressure reached ten pounds and a half (4.8 kilograms), air escaped between the peritoneal layers of the meso-colon; at this stage the longitudinal distention of the bowel exceeded twice its normal length.

*Experiment 35.* Dog, weight twenty-three pounds (10.4 kilograms). Experiment the same as the preceding. Air was pumped in rapidly until the mercury gauge registered ten and a half pounds (4.8 kilograms) of pressure, when the sigmoid flexure on its free surface gave way with a loud report, the rent being about one inch and a half (38 mm.) in length.

*Experiment 36.* Dog, weight eighteen pounds (8.2 kilograms). Entire colon distended by rectal inflation of air, the ileum being tied just above the ileo-cæcal valve. Under a pressure of six pounds (2.7 kilograms), the peritoneum ruptured in a longitudinal direction, opposite the meso-colon, and the remaining tunics gave way a little later, under the same pressure.

These experiments are of the greatest importance in showing that the pressure which was found necessary to apply in rupturing a healthy intestine, was greatly in excess of that which is required to force air through the ileo-cæcal valve, or even the whole length of the alimentary canal. It only requires from one-quarter of a pound to a pound and a half (.1 to .7 kilogram) of pressure to force air through the ileo-cæcal valve, and from half a pound to two pounds and a half (.2 to 1.1 kilograms) to force it from anus to mouth, while even the weakest portion of the gastro-intestinal canal effectually resisted a distending force of from eight to ten pounds (3.6 to 4.5 kilograms).

The experiments on the human cadaver, where the resisting power of the gastro-intestinal canal to diastaltic force was greatly reduced by ante-mortem pathological changes, show that under such circumstances it would have been safe to resort to inflation, as the pressure required to rupture the colon or small intestines exceeded that which has been found adequate to force air or gas beyond the ileo-cæcal valve, or even the entire length of the alimentary canal. When an intestine is slowly distended to its utmost capacity by inflation of air or gas, and the pressure is maintained uninterruptedly, rupture occurs at one of two points; either a longitudinal laceration of the peritoneal coat takes place on the convex surface of the bowel opposite the mesenteric attachment, or minute ruptures on the mesenteric side give rise to extravasation of air or gas between the two serous layers of the mesentery. In either case, if the pressure is increased, complete rupture takes place at the point where the laceration first commenced.

## III. Distention of Gastro-Intestinal Canal by Rectal Insufflation of Hydrogen Gas.

In this section will be found an account of the experiments which were made preliminary to the practical application of the hydrogen gas test as a diagnostic measure in penetrating wounds of the abdomen, and which furnish only so many more demonstrations of the permeability of the ileo-cæcal valve and the entire alimentary canal to rectal inflation of hydrogen gas.

*Experiment 37.* Dog, weight fifteen pounds (6.8 kilograms). Under ether anæsthesia, hydrogen gas from rubber balloon was slowly forced into the rectum until the entire anterior abdominal wall had become uniformly dis-

tended and tympanitic, when the distended stomach was punctured with a large aspirator needle and gas escaped in a steady stream, which when ignited burned with a continuous flame. After a considerable portion of the gas had been evacuated in this manner the upper abdominal region receded, and the flame was extinguished. The animal recovered without any untoward symptoms.

*Experiment 38.* Dog, weight seventeen pounds (7.7 kilograms). Without anæsthesia hydrogen gas was inflated per rectum until it escaped through a tube which had been introduced into the stomach. As it escaped from the stomach tube it was ignited and burned with a large blue flame. The abdominal muscles were so rigid that distention was never well marked, and the inflation required a good deal more force than in animals where muscular rigidity had been overcome by an anæsthetic. The dog remained perfectly well after the experiment, and in a few hours the remaining tympanites had disappeared.

*Experiment 39.* Dog, weight thirty-five pounds (15.8 kilograms). No anæsthetic used. On account of rigidity of abdominal muscles it required persistent efforts to force hydrogen gas from rubber balloon per rectum through the whole alimentary canal. As soon as the stomach had become distended by the gas, the animal vomited; at the same time gas escaped by repeated eructations. The animal manifested no signs of suffering after the experiment.

*Experiment 40.* Dog, weight twenty-seven pounds (12.2 kilograms). Under anæsthesia hydrogen gas was inflated per rectum until it escaped through tube which had been introduced into the stomach; a lighted taper was applied to the free end of the tube, and the gas ignited and burned with the characteristic blue flame.

*Experiment 41.* Large Newfoundland dog. Under anæsthesia a duodenostomy was made, and hydrogen gas injected per rectum and ignited as it escaped from a rubber tube, which had been inserted into the distal portion of the bowel through the fistula.

*Experiment 42.* Adult male; abdominal organs healthy; no anæsthesia. Inflation of hydrogen gas per rectum. The gas was stored in a four-gallon (9 litres) rubber balloon and was forced into the rectum by compression. As the distention progressed the colon could be distinctly mapped out from sigmoid flexure to cæcum by inspection and percussion. As soon as the cæcum had become visibly prominent, a stethoscope was applied over the ileo-cæcal region, and as the valve became incompetent by overdistention of cæcum, a distinct gurgling sound could be heard as the gas entered the ileum. Whenever inflation was arrested the gurgling sound disappeared, but was heard again whenever the ileo-cæcal valve was opened by renewed inflation.

Distention of the small intestines was attended by resonance and prominence of umbilical and hypogastric regions. The incompetency of the ileo-cæcal valve was invariably announced by a reduction in the pressure. The patient complained of a sensation

of distention in the umbilical region and intermittent colicky pains which, however, disappeared completely after a few hours. The pain appeared to be less severe than after similar experiments with inflation of air.

*Experiment 43.* Young man in comparatively good health. Inflation same as in preceding experiment. Auscultation over ileo-cæcal valve revealed the same sounds as the gas escaped from the colon into the ileum. The sound seemed to vary somewhat according to the size of the opening in the valve and the force used in making the inflation, and always disappeared as the valve closed after suspension of inflation. The colicky pains subsided as the small intestines emptied themselves of their new contents. The assistant who compressed the rubber balloon was always able to announce the beginning of the incompetency of the ileo-cæcal valve, by experiencing a sudden diminution in the pressure.

*Experiment 44.* Adult male, suffering from gastric catarrh. Hydrogen gas inflation per rectum to extent of causing great distention of abdomen, which caused the hepatic dullness to ascend at least two inches. Auscultatory signs the same. Sharp colicky pains in the umbilical region were relieved by a free escape of gas through rectum.

*Experiment 45.* Hysterical female. Abdomen flat and dull on percussion from umbilicus to pubes; no resonance over sigmoid flexure. Rectal inflation with hydrogen gas. Compression of rubber balloon corresponding to only one-fourth pound (.1 kilogram) of pressure readily dilated the whole colon, its course being indicated by a distinct prominence and tympanitic resonance from sigmoid flexure to cæcum. Under the same pressure the gas escaped with little or no resistance through the ileo-cæcal valve from the colon into the ileum, the occurrence being attended by the characteristic auscultatory sounds and followed by distention and resonance of space from umbilicus to pubes. Amount of gas inflated about four litres. The patient complained of some pain in the region of the splenic flexure of the colon during the distention of the colon, and later of slight intermittent pain in the region of the umbilicus.

*Experiment 46.* Middle-aged woman, suffering from retroversion of the uterus. Abdomen flaccid and dull on percussion in the median line from umbilicus to pubes. Rectum distended with hardened fæces. Hydrogen gas inflated in the usual manner. The mercury gauge registered two and a half pounds (1.1 kilograms) of pressure before the gas reached the sigmoid flexure, after this it fell to one pound (.45 kilogram), and the inflation progressed without any further resistance. As soon as the gas passed through the ileo-cæcal valve the pressure fell to three-quarters of a pound (.3 kilogram), and remained so during the inflation of the small intestines, slight variations marking the opening and closing of the ileo-cæcal valve. As the umbilical and hypogastric regions became prominent and tympanitic the patient complained of a griping pain. About eight litres of gas were injected. A few hours after the experiment all symptoms had disappeared.

*Experiment 47.* Female recently operated on for laceration of perineum. Rectum empty. Abdomen flaccid; umbilical, hypogastric, and right iliac regions dull on percussion. The inflation was made very slowly and the pressure never exceeded one pound (.45 kilogram). As the large intestine became distended the transverse colon came plainly into view. On auscultation over the ileo-cæcal valve the escape of gas into the ileum was marked by a blowing sound, which was increased or diminished in pitch by the degree of pressure. As the lower portion of the small intestines became distended the lower part of the abdomen became prominent and tympanitic, and the patient complained of colicky pains. About three litres of gas were inflated. In half an hour the patient appeared as well as before inflation.

*Experiment 48.* Middle-aged physician suffering from typhlitis. This was the second attack, and the acute symptoms had subsided. Over the cæcum a circumscribed area of dullness and tenderness. On palpation it appeared as though the swelling were adherent to the anterior abdominal wall. The area of dullness was outlined externally by pencil marks, before inflation was commenced. As the colon became distended under a pressure of one-fourth of a pound (.1 kilogram), the circumscribed, indurated region became more prominent, imparting to the palpating fingers the feeling of hardness, but on percussion it was resonant, showing conclusively that the inflamed and indurated wall of the cæcum had been lifted forward by the pressure of the gas. Under the same pressure the gas escaped in a continuous stream into the ileum, its passage through the ileo-cæcal valve being attended by a well-marked blowing, gurgling sound. The patient felt the entrance of gas into the ileum distinctly, and complained soon after of a slight colicky pain in the umbilical region. The space between umbilicus and pubes, which before inflation was completely dull on percussion, now became more prominent and tympanitic. Only two litres of gas were used in this experiment.

*Experiment 49.* Young physician in perfect health. Region between umbilicus and pubes perfectly dull on percussion, also left iliac fossa. Inflation of four litres of hydrogen gas under one-third of a pound (.15 kilogram) pressure. The outlines of the distended colon could be clearly seen and marked out by percussion before the gas escaped into the small intestines. The passage of gas through the ileo-cæcal valve was again attended by a well-marked gurgling sound, after which the entire abdomen became prominent and tympanitic. The patient felt a sensation of distention during the inflation of the colon, and as the small intestines became distended, complained of griping pains. Gas escaped freely by eructations and per rectum, which soon relieved the colicky pains in the umbilical region.

*Experiment 50.* Medical student in robust health. Region from umbilicus to pubes flat on percussion, while the course of the entire colon was tympanitic. Rectal inflation with hydrogen gas. When the resistance of the ileo-cæcal valve was overcome the mercury gauge registered one-half pound (.2 kilogram) of pressure. The passage of gas through the ileo-cæcal valve was attended by a gurgling sound which was heard at some distance by a number of persons present in the room. Later a continuous blowing (almost amphoric)

sound could be heard over the ileo-cæcal valve. The subject of the experiment was conscious of the passage of gas from colon into ileum, and soon after complained of a colicky pain which he referred to the umbilical region. The whole abdomen became uniformly distended and tympanitic on percussion, and the distress caused by the great distention was only relieved by a free escape of gas by eructations and through the rectum. Four litres of gas were used in this experiment.

*Experiment 51.* Young physician in good health. Rectal inflation of four litres of hydrogen gas under a pressure of only one-third pound (.15 kilogram). Distention of colon well-marked previous to escape of gas through the ileo-cæcal valve. As soon as the gas entered the ileum the middle and lower portion of the abdomen became distended and tympanitic. The inflation was continued until the stomach became distended and gas escaped by eructation. The subject of the experiment complained of quite severe colicky pains as long as the small intestines remained distended by gas.

*Experiment 52.* The writer of this paper, being desirous of experiencing himself the sensations which would be caused by inflation of hydrogen gas, submitted himself to experimentation under a pressure of one-half pound (.2 kilogram). Nearly six litres of gas were inflated per rectum. The distention of the colon caused simply a feeling of distention along its course, but as soon as the gas escaped into the ileum colicky pains were experienced, which increased as insufflation advanced, and only ceased after all the gas had escaped, an hour and a half later. When the intestines and the stomach had become fully distended, the feeling of distention was distressing, and was attended by a sensation of faintness which caused a profuse clammy perspiration. A great deal of the gas escaped by eructation, which was followed by great relief. The colicky pain attending inflation of the small intestines by air or gas, was evidently caused by increased peristaltic action of the bowels in their attempt to expel their contents, as it always assumed an intermittent type and subsided promptly after the escape of the gas.

In none of these experiments did the pressure in overcoming the resistance offered by the ileo-cæcal valve exceed one pound (.45 kilogram), and often a steady, long-continued pressure of one-fourth or one-third of a pound (.1 to .15 kilogram) sufficed. Every time the ileo-cæcal valve was rendered incompetent by distention of the cæcum, the pressure was promptly diminished owing to the escape of gas from the colon into the ileum. In the experiment where the inflation was made in a case of typhlitis, the ileo-cæcal valve offered no resistance, and the gas escaped freely into the ileum. The valve in all probability had been rendered partially or completely incompetent during the course of local inflammation, or the indurated, thickened walls of the cæcum, when distended during the inflation, were better adapted to effect incompetency of the valve. These

experiments also furnish strong proof of the fact that inflation, to be safe and effective, should be done very slowly under a low, steady pressure, continued only for a short time; and is attended by no risks whatever of rupturing a healthy intestine and, when cautiously practiced, can be resorted to even in cases where the resisting power of the intestinal wall has been diminished by antecedent pathological processes.

As I was searching for an innocuous, non-irritating gas which, when inflated into the gastro-intestinal canal, would escape into the peritoneal cavity in case a wound or perforation existed, and had decided on trying hydrogen gas, it became necessary to study experimentally the effect of this gas on the different tissues of the living body. The numerous inflation experiments on man and dogs have demonstrated the safety of pure hydrogen gas when employed in this manner, as not in a single instance were any immediate or remote toxic symptoms observed which could be referred to absorption of the gas; hence we have the assurance that the inflation of a large quantity of hydrogen gas is unattended by any risk whatever as far as intoxication is concerned. The following experiments also show the innocuity and non-irritating qualities of hydrogen gas when brought in contact with the tissues most susceptible to inflammatory reaction in the living body; at the same time they show that hydrogen gas is removed by absorption in a comparatively short time, when injected into serous cavities or into the subcutaneous connective tissue:

## IV. Hydrogen Gas is Innocuous and Non-Irritating when Brought in Contact with Living Tissues and is Promptly Removed by Absorption.

### 1. Peritoneal Cavity.

*Experiment 53.* Dog, weight forty-five pounds. A circumscribed spot to the right of the linea alba was shaved and thoroughly disinfected, and through this space a well disinfected, medium sized trocar was plunged into the peritoneal cavity. To the cannula of the trocar the rubber tube of the inflation balloon charged with hydrogen gas was attached, and the whole peritoneal cavity filled with gas by compressing the balloon. About four litres of gas were injected. No gas escaped upon the withdrawal of the cannula and the puncture was sealed with cotton and iodoform collodium. The animal appeared to suffer but little pain, and the next day the tympanites had disappeared and the dog was as frisky and lively as before the inflation. Two

days after the experiment was made the dog was killed and the peritoneal cavity carefully examined. Not a trace of the gas remained and the peritoneum throughout presented a normal appearance.

### 2. Pleural Cavity.

*Experiment 54.* Dog, weight twenty-five pounds. After thorough disinfection, an aseptic hollow needle was inserted between the seventh and eighth ribs in the axillary line into the left pleural cavity; and hydrogen gas from rubber balloon forced through it until the pleural cavity was thoroughly distended. On making a physical examination of the chest at this time the apex of the heart was found to the right of the sternum; vesicular breathing on left side absent; abnormal resonance on percussion of this side. The respirations became superficial and greatly increased in frequency. On withdrawing the needle no gas escaped externally, but a circumscribed subcutaneous emphysema which appeared, showed that some of the gas had escaped through the puncture in the pleura into the subcutaneous connective tissue. Twenty-four hours after the inflation the dog appeared to be in perfect health. The normal relations in the chest had become restored and the subcutaneous emphysema was less extensive. The animal was kept under observation for a considerable length of time, but at no time could symptoms of pleuritis be detected.

### 3. Subcutaneous Cellular Tissue.

*Experiment 55.* Old dog, weight forty-three pounds. A small, perfectly aseptic trocar was inserted through the skin into the loose cellular tissue in the right inguinal region, and through the cannula two litres of gas were injected, the gas distributing itself through the loose connective tissue over a large surface of the body. Upon the withdrawal of the cannula the puncture was hermetically sealed with iodoform collodium and cotton. The subcutaneous emphysema disappeared completely in forty-eight hours, and no traces of inflammation could be found at the point of puncture, or at any place where the gas had come in contact with the tissues.

*Experiment 56.* Dog, weight twenty-five pounds. Subcutaneous inflation of two litres of hydrogen gas through the cannula of a small trocar into the left side of the chest. The subcutaneous emphysema reached from the clavicle and axilla on that side to the crest of the ilium, the gas at some points elevating the skin at least four inches from the subjacent tissues. The gas was absorbed somewhat more slowly than in the preceding experiment, but three days after the inflation no trace of emphysema could be detected, and the subcutaneous connective tissue was as pliable and movable as before the inflation.

## V. Rectal Insufflation of Hydrogen Gas in the Diagnosis of Penetrating Gunshot Wounds of the Abdomen.

In these experiments the animals were strapped on one of Pasteur's operating tables. Abdomen shaved, and after complete

etherization the shooting was done at short range with a thirty-two calibre revolver. Inflation of hydrogen gas was practiced immediately after the shot was fired, and after its diagnostic value was carefully studied, the abdomen was opened and its contents examined for visceral injuries. In all cases where the colon was perforated, inflation could be done under very slight pressure, as the gas readily escaped into the peritoneal cavity, and from there through the bullet wound in the abdominal wall, where it was ignited as it escaped. As it is not my object at present to give the result of the operative treatment, the experiments will only be described in reference to diagnosis as verified by abdominal section; but in every case an attempt was made to save the life of the animal by operative treatment, and in a few instances the efforts were rewarded by success.

*Experiment 57.* Dog, weight thirty pounds. The abdomen was opened by an incision through the linea alba and a coil of the small intestine was drawn forward into the wound, and an incision half an inch (13 mm.) in length was made on the convex side and the intestine returned. A small glass tube was inserted into lower angle of wound, and the rest of the wound closed by sutures. About two litres of hydrogen gas were inflated per rectum, when the gas escaped through the glass tube, and when ignited burned with a continuous steady blue flame as long as the inflation was continued. The wound was opened and a small quantity of gas was found in the peritoneal cavity. The whole intestinal tract below the visceral wound was found moderately distended by gas, while above the wound the intestine was normal in size.

*Experiment 58.* Dog, weight fifteen pounds. When the dog was completely under the influence of ether, hydrogen gas was forced from anus to mouth, and while the abdomen was still moderately distended the animal was shot in the abdomen, the bullet being directed transversely from the point of entrance on the side of the abdomen two inches (5 cm.) to the right of the median line, and on a level with the umbilicus. On appliying a lighted taper to wound of entrance, and compressing the abdomen, hydrogen gas escaped and was ignited. When the inflation was resumed the gas burned with a continuous flame at the wound of entrance. The abdomen was then opened and two perforations in the stomach were found, one on the anterior surface near the pylorus, and the other on posterior surface at the cardiac extremity, about an inch above the omental attachment. The distention of the stomach by hydrogen gas had brought this organ within range of the track of the bullet.

*Experiment 59.* Dog, weight twenty pounds. Under complete anæsthesia the animal was shot in the abdomen, the bullet taking the same direction as in the previous experiment, only that the track was about an inch (2.5 cm.) above the umbilicus. Immediately after the shooting hydrogen gas was

inflated per rectum, and its presence in the abdominal cavity became evident by a marked tympanites, absence of liver dullness, and later by a localized emphysema around the wound of entrance. As the pressure was continued bubbles of gas escaped, and on applying a lighted taper, ignited with a feeble explosive report. The abdomen was opened, and the stomach showed two perforations, one just above the omental attachment near the pylorus, and the other on the same level at the cardiac extremity. Little hæmorrhage, and no extravasation of contents of stomach.

*Experiment 60.* Dog, weight thirty pounds. Animal anæsthetized and shot in abdomen at a range of two feet; wound of entrance two inches to the right of, and on a level with the umbilicus. Wound of exit one inch above the middle of left crest of ilium. Inflation of hydrogen gas per rectum soon caused extensive tympanites, and as but little force had been used, the conclusion was drawn that some part of the descending colon had been injured. As the gas did not readily escape through the bullet wounds, a small cannula was inserted into the abdominal cavity through the wound of entrance, when the gas escaped freely and was ignited. On opening the abdomen examination revealed the following visceral injuries: Two perforations in the descending colon; four in the ileum, within a distance of ten inches of the ileo-cæcal valve; eight in the upper part of the ileum, within the space of one foot (30.5 cm.) of the intestine. The mesentery was perforated at three points, and a number of mesenteric vessels of considerable size were severed, which gave rise to profuse hæmorrhage.

*Experiment 61.* Large coach dog. The animal was completely etherized, and shot in the abdomen at close range. Wound of entrance midway between linea alba and vertebral column on left side, a little below the level of the umbilicus; wound of exit close to the last lumbar vertebra over crest of ilium on opposite side. Rectal inflation of hydrogen gas under slight pressure at once produced diffuse tympanites, and the gas escaped freely through wound of entrance, where it was ignited and burned with a large steady blue flame as long as the inflation was continued. On opening the abdomen gas escaped, but inspection showed that the small intestines contained no gas, a condition which pointed to the colon as the seat of perforation. One perforation was found in the anterior wall of the sigmoid flexure, and two perforations in the cæcum. In the small intestines two perforations were found in the ileum near the cæcum, and three in the upper portion of the jejunum. Among the other organs injured were the spleen, and the receptaculum chyli; a number of perforations were found in the mesentery.

*Experiment 62.* Large dog. Profound ether narcosis. Shot in the abdomen, the bullet entering on a level with the umbilicus and about one inch to the left of the median line. Point of exit two inches from spinal column, and a little above the lower border of the chest. On inflating the rectum with hydrogen gas, hardly any force was required to distend the abdomen, and for this reason it was believed that the colon in some part of its course had been injured. Gas escaped readily through the wound of entrance, where it was lighted and burned with the characteristic blue flame. The abdomen when

opened was found almost completely filled with blood. The source of this profuse hæmorrhage was the right kidney which showed a perforation through the centre. An examination of the gastro-intestinal canal revealed two perforations of the cæcum, and five, of the small intestines. After passing through the kidney the bullet perforated the diaphragm, traversed the pleural cavity, and escaped through the chest wall two inches (5 cm.) to the right of the spine.

*Experiment 63.* Old dog, weight thirty-five pounds. Thoroughly etherized and shot in the abdomen, the bullet entering three inches (7.6 cm.) to the right of, and an inch and a half (3.8 cm.) below the umbilicus, passing almost transversely through the abdominal cavity and escaping at a corresponding point on left side. Inflation of hydrogen gas was attempted, but failed on account of the apparatus being out of order. The abdomen was opened and no gas was found even in the colon. Twelve perforations of the small intestines were found, and a number of perforations of the mesentery, which had caused profuse hæmorrhage.

*Experiment 64.* Large, black dog. Etherized and shot in the abdomen; wound of entrance three inches (7.6 cm.) to the right of, and an inch and a half below the umbilicus; wound of exit near a corresponding point on opposite side, the bullet taking nearly a transverse course. Rectal inflation of hydrogen gas gave a prompt positive result. The abdomen was opened and five perforations of small intestine were found, besides laceration of thoracic duct, and a number of perforations in mesentery. Colon and small intestine below the lowest point of perforation contained gas, while above the lowest perforation the bowel contained no gas.

*Experiment 65.* Dog, weight twenty-five pounds. Under full anæsthesia the animal was shot in the abdomen, the bullet passing in a nearly transverse direction through the abdominal cavity an inch and a half below the umbilicus from point of entrance; wound of exit midway between linea alba and spine. Rectal insufflation of hydrogen gas made under very low pressure, led to rapid distention of the abdomen, an occurrence which furnished strong evidence that the gas had escaped through a perforation in the colon into the peritoneal cavity. The gas escaped in bubbles through the wound of entrance, and when a lighted taper was held near the wound, it burned with a jet varying in size. On opening the abdomen gas escaped from the peritoneal cavity; small intestines empty, and only a small amount of gas in the colon. The following intra-peritoneal injuries were found: Four perforations of the duodenum, two of the jejunum, and one of the cæcum; also a perforation nearly through the centre of the left kidney, laceration of the receptaculum chyli, and a number of perforations in the mesentery. The bullet was found between the left kidney and the abdominal wall.

In all of these experiments the bullet was fired through the abdomen from side to side transversely, or somewhat obliquely, directions which invariably brought into the track of the bullet a number of intestinal coils, and often the colon. In the two experi-

ments where the track of the bullet was a little higher up, the intestines escaped, but the stomach showed two perforations, one near the pyloric, and the other near the cardiac extremity. Rectal insufflation of hydrogen gas proved an infallible test in every instance, except in the case where it failed on account of the inflation apparatus being out of order. Contrary to the experience of other experimenters, I found that fæcal extravasation does not uniformly take place soon after gunshot wounds of the intestines; in the cases where I observed it, some part of the colon had been wounded. Intestinal inflation does not, therefore, tend to increase the frequency of this occurrence, and must, on this account, be looked upon as a harmless measure.

Inflation, as a preliminary measure, greatly expedites the first step in the operation of abdominal section in cases where the intestine has been perforated or injured, as the gas which escapes into the peritoneal cavity separates the intestines from the anterior abdominal wall, and the incision can be made safely and rapidly without fear of wounding the intestines. Penetrating wounds of the abdomen, where the course of the bullet is in an opposite direction to that which has been described in the preceding experiments, that is, in an antero-posterior direction, may not implicate the intestines at all; or if visceral injury is inflicted, it is more likely that only a single perforation exists, and never does the surgeon meet with such a multiplicity of lesions as have been cited above. Unless the surgeon can ascertain beforehand, that in a case of penetrating wound of the abdomen an injury to some portion of the gastro-intestinal canal exists, the very means which he resorts to in making an anatomical diagnosis is often an imminent source of danger, as only too often he may have to examine every inch of the gastro-intestinal canal for this purpose, a procedure which is always attended by great risk to life. If by such a simple and harmless procedure as insufflation of hydrogen gas, he can satisfy himself that the gastro-intestinal canal is perforated, the course to pursue becomes clear—to open the abdomen, *seek for the perforation until he finds it*, and adopt proper treatment for the visceral injury.

Cases have also happened in which the operator opened the abdomen, sought for, found and treated one or more perforations and, on making the autopsy a day or two later found, to his great chagrin and sorrow, a perforation which he had overlooked at the

time of operation. It seems to me that in cases in which any doubt exists as to the integrity of the remaining portion of the intestinal canal, after closing one or more perforations, it would be advisable to search for additional perforations by resorting again to slow and careful inflation before the abdominal wound is closed. If no other perforations exist the gas will be confined to the interior of the gastro-intestinal canal, and if the stomach or intestines at some point difficult of access are injured, the leakage of gas through the perforations will lead the surgeon to the wound.

In the practical application of rectal insufflation of hydrogen gas, as a means of diagnosis in penetrating wounds of the abdomen, the field of possible operation should be carefully prepared by shaving and disinfection before inflation. After thorough disinfection of the external wound or wounds, and the field of operation, the patient should be placed thoroughly under the influence of an anæsthetic for the purpose of relaxing the abdominal muscles, which greatly facilitates the inflation.

In the absence of a Wolf's bottle, hydrogen gas can be readily generated in a large wide-mouthed bottle into which a small handful of chips of pure zinc is placed. The mouth of the bottle is closed with a cork with two perforations, through which two glass tubes are inserted, one for the purpose of pouring in water and sulphuric acid, and the other, which should be bent nearly at right angles, for leading away the gas. This glass tube and a rubber balloon with a capacity of sixteen litres of gas are connected by means of a rubber tube. In from five to ten minutes the requisite amount of gas can be generated and everything is ready for the inflation. The rubber tube connecting the balloon with the rectal tip of an ordinary syringe should be interrupted by a stop-cock, so that the escape of gas can be prevented whenever inflation is temporarily suspended. The return of gas along the sides of the rectal tip can be readily prevented by an assistant pressing the anal margins firmly against it.

*The inflation must always be made slowly, as long continued, uninterrupted pressure accomplishes most effectually lateral and longitudinal dilatation of the cæcum;* conditions which render the ileo-cæcal valve incompetent, and which must be secured before inflation of the small intestines is possible, The entrance of gas from the colon into the ileum is always attended by a diminution of

pressure, and its occurrence can invariably be recognized by a gurgling or blowing sound over the ileo-cæcal valve, sometimes sufficiently loud to be heard at some distance.

If, after inflation, abdominal distention and tympanites be from the very first diffuse, and liver dullness has disappeared, it is a certain indication that they are due to the presence of gas in the peritoneal cavity, and not to distention of the gastro-intestinal canal. If, on the other hand, the distention and tympanites follow the course of the colon, and after the entrance of the gas through the ileo-cæcal valve, are circumscribed and limited to the umbilical and hypogastric regions, and gradually extend to the upper portion of the abdomen, *and the liver dullness is displaced upwards*, they are in all probability caused by a gradual and successive inflation of the intact bowel in an upward direction.

In some penetrating wounds of the abdomen it is difficult, if not impossible to follow the course of the bullet through the abdominal wall with a probe or finger, on account of the relative change of position of the different layers of tissues in the track of the bullet, obliterating the canal; but even in these cases a moderate distention of the peritoneal cavity by an accumulation of gas outside of the intestines, will force bubbles of gas through the tortuous canal. By this sign the surgeon may know positively that some portion of the gastro-intestinal canal has been perforated; and in order to prove that the bubbles which escape are part of the hydrogen gas which has been inflated, he applies a lighted match or taper. If it is hydrogen gas it will ignite with a slight explosive report, and burn with a characteristic blue flame. The burning of the escaping hydrogen gas on the surface of the external wound is a most effective means in securing for the wound an aseptic condition, and on that account, the escaping gas should be lighted, both for diagnostic and therapeutic purposes, in all cases in which rectal insufflation of hydrogen gas reveals the presence of visceral injuries of the gastro-intestinal canal.

As hydrogen gas from its low specific gravity will always occupy the highest space in a cavity partially filled with fluids, it is necessary to place the external abdominal wound in such a position that blood or any other fluid that may be present in the abdominal cavity will not interfere with its ready escape. If the wound is anterior

the patient must be placed in the dorsal position; if lateral, on the opposite side, during the inflation. If during inflation, early and diffuse tympanites takes place, it speaks in favor of perforation of the colon.

Should the external wound prevent the escape of gas from the peritoneal cavity, by sliding of the different layers of tissue of the wound in the abdominal wall, or by the presence of a coagulum in the track made by the bullet, it becomes necessary to secure a sufficient degree of patency of the wound for the escape of gas, by careful probing or the removal of coagulated blood. The finding of perforations is also greatly facilitated by inflation, as the bowel below the lowest perforation will always be found at least slightly dilated by gas. If this perforation is now closed and additional perforations are suspected to exist, the inflation can be repeated, and the bowel will again become distended as far as the next perforation, and this process can be repeated until the entire intestinal canal has been examined. By searching for leaking points in this manner, but little manipulation of the intestines becomes necessary, and thus one of the great sources of danger in the operative treatment of wounds or perforations of the gastro-intestinal canal is avoided.

The moderate distention of the intestines left after treating the visceral wounds, never interfered with the return of the intestines into the abdominal cavity or the closure of the external wound in any of the experiments; and the numerous observations made in reference to the disappearance of the gas by absorption, or escape through the natural outlets, are conclusive in showing that the distention due to the presence of the gas disappears in a remarkably short time. It can therefore be safely stated that rectal insufflation of hydrogen gas in the diagnosis and treatment of penetrating wounds of the abdomen, does not interfere with an *ideal* healing of the visceral and laparotomy wounds.

After a careful study of the subject of rectal insufflation of hydrogen gas in its various aspects, I do not hesitate to recommend its adoption in practice as an infallible diagnostic test in demonstrating the existence of a wound of the gastro-intestinal canal in penetrating wounds of the abdomen, or perforations from any other cause, without resorting to an exploratory laparotomy.

In conclusion I beg leave to submit the following propositions:

1. The entire alimentary canal is permeable to rectal insufflation of air or gas.

2. Inflation of the entire alimentary canal from above downwards through a stomach tube seldom succeeds, and should therefore only be resorted to in demonstrating the presence of a perforation or wound of the stomach, and for locating other lesions in the organ or its immediate vicinity.

3. The ileo-cæcal valve is rendered incompetent and permeable, by rectal insufflation of air or gas under a pressure varying from one-fourth of a pound to two pounds.

4. Air or gas can be forced through the whole alimentary canal from anus to mouth, under a pressure varying from one-third of a pound to two pounds and a half.

5. Rectal insufflation of air or gas to be both safe and effective must be done very slowly and without interruptions.

6. The safest and most effective rectal insufflator is a rubber balloon large enough to hold sixteen litres of air or gas.

7. Hydrogen gas should be preferred to atmospheric air or other gases for purposes of inflation in all cases where this procedure is indicated.

8. The resisting power of the intestinal wall is nearly the same throughout the entire length of the canal, and in a normal condition yields to diastaltic force of from eight to twelve pounds of pressure. When rupture takes place it either occurs as a longitudinal laceration of the peritoneum on the convex surface of the bowel, or as multiple ruptures from within outwards, at the mesenteric attachment. The former result follows rapid, and the latter slow inflation.

9. Hydrogen gas is devoid of toxic properties, non-irritating when brought in contact with living tissues, and rapidly absorbed from the connective tissue spaces and all of the large serous cavities.

10. The escape of air or gas through the ileo-cæcal valve from below upwards is always attended by a blowing or gurgling sound, heard most distinctly over the ileo-cæcal region, and by a sudden diminution of pressure.

11. The incompetency of the ileo-cæcal valve is caused by a lateral and longitudinal distention of the cæcum, which mechanically separates the margins of the valve.

12. In gunshot or punctured wounds of the gastro-intestinal canal, insufflation of hydrogen gas enables the surgeon to demonstrate positively the existence of the visceral injury, without incurring the risks and medico-legal responsibilities incident to an exploratory laparotomy.

# INFLATION OF THE STOMACH WITH HYDROGEN GAS IN THE DIAGNOSIS OF WOUNDS AND PERFORATIONS OF THIS ORGAN, WITH THE REPORT OF A CASE.[1]

In my paper on "Rectal Insufflation of Hydrogen Gas as an Infallible Test in the Diagnosis of Visceral Injury of the Gastro-Intestinal Canal in Penetrating Wounds of the Abdomen," read in the Surgical Section of the American Medical Association, I incidentally called the attention of the medical profession to the value of inflation of the stomach as a diagnostic measure, in cases of injury or perforation of this organ, in that part of the paper which treated of inflation of the alimentary canal through the stomach tube. We should naturally expect that the alimentary canal could be inflated with more ease and with a less degree of force by following the normal peristaltic wave. That this is not the case can be seen from the experiments given in detail in the paper referred to.

These experiments demonstrate conclusively that it is more difficult to inflate the alimentary canal from above downward than from below upward; as in the living animal I succeeded in only one instance in forcing hydrogen gas from the mouth to the anus, while in others, a degree of force sufficient to rupture the peritoneal coat of the stomach, only effected distention of the stomach and upper portion of the intestinal canal. It is evident that great distention of the stomach constitutes an important factor in causing or aggravating intestinal obstruction, as it effects compression, which again causes impermeability of the intestines, or aggravates conditions arising from an antecedent partial permeability, by producing sharp flexions among the distended coils of the intestines.

*For diagnostic and surgical purposes, the stomach can be readily inflated almost to any extent through a stomach tube, and when it becomes necessary to ascertain the presence of a visceral*

*wound or perforation of this organ, this method of inflation may be resorted to with advantage.*

I have recently had an excellent opportunity to apply this test in a case of gunshot wound of the chest and abdomen, in which, without it, it would have been impossible to make a correct diagnosis. The insufflation made the diagnosis positive, and the information obtained from it justified the treatment by laparotomy, although the general symptoms were so grave that it appeared doubtful if the patient would live long enough to complete the operation.

C. H., seventy-two years of age, was brought to the Milwaukee Hospital by the police patrol, at 7 A.M., July 9, 1888, for a suicidal pistol (44-calibre bulldog) wound of the chest, inflicted about two hours previously. Pistol held in the left hand, as ascertained from the patient and confirmed subsequently by examination of the direction of the bullet. The patient stated that he had pointed the pistol toward the heart.

*Examination*, 7 A.M. Wound of entrance situated in the left sixth intercostal space, surrounded by emphysema. Seventh rib fractured at junction of cartilage and bone. No wound of exit. Patient conscious; complains of severe pain in the epigastric region, increased by pressure. Pulse rapid and weak. Vomits and expectorates blood. Area of liver dullness diminished. Percussion and respiratory sounds normal. No evidence of hæmo- or pneumo-thorax.

9 A.M. Flexible tube introduced and stomach inflated with hydrogen gas from a four-gallon rubber balloon. Inflation effected by continuous pressure on the balloon. Gas escaped and ignited at the wound of entrance with an audible sound. Field of operation thoroughly disinfected. Patient etherized and laparotomy made by incision from the ensiform cartilage to the umbilicus. The omentum and stomach were drawn forward into the wound. A large perforation, about one and a half inches in length (due to the oblique direction of the bullet), was found in the stomach, midway between the pylorus and the cardiac end, on the greater curvature. Stomach partially filled with coagulated blood. With the index finger introduced through this perforation, another was detected on the lesser curvature and near the cardiac end. The omentum, which was adherent to the colon, was torn through and exploration of the posterior surface of the stomach failed to reveal the old site of the second wound, which was felt by the digital exploration of the interior of the organ. The blood-clots were removed from the stomach by irrigation through the lower wound.

For the purpose of locating with accuracy the second wound, the stomach was inflated through the bullet wound on the anterior surface with hydrogen gas, the escape of which made it easy to locate the second wound. The omental opening was enlarged by tearing, and the perforation was discovered on the posterior surface at the lesser curvature and close to the cardiac orifice. Great difficulty was experienced in dragging the stomach sufficiently forward and downward into the abdominal incision to suture the perforation, which

was two inches in length. It was closed by a continuous Lembert suture of silk, the anterior wound by a Czerny-Lembert suture.

Considerable blood was found behind the stomach, in the region of the pancreas. The hæmorrhage had evidently taken place from lacerated vessels of considerable size at both perforations, as well as from vessels in the pro-peritoneal space. Probable direction of the bullet from above downward, backward and to the right. At this stage collapse from shock and hæmorrhage supervened. The body was partially inverted and a saline infundation of fifteen ounces of a six-tenths per cent. salt solution performed. Brandy was injected subcutaneously and the faradic current applied to the phrenic and pneumogastric nerves without any apparent effect. Death occurred before the abdominal wound could be closed.

The abdominal incision was sutured and inflation of hydrogen gas per rectum, made to test the condition of the sutured stomach. A stomach tube was introduced and the gas, under a pressure of not more than a pound, forced through the entire gastro-intestinal canal, igniting and burning with a continuous flame as it escaped from the end of the stomach-tube, which showed that no gas escaped through the sutured wounds. Post-mortem was made immediately. Wound of entrance in the sixth intercostal space, seventh rib fractured at junction of cartilage and bone, both pleural cavities obliterated by adhesions, margin of lower lobe of left lung perforated, pericardium intact, lacerated opening in diaphragm admitting two fingers. Perforations in stomach as described. Liver and spleen not injured, upper margin of tail of pancreas lacerated. Bullet passed to the left of the aorta, entered the left crus of the diaphragm, fractured the last rib at the neck and perforated the spinal column, entering between the last dorsal and the first lumbar vertebra, escaping through the body of the latter and fracturing its right transverse process. Bullet found in the subcutaneous connective tissue of right lumbar region. The spinal canal was opened by the bullet in its passage through the vertebra, and loose fragments of bone lay in the canal. The membranes of the cord were intact and the cord itself uninjured.

The location of the wound of entrance in this case, did not indicate that the bullet had entered the abdominal cavity, unless the revolver was held in the left hand; in that case, as it was directed toward the heart, the track of the bullet would be necessarily downward, backward and from left to right. Taking it for granted that the bullet took this direction, it would still have been possible for the stomach to escape injury. The circumscribed emphysema around the external wound and the hæmoptysis, as well as the location of the wound, left no doubt that the lower lobe of the lung was injured. The absence of hæmothorax and pneumothorax was explained by the post-mortem, as the left pleural cavity was found completely obliterated by adhesions. Under a pressure of not more than half a pound to the square inch, the hydrogen gas was forced

through the external wound, where it was lighted and burned in a large continuous flame until it was extinguished by compression with a large moist sponge. Very little gas was found in the peritoneal cavity.

In perforation of the stomach without an external wound, inflation of the organ with hydrogen gas will render the abdomen universally tympanitic; as the gas will escape into the peritoneal cavity and, as it always occupies the highest plane, on account of its low specific gravity, it will push the abdominal organs backward. Thus it happens that the liver dullness disappears completely, which fact alone, if established, makes the diagnosis of perforation positive, unless the organ is fixed in its place by peritoneal adhesions, the result of a previous peri-hepatitis.

In cases of perforating ulcer of the stomach or duodenum, if this simple diagnostic measure is resorted to in time, it will prove the means, by prompt surgical treatment, of saving many a life that would have been sacrificed under the expectant plan of treatment.

It has been claimed that hydrogen gas is objectionable for purposes of inflation, as when it is mixed with a certain proportion of oxygen or atmospheric air it forms an explosive compound. Against this argument I can say that no accidents of any kind have occurred during any of my numerous experiments on animals, nor in the few cases in which it has been applied in practice. Hydrogen gas has the lowest specific gravity of all the gases known, and on this account, as well as from its non-toxic qualities, it should always be preferred to other gases, or to atmospheric air simple or medicated. The hydrogen gas test, if successful, appeals both to the sense of sight and hearing in cases of perforating wounds. The preparation of the gas is so simple and rapid that its use is applicable not only in hospital and city, but also in country practice.

I have recently been able to make a correct diagnosis in several cases of obscure abdominal tumors, by resorting to stomach and rectal inflation of hydrogen gas, which, without these diagnostic measures, would have been impossible, short of exploratory laparotomy. The relation of tumors of the abdominal cavity to the different organs and the peritoneal cavity, can be mapped out and studied with great accuracy by dilating the stomach and different portions of the intestinal canal, at intervals, by inflation with this harmless and readily procurable gas.

# TWO CASES OF GUNSHOT WOUND OF THE ABDOMEN, ILLUSTRATING THE USE OF RECTAL INSUFFLATION WITH HYDROGEN GAS AS A DIAGNOSTIC MEASURE.[1]

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Case I. J. J., sixteen years of age, was out hunting with some companions, on Sunday, September 9, 1888, one of whom accidentally discharged his 22-calibre rifle at a distance of about one hundred and fifty feet, the bullet striking the patient in the abdomen. The injury caused but little pain, and immediately after the accident, the patient walked about forty yards to a farm house, where he was placed in bed. From there he was conveyed on a cot, in a farmer's wagon, to the Milwaukee Hospital, some six miles distant. The accident occurred about noon, and he arrived at the hospital at 3 P. M.

*Examination.* Patient complained of considerable pain in the abdomen; pulse 80 and soft; his general appearance indicated no serious injury. On undressing him, a bullet wound, with omentum protruding, was found two inches to the right of the middle line, and on a level with the anterior superior spine of the ilium. Left iliac region dull on percussion; and in right, a cracked-pot sound was elicited on percussion. A rectal enema was administered, and was followed by a free fæcal discharge, without admixture of blood. On washing the fæces afterward, the bullet was found.

*Operation.* Ether, as an anæsthetic; thorough disinfection of abdominal wall; rectal insufflation of hydrogen gas, followed by the escape of bubbles of the gas, within a few seconds, at the wound of entrance, into which had been placed a hæmostatic forceps, the blades separated so as to render the canal patent. The gas was lighted, and after thorough cauterization of the wound by the flame, was extinguished by the application of a wet sponge.

Laparotomy by median incision, eight inches in length, from pubes upward. About a pint of fluid blood in the peritoneal cavity, and hæmorrhage continuing from the mesenteric veins at two points of perforation on the mesenteric side of the bowel, and to a less extent from perforations of the mesentery, arrested by ligating *en masse*. Within a distance of four feet, near the middle of the ileum, were found ten perforations, two of which were at the mesenteric border; also four perforations of the mesentery. Another perforation of the bowel was found within four inches of the ileo-cæcal valve on the convex side of the intestine, making so far eleven in all. All were closed by Czerny-Lembert sutures. At two points the perforations were so close together that it was found necessary to invert half the circumference of

the bowel on the convex side, thus producing considerable narrowing of its lumen.

Two hours had been consumed in arresting the hæmorrhage and closing the eleven perforations, and the patient at this time had become pulseless; yet it was deemed absolutely necessary to determine beyond all doubt if any more perforations existed, by repeating the rectal insufflation of hydrogen gas. On repeating this test it was found that gas escaped freely from the pelvic cavity, without reaching the ileo-cæcal region, showing that at least one more perforation was below this point. The sigmoid flexure was brought into the wound and compressed between the index finger and thumb. Insufflation was again followed by escape of gas, demonstrating that the perforation was below this point. Inch by inch the bowel was examined by this method in a downward direction, until a perforation was found in the anterior portion of the rectum, at a point where the peritoneum covering its anterior wall is reflected upon the bladder. This perforation was rendered accessible to direct treatment by an assistant making traction on the colon, and by keeping the margins of the wound well retracted by means of a pair of Hegar's retractors. It was closed by five Lembert sutures, with the greatest difficulty, on account of its deep situation, and the inadequate light furnished by two candles.

From the perforations in the ileum there escaped pieces of green apples and intestinal contents, and from that in the rectum, fluid fæces.

The peritoneal cavity was freely irrigated with a one-third per cent. solution of salicylic acid. After completion of peritoneal toilet, a glass drain was introduced in such a manner that the distal open end was placed opposite the sutured rectal wound, and the abdominal incision closed in the usual manner.

Whiskey was freely administered hypodermically during the operation and after its completion, as the patient remained pulseless for half an hour.

Time of operation two and a half hours.

The foot of the bed was elevated and dry heat applied to the extremities.

10 P. M. Temp. 99.5° F.; pulse rapid and weak. About one ounce of bloody serum withdrawn from glass drain.

*Sept. 10th.* 8 A. M. Temp. 99° F.; pulse 126. Clear serum only in the drain; about one drachm withdrawn every three hours. During the day the patient was slightly delirious, and in the absence of the nurse he got out of bed and walked across the ward to another bed. 8 P. M. Temp. 99.8° F.; pulse 144. Some tympanites. Ordered one drachm of turpentine in half a pint of warm water, as an enema, which was followed by free discharge of fæces and flatus.

*11th.* Temp. normal; pulse 104. Natural passage from bowels; delirium continues.

*12th.* Temp. normal; pulse 96. Delirium disappeared. Allowed liquid food in small quantities.

*13th.* Pulse 72. The contents of the glass drain have a suspicious fæcal odor. Glass, replaced by rubber drain. Slight diarrhœa, which relieved the tympanites.

*14th.* 9 A. M. Temp. 101° F.; pulse 126. A fæcal fistula has formed along the track of the drainage-tube. Large rubber tube introduced through the anus, and left in rectum to allow free escape of fluid fæces. Fluid injected into fistula does not flow through the rectal tube. Rectum disinfected every four hours with saturated salicylic acid solution.

*17th.* Temp. normal; pulse 108. Free discharge of fluid fæces from rectal tube and fistula.

*18th.* Sutures removed from the abdominal incision; only deep parts united; granulating surfaces approximated by strips of adhesive plaster over an antiseptic compress.

*19th.* Fluid flows freely from fistula through the rectal tube. No fæces have escaped through fistula for twelve hours.

*20th.* Rectal tube withdrawn, followed by return of fæcal discharge through fistula.

*Oct. 1st.* The discharge of fæces through the fistula has been gradually diminishing, and has now ceased.

*19th.* Fistulous track completely closed. Abdominal incision all healed, except a small granulating surface at lower angle.

Patient discharged cured, November 3d.

REMARKS.—The subjective symptoms in this case four hours after injury, and after transporting the patient a distance of six miles, furnished no indications whatever of the extent of visceral injury which was found on exploring the abdominal cavity. The rectal insufflation of hydrogen gas at once rendered the diagnosis positive, and pointed out the necessity of treatment by abdominal section. Eleven perforations were found and sutured without much difficulty, but the last perforation in the deepest portion of the pelvis could not have been found by any other means of diagnosis short of rectal insufflation. Had this perforation been overlooked, death from septic peritonitis would have been inevitable. Drainage was resorted to in this case, not only from the fact that fæcal extravasation had taken place, but also for the reason that owing to the difficulty in gaining access to the rectal wound, I feared that the suturing was not as perfect as it should be, and by proper drainage I wished to prevent possible extravasation into the peritoneal cavity from this cause. Subsequent events showed the propriety of this precaution.

CASE II. J. E. (case of Drs. Gudden, Steele, and Gordon, of Oshkosh), eighteen years of age, was out target-shooting with a companion, who, while raising his 22-calibre rifle to his shoulder, accidentally discharged it; the bullet struck the patient in the abdomen. He was about forty feet distant, and almost directly facing his companion. When first seen by Dr. Gudden,

within half an hour after the injury was received, he was suffering severe pain in the abdomen, was pale, covered with cold, clammy perspiration, and vomited frequently. He was placed in a carriage and conveyed to his home, a distance of two miles. During the journey, the severity of the abdominal pain was so increased by the motions of the carriage, as to necessitate repeated stops.

I saw the patient, with the above-named physicians, October 9th, 4 A. M., twelve hours after the accident.

*Examination.* The wound of entrance was found to be at the outer margin of the left rectus, about one inch below the level of the umbilicus. Abdomen dull on percussion in left iliac region, pulse 140, temperature 100° F. Penetration of the abdomen was proved by the introduction of a grooved director, which was left in place during the insufflation of the hydrogen gas.

The patient was placed under the influence of chloroform, and during the operation the narcosis was maintained with ether. The abdomen was thoroughly disinfected, and rectal insufflation of hydrogen gas practiced to ascertain if any perforation of the intestine existed. Under a pressure of about half a pound to the square inch, and the use of one-quarter of a gallon of gas, in a few minutes the gas escaped along the groove of the director, and, on applying a match, lighted as it escaped. The flame was now extinguished by a moist sponge, and the abdomen opened by a median incision, five inches in length, extending from the umbilicus to near the pubes.

On exposing the peritoneum at the lower angle of the incision, through this membrane there was observed a structure closely resembling an over-distended bladder. That this structure was a distended bladder was improbable, as the patient had urinated before the anæsthetic was administered. The peritoneum was carefully incised between two forceps, and divided upon a grooved director to the same extent as the external incision, and it was then discovered that what appeared to be an over-distended bladder, was a coil of small intestine distended with blood to twice its normal size. The whole pelvic cavity was found filled with fluid blood. On withdrawing the small intestine, five perforations near the junction of the jejunum and ileum, and within a distance of three feet, were found; four occurred in pairs on the lateral aspect of the bowel, and one at the mesenteric attachment. All the perforations were disproportionately large to the size of the bullet, and would easily admit the tip of the index finger. The intestine, at the point of injury, was covered with a thick layer of recent plastic lymph, and the parietal peritoneum presented all the evidences of a beginning diffuse septic peritonitis. The intestine, which was over-distended by blood-clots for about three feet, was emptied and irrigated with a one-third per cent. solution of salicylic acid, which was used for constant irrigation during the entire time required in suturing the perforations, which were closed by Czerny-Lembert sutures.

Further examination disclosed four perforations of the mesentery, from two of which quite profuse venous hæmorrhage was still going on. The hæmorrhage was arrested by ligature *en masse*, by passing a needle threaded

with fine silk, through the entire thickness of the mesentery, on either side of the perforations.

Rectal insufflation of hydrogen gas was repeated, so as to ascertain if any other perforations existed; and the gas after it had been gently forced beyond the highest perforation, was made to traverse the balance of the entire intestinal canal by drawing forward loops of the intestine and returning them as examined without further insufflation. This procedure was found entirely satisfactory and practical, as the gas on account of its low specific gravity, readily entered the highest point in the prolapsed intestinal loop.

The abdominal cavity was irrigated with salicylic acid solution, numerous coagula removed, the toilet completed, a glass drain introduced into the pelvis, and the abdomen closed.

Duration of operation two hours. Patient collapsed, pupils greatly dilated, and almost pulseless in spite of repeated hypodermic injections of brandy, which were administered when signs of collapse became apparent, throughout the operation. Enema of a teacupful of warm water and two ounces of brandy. Foot of bed elevated and external dry heat applied.

In an hour and a half he rallied somewhat from the operation, but again sank and died at 3 P. M., eight hours after the completion of the operation.

*Post-mortem* eighteen hours after death (Drs. Steele, Gudden, Gordon). Circumscribed peritonitis present at time of operating, now diffuse; very little fluid in abdominal cavity; several small blood-clots in vicinity of transverse colon. The perforations were all securely closed, and the bullet was found in the soft tissues to the right of the spinal column, between the fourth and fifth lumbar vertebræ, and near the ascending colon. The bullet, though only of 22-calibre, was oblong, and may thus explain the unusually large size of the perforations.

REMARKS.—This case compared with the foregoing, furnishes a strong argument in favor of early operative interference in cases of gunshot or stab wounds of the abdomen, in which the existence of visceral lesions can be demonstrated by rectal insufflation of hydrogen gas. In the first case, although twelve perforations were found and sutured, and fæcal extravasation had taken place, no evidences of peritonitis were found, and the patient recovered. In this case, twelve hours intervened between the time the injury was received and the treatment by laparotomy, during which time a septic peritonitis had developed, the extension of which the operation did not arrest, and from the effects of which the patient died.

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