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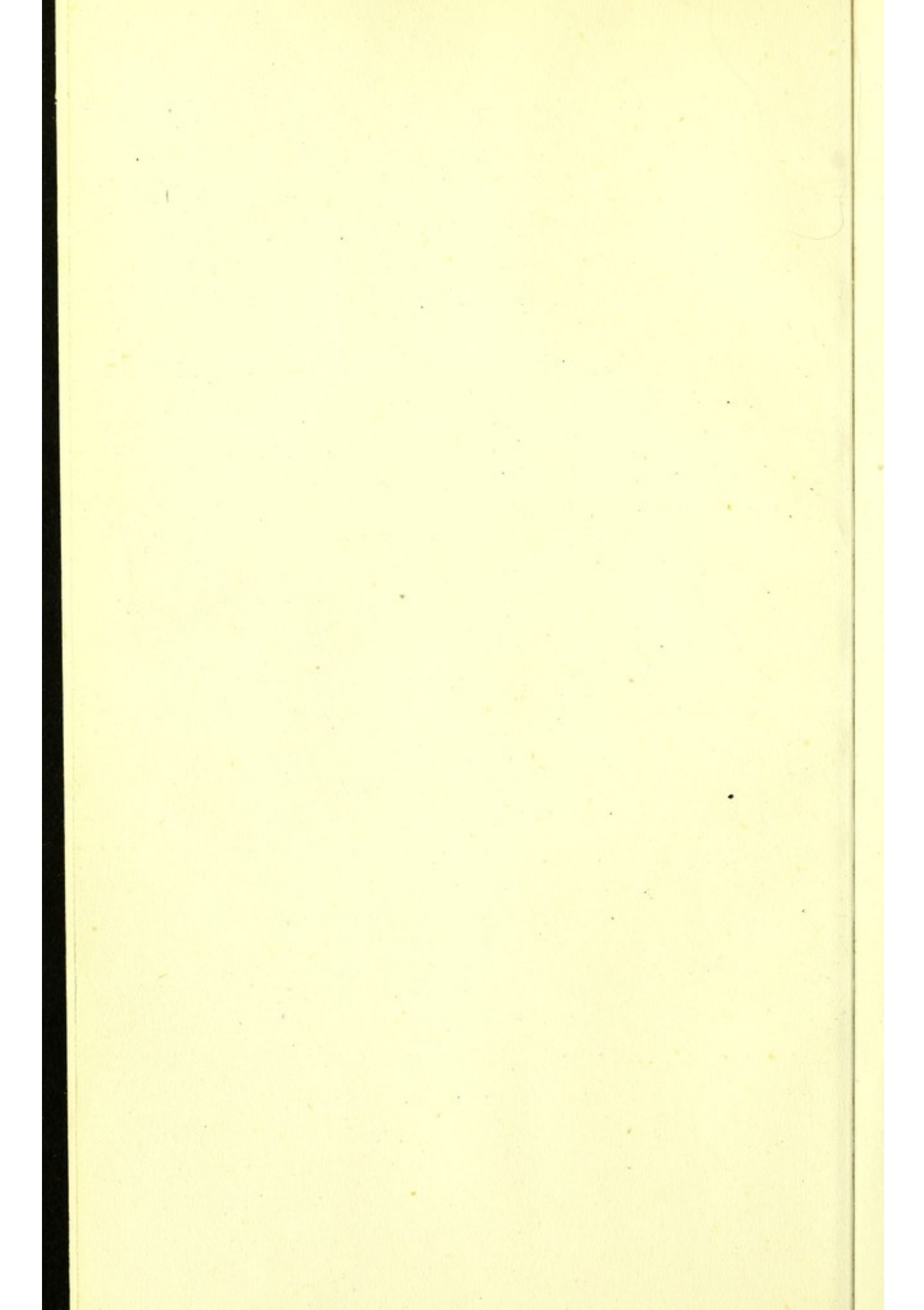
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*B. W. Richardson Esq.
with Dr Snow's kind
Regards*

ON THE
CAUSE AND PREVENTION
OF
DEATH FROM CHLOROFORM.
BY
JOHN SNOW, M.D.

Reprinted from the "London Journal of Medicine."

[1852]



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ON THE CAUSE AND PREVENTION OF DEATH FROM CHLOROFORM.

CHLOROFORM, like other medicines which relieve or prevent pain, is capable of causing death, if its action be carried too far. When a certain quantity of it is present in the blood, sensibility is so far diminished, that surgical operations may be performed without pain; whilst a certain additional quantity has the effect of diminishing sensibility to such an extent, that the necessity for breathing is no longer felt, the respiratory movements cease, and the circulation of the blood is by this means soon arrested. In some cases, as we shall see, sufficient chloroform is absorbed to arrest the action of the heart by its own influence.

When animals, such as dogs, cats, rabbits, and guinea-pigs, are made to respire air containing from three to five per cent. of chloroform, till they cease to breathe—a process which generally occupies ten or fifteen minutes—the heart can be heard to beat, by means of the stethoscope applied to the chest, for a minute or longer after the breathing has ceased; and it often happens that, about the time when the heart's action fails, the animal makes two or three gasping inspirations, that have the effect of restoring the contractions of the heart, which recommence with great rapidity. If the animal has been withdrawn from the chloroform, these gasping inspirations have generally the effect, when they occur, of thoroughly reestablishing both the breathing and circulation; but, if it is made to breathe the chloroform during these gasps, the action of the heart is again arrested, and the natural breathing does not return.

When the same kind of animals are made to respire air charged with upwards of eight per cent. of vapour of chloroform, death occurs with great rapidity, and in a different manner from that just described. The action of the heart ceases about the same moment as the breathing—in three instances, indeed, it has ceased before the breathing; and, although gasping inspirations have several times occurred after the chloroform was withdrawn, it has rarely happened that these inspirations have had the effect of restoring the heart's action.

I have observed the manner in which the breathing and circulation ceased in twenty-nine instances, with the stethoscope applied to the chest of the animal, when the quantity of chloroform in the air they breathed was known; but the following three experiments will suffice to show the different ways in which death occurs under the influence of chloroform, according as its vapour is more or less diluted with air. I may here remark, that the results of the experiments mentioned in this paper, can be applied with great propriety to elucidate what occurs in the human subject, both on account of the exact similarity between the effects of chloroform on the lower mammalia and on man, when confined within safe bounds, and also from the close resemblance of the phenomena caused by the less diluted vapour, to what has been described as occurring in the accidents to patients.

EXPERIMENT I. A young but full-grown cat was placed in a glass jar, of the capacity of 1,600 cubic inches, and a fluid drachm of chloroform was introduced, by a portion at a time, through a tube in the cover of the jar. As twenty-five minims of chloroform produce twenty-six cubic inches of vapour, the atmosphere which the cat had to breathe contained nearly four per cent. of vapour, and the jar was moved about, to ensure the uniform mixture of the vapour with the air. In five minutes, the cat became insensible, and lay breathing naturally. In about ten minutes more, the breathing became very feeble, and it ceased altogether in about another minute, or sixteen minutes after the cat commenced to breathe the chloroform. It was immediately taken out and laid on a table, and the stethoscope was applied to the chest. The heart could be heard beating distinctly at first, but the pulsations became slower and feebler, and in about a minute they could be no longer heard. Just at this time, however, the cat took a gasping inspiration, and immediately the heart was heard to beat in a most rapid manner. The gasps were repeated, and the action of the heart became less rapid, but stronger. In a little time, both the breathing and the action of the heart became natural, the cat remaining, however, insensible for some minutes.

EXPERIMENT II. A cat, about the same size as the last, was put into the same jar, and the same quantity of chloroform was introduced. It was removed at the end of four minutes, when it was so far insensible as to offer no resistance. Being laid on the table, it was made to breathe air charged with ten per cent. of vapour of chloroform from a bladder. Twenty-five minims of chloroform were put into the bladder, which held 250 cubic inches, and it was filled up with the bellows. A portion of another bladder, which was attached to the stop-cock, was made to surround the head of the cat, and it consequently breathed to and from the bladder. In half a minute it was quite insensible: in about half a minute more the breathing became difficult, and the sounds of the heart less distinct. The breathing became gradually slower, and ceased altogether between three and four minutes after the respiration from the bladder commenced. The sounds of the heart were rather frequent, and scarcely audible, just before the breathing ceased, and they could not be heard afterwards. The chest was opened three-quarters of an hour after death. The lungs were of a pale red colour, everywhere permeated with air; and a small quantity of fluid blood flowed from them on making an incision. The right cavities of the heart were quite full of blood, and the left cavities contained a small quantity.

EXPERIMENT III. A cat was made insensible in the same manner as the two previous ones. As it made strong efforts to get out of the jar, and consequently breathed more deeply, the chloroform took effect sooner; and it was removed and laid on the table, in a passive state, at the end of two minutes and a half. The respiration and sounds of the heart were quite natural. The nose of the animal was placed in the mouth of a metal vessel, lined with bibulous paper, and used as a chloroform inhaler. The inhaler contained chloroform, and was surrounded with water of the temperature of 110° Fahr. The stethoscope was kept applied to the chest whilst the chloroform was exhibited. After four or five inspirations from the inhaler, the heart suddenly ceased to

beat, the breathing still going on. The inhaler was removed as soon as I was satisfied that the action of the heart had ceased, and there were two or three rather convulsive respirations afterwards, and then the breathing stopped; but, between one and two minutes later, there were two or three feeble inspirations, accompanied with motion of the nostrils, but no returning action of the heart could be heard. The chest was opened ten minutes after death. The lungs were quite pale throughout. There was a little clear serum in the pericardium. The heart appeared quite motionless when first observed; but, after exposure to the air for a short time, there were some slight contractions of a few fibres of the right ventricle. The right auricle and ventricle were filled with blood.

The air in the inhaler which this cat breathed, probably contained between twenty and thirty per cent. of vapour of chloroform.

In all the experiments that I have made on animals with sulphuric ether, in which the mode of dying has been observed, the heart has continued to beat after the breathing has ceased. The reason of this is, that the action of sulphuric ether, even when the air contains half its volume of the vapour, is not more rapid or powerful than the vapour of chloroform, when it constitutes but five per cent. of the inspired air.

In order to see more precisely the action of the vapour of chloroform on the heart, when not sufficiently diluted, the chest and pericardium were opened on four occasions, in cats and a rabbit, and chloroform was exhibited by artificial respiration. I was assisted by Mr. Peter Marshall in these experiments, and the following is the account of one of them.

EXPERIMENT IV. A young rabbit, rather more than half-grown, was made insensible by breathing air charged with four per cent. of vapour of chloroform in a large jar. The trachea was then opened, and a tube was introduced and tied. The lungs and heart were then exposed, by making an incision and removing the lower half of the sternum, with the adjoining part of the cartilages of the ribs on each side. The front of the pericardium was also cut away, to expose the heart. Whilst these operations were performed, artificial respiration was kept up by means of a bladder of air attached to the tube in the trachea. The heart contracted vigorously and quickly, and the lungs were of a light red colour. The rabbit was beginning to show signs of returning sensibility, when the bladder of air was changed for one containing ten per cent. of vapour of chloroform. The bladder contained 125 cubic inches, and twelve minims of chloroform were put in before it was filled with the bellows. Three or four inflations of the lungs only were made, when I perceived that the heart was beginning to be affected, and I changed the chloroform for a bladder containing only air. These three or four inflations of the lungs with chloroform, had the effect of causing the right cavities of the heart to become distended with blood, and its pulsations to become much slower. In two or three minutes, however, the action of the heart was quite reestablished by the artificial respiration, the pulsations being vigorous and frequent, and the ventricles being apparently emptied at each contraction. The bladder charged with ten per cent. of chloroform was again attached, and artificial respiration was made with it. The right ventricle began

almost immediately to become distended; and, by the time that eight or ten inflations of the lungs had been made, the contractions of the heart were very slow and feeble. Artificial respiration with air was resumed, but without the effect of restoring the action of the heart. The lungs were observed at the time when the right ventricle was becoming distended, and it was noticed that their colour was unchanged. They afterwards became paler, as the artificial respiration was continued after the ventricle had ceased to empty itself. No contractions of the diaphragm were observed after the first inflation of the lungs with chloroform, and the rabbit did not gasp at any time; whilst the cats had been observed to make a few gasping efforts at inspiration, at the time when the heart's action was ceasing.

The circumstance of the lungs not changing in colour at the moment when the right ventricle was becoming distended, which was observed in the cats as well as in the rabbit, shows that the distension arose from the failure of the contractile power of the heart, and not from impediment to the pulmonary circulation; for, in the latter case, the lungs would have become congested, and of a deeper colour. In one of the cats, it appeared to me that the left, as well as the right ventricle, was distended with blood; but this distension of the left ventricle did not continue.

There is no reason to believe that any of the accidents from chloroform have arisen from the continued exhibition of the vapour well diluted with air. On the contrary, the sudden manner in which the alarming symptoms came on in every case, shows that they were produced by the respiration of air containing not less than eight or ten per cent. of the vapour; and, from the history of the cases, it is most probable that the heart was disabled, in most instances, by the direct action of the chloroform. No systematic means were taken for properly diluting the vapour with air, in any case in which death has happened. The chloroform was exhibited on a handkerchief, or towel, or piece of lint, in all the cases but three; and, in two of these, it was not applied by a medical man. In order to show how easily accidents may happen with chloroform, I must beg attention to a few circumstances connected with its physical as well as physiological properties. On a former occasion, I showed,¹ both from experiments on animals, and the amount of chloroform consumed in inhalation, that the average quantity of it in the blood of an adult patient, when insensible to the surgeon's knife, is about eighteen minims, and that, if twice that amount were present in the blood, it would suffice to cause death, even if it were uniformly distributed. Now thirty-six minims of chloroform, when in the form of vapour, only occupy thirty-seven and a half cubic inches, or very little more than a pint. It is true that the vapour of chloroform does not exist in a separate state at the ordinary temperature and pressure of the atmosphere; but air, when saturated at 60°, contains rather more than twelve per cent. of the vapour; and, supposing the air to contain ten per cent., which it does when the chloroform dew point is at 55°, the thirty-six minims would be contained in 375 cubic inches of air, more than half of which might possibly be in the lungs at one time.

¹ Medical Gazette, vol. xliii, p. 414.

The quantity of blood contained in the adult human being, has been estimated by M. Valentin to average thirty pounds; and the thirty-six minims of chloroform, mentioned above, is only one minim and one-fifth, or one cubic inch and a quarter of vapour, for each pound of blood measuring about twenty-seven cubic inches. Consequently, if a pound or two of blood should be impregnated to this extent with chloroform, and sent to circulate in the nervous centres, the respiration might cease before the remainder of the blood should be equally charged with vapour. Moreover, I ascertained that a little more chloroform than this, viz., one-eighteenth part as much as the blood will dissolve, or about a cubic inch and a half of vapour to each pound of blood, has the effect of stopping the contraction of the heart by its own influence.¹ Now, 100 cubic inches of air, containing ten per cent. of vapour, if present in the air cells of the lungs, might yield this amount of chloroform to two or three pounds of blood, and still retain from five to seven per cent. It is easy to perceive, therefore, that death might be caused by a very small quantity of chloroform, if it were inhaled in a concentrated state; and, indeed, in the Experiment No. iv., on the rabbit related above, the action of the heart was arrested by three or four inflations of the lungs in so short a time, that only a portion of the blood in the body could have become impregnated with the chloroform. The necessity of having the vapour sufficiently and systematically diluted with air, must, therefore, be evident. By such a plan, it is true, the patient cannot be made insensible in so short a time as was recommended by Dr. Simpson on the introduction of chloroform. Three or four minutes must be occupied in gradually and equally charging the blood with the requisite amount of vapour, but it is time well expended on the safety which it ensures.

The quantity of chloroform contained in the air the patient breathes during the use of the handkerchief, depends on the amount of surface wetted by the chloroform—on the proportion of air which comes in contact with the wetted surface, or passes into the lungs without this contact—on the extent to which the handkerchief is now warmed by the breath, now cooled by the evaporation, and on the force with which the inspired air impinges on the surface of the handkerchief moistened with chloroform. It must be evident, therefore, that the amount of vapour contained in the air the patient breathes is very uncertain; and when it is stated that the agent has been administered in exactly the same manner in two cases in which the handkerchief has been employed, it would be more correct to say that it was exhibited in an equally uncertain way in each instance; and the difference in the result should be attributed rather to the want of uniformity in the method employed, than to a difference of susceptibility in the patients: for in administering chloroform by a uniform method, I find very little difference in the susceptibility of persons to its chief effects, whatever variety there may be in the symptoms they evince previous to becoming insensible.

It will be remembered that Dr. Simpson recommended the general use of undiluted chloroform very quickly after its existence was made known to him by Mr. Waldie, and that amongst the advantages which

¹ Medical Gazette, vol. xliii, p. 415.

he stated that chloroform possessed over sulphuric ether was this, that it requires no particular apparatus for its administration. There can be no doubt that this was a great error. Chloroform being more powerful, when inhaled, than any other agent which has been used in a similar manner, except bisulphuret of carbon and hydrocyanic acid, particularly requires mechanical means for its regulation; but the high position of Dr. Simpson, and his previous services in this department, more particularly in being the first to administer ether in labour, gave his recommendations very great influence; the consequence of which is, that the practice of anæsthesia is at present probably in a much less satisfactory state than it would have been if chloroform had never been introduced. There are a few patients who submit now to the pain of operations, and many who inhale chloroform not without considerable fear; whilst, if we had been confined to the use of sulphuric ether, which is incapable of causing sudden death without giving distinct and timely warning, there can be no doubt that confidence in it would before this have been universal. I do not propose, however, that we should return to the use of sulphuric ether; for chloroform possesses certain conveniences of which it is easy enough to avail ourselves, whilst we disarm it of danger. To do this, all that is required, is to ensure that its vapour shall be sufficiently diluted with atmospheric air: not, be it remembered, for the purposes of respiration, as the physical properties of chloroform ensure this; but in order to prevent its absorption into the blood with such rapidity, that there is no time to watch its effects.

There are two ways of effecting with certainty the sufficient dilution of the vapour with atmospheric air: the first and best, is to employ a suitable inhaler; the second, is to dilute the chloroform with rectified spirit of wine before pouring it on a handkerchief or sponge.

In the apparatus which I usually employ, the air which passes over the bibulous paper, when the patient breathes in the usual manner, takes up between five and six per cent. of the vapour of chloroform. I have ascertained this by weighing the inhaler before and after passing a measured quantity of air through it, in the way in which it passes in ordinary respiration, the loss of weight denoting the amount of chloroform which had evaporated. The apparatus is, besides, provided with valves, by means of which the air thus charged with chloroform can be still further diluted to any extent desired; and I always commence the inhalation with air containing very little chloroform, gradually increasing the quantity of vapour, and usually diminish it again as the insensibility attains the desired point, or at any time when the breathing is deeper and quicker than usual.

As regards the dilution of chloroform with spirit, this is the form in which it was first used for inhalation under the name of chloric ether, which is a tincture of chloroform in rectified spirit of wine, containing from twelve to eighteen per cent. of the active ingredient. Dr. Bigelow of Boston, U.S., had tried this preparation, but Mr. Jacob Bell was the first to use it with success. It was occasionally employed in St. Bartholomew's Hospital, and in the private practice of Mr. Lawrence, but did not come into general use on account of its expense and the uncertainty of its action. It is only capable of yielding between one and a half and two per cent. of vapour of chloroform

at the commencement of inhalation, and much less afterwards. I do not think that it would be possible to kill a person by the inhalation of chloric ether if it were attempted, but it is tedious and uncertain in its effects; and if we wish for a preparation of chloroform that can be given safely and effectually with no other apparatus than a handkerchief, it must be something between pure chloroform and the so called chloric ether. One part by measure of chloroform to two of spirit, as recommended by Dr. Warren of Boston, U.S., and called strong chloric ether by him, answers generally very well, but he found it to fail in a few instances in the way in which he employed it. I believe that equal parts by measure of chloroform and rectified spirit, would not fail in any instance to cause insensibility, if judiciously employed on a handkerchief or sponge, and that it would not be liable to cause accident. Certainly the care which has sufficed to limit the deaths from undiluted chloroform, when thus employed, to about eighteen, would have been more than sufficient to prevent them altogether, if the chloroform had been diluted with an equal measure of spirit.

When chloroform thus diluted is first poured on a handkerchief, it is capable of yielding only a little more than half as much vapour to air which is brought in contact with it, as it yields in the undiluted state. As the process of inhalation continues, it yields less and less vapour, a weaker solution being left on the handkerchief. But by adding more of the mixture, the process goes on as at first. It is some little disadvantage that a combination of chloroform and spirit does not yield a uniform amount of vapour throughout the process of inhalation; but this is not of much consequence in using a handkerchief or sponge—the only method in which it is recommended—for this plan of administering chloroform does not admit of regularity or uniformity under any circumstances. During the removal of tumours of the maxillary bones and other operations on the face, in which I could not continue to employ the inhaler, I have been in the habit for the last three or four years of using chloroform diluted with an equal measure of spirit on a sponge, whenever I was aware beforehand of the nature of the case, and had time to be provided with it. At other times, I have poured only fifteen or twenty minims of chloroform on the sponge at once. The spirit is not at all irritating to the air passages, and its effects would not be injurious if it were inhaled in larger quantity; but owing to its small volatility as compared with chloroform, the patient does not inhale more than a few minims of it in the course of an operation, the greater part remaining behind on the handkerchief or sponge. I have often given chloroform thus diluted on a sponge or handkerchief to make animals insensible during physiological experiments, without ever meeting with the accidents which so frequently happen in giving undiluted chloroform to animals in the same manner.

The two following experiments show the great difference in action between undiluted chloroform and chloroform diluted with spirit, when given on a handkerchief, to the extent of causing death.

EXPERIMENT V. A cat was made insensible by breathing air containing four per cent. of vapour of chloroform for five minutes in a large glass jar. It was then taken out and laid on the table, and a folded handkerchief, on which two fluid drachms of chloroform had

just been poured, was applied so as to inclose its nose, without, however, interfering with respiration. The stethoscope was at the same time applied to the chest. At the time when the handkerchief was applied, the breathing and sounds of the heart were natural. The cat had not taken more than five or six inspirations after its application, however, when the breathing became sonorous and laboured, and the sounds of the heart became less distinct; and after two or three inspirations more, the heart could be no longer heard. At this moment the handkerchief, which contained nearly as much chloroform as when applied, was removed from the nose, and the cat made twelve or thirteen deep and gasping inspirations afterwards, which occupied about half a minute, but they did not restore the action of the heart. The chest was opened eight minutes after death. The lungs were quite pale. The right cavities of the heart were very full of blood. There were very feeble contractions of the right auricle, but none of any other part of the heart. On the descending cava being cut near the auricle, a quantity of blood flowed, and after this, together with the exposure to the air, some very feeble contractions of the right ventricle were observed. The left ventricle of the heart, when opened on the following day, was found to contain very little blood.

EXPERIMENT VI. Another cat was made insensible in the same way as the last, and being laid on the table, and the stethoscope applied, it was found that the breathing and the action of the heart were natural. Two fluid drachms of a mixture of chloroform with rectified spirit, in equal volumes, were poured on a handkerchief, which was applied round the nose, as in the previous experiment. In about a minute after the handkerchief was applied, and when the cat had taken about thirty inspirations, the breathing became laboured and sonorous, and the action of the heart became very rapid. The heart's action next became slow, the breathing continuing of the same character. In about half a minute longer, the pulsations of the heart became more frequent and distinct, but the breathing at the same time became slow and feeble, and it ceased about three minutes after the handkerchief was applied. The sounds of the heart could be heard for about a minute after the breathing ceased. The chest was opened a quarter of an hour after death. The lungs were of a bright red colour, and contained a moderate quantity of blood. The right auricle was contracting regularly and vigorously, but the other parts of the heart were not contracting, till on making an opening in the vena cava, which relieved the distension of the right ventricle, it began to contract, but less frequently than its auricle. The left ventricle of the heart was about one-third filled with blood.

In another experiment on a cat, with chloroform diluted in the same manner, 130 pulsations of the heart were counted after the breathing had stopped; and then, when the heart's action had nearly ceased, the breathing recommenced by gasping inspirations, which had the effect of causing the heart to beat again with great rapidity; but, as the chloroform was kept applied, the breathing and circulation soon ceased altogether.

The following list contains, I believe, all the cases on record in which death has been caused by the administration of chloroform. I have not included three or four deaths which have happened to persons who

have poured chloroform on a handkerchief, and inhaled it when no one was present; for an accident is so natural a consequence of such a proceeding, that these cases do not come within the scope of this paper. The appearances met with after death in two of them will be noticed, however, further on.

1. January 28, 1848. Hannah Greener, aged 15, near Newcastle. Toe-nail operation.

2. Feb. 23, 1848. Mrs. Simmons, Cincinnati, U.S. Extraction of teeth.

3. March 1848. Patrick Coyle, America. Operation for fistula in ano.

4. A young woman at Hyderabad, in Hindostan. Amputation of the distal phalanx of a finger.

5. May 1848. Madlle. Stock, aged 30, Boulogne. Opening an abscess.

6. 1848. Charles Desnoyers, aged 22, Hôtel Dieu de Lyon. Trans-current cauterisation of diseased wrist.

7. Dec. 1848. Young gentleman at Govan, near Glasgow. Intended toe-nail operation.

8. Jan. 19, 1849. John Griffith, seaman, aged 31, New York Hospital. Removal of hæmorrhoids.

9. Jan. 24, 1849. J. Verrier, aged 17, Lyons. Intended amputation of finger.

10. Feb. 20, 1849. Samuel Bennett, labourer, Westminster. Amputation of toe.

11. Aug. 23, 1849. Madame Labrune, Langres, France. Intended extraction of tooth.

12. Oct. 10, 1849. John Shorter, aged 48, St. Thomas' Hospital. Toe-nail operation.

13. Nov. 1849. Girl named Jones, Shrewsbury. Removal of eyeball.

14. Young lady, Berlin. Intended extraction of tooth.

15. Feb. 1850. Artilleryman on board ship in the Mauritius. Amputation of last phalanx of middle finger.

16. June 1850. Alex. Scott, aged 34, Guy's Hospital. Removal of portion of hand.

17. Sept. 20, 1850. James Jones, aged 24, Cavan Infirmary, Ireland. Intended amputation below the knee.

18. April 1851. John Holden, Stepney Workhouse. Intended operation on penis.

19. June 10, 1851. Madame Simon, aged 36, Strasbourg. Extraction of teeth.

20. July 8, 1851. Thos. Hutton, a mulatto, aged 45, Dreadnought Hospital Ship. Extirpation of testis.

21. Oct. 1851. Elizabeth Hollis, aged 37, Chipping Norton, Somerset. Intended operation for cancer of os uteri.

The above list contains two or three cases that have not appeared together in any previous table, whilst, on the other hand, I have excluded some deaths that have been attributed to chloroform, either because the fatal event was clearly due to something else, or because there are no means of deciding the point.

In a table given by Dr. Bouisson,¹ the death of a child, aged twelve years, during amputation of the leg, at the hospital at Madrid, is given. But this is an operation which is sometimes preceded or accompanied by circumstances which may be fatal; and as the published particulars are not sufficient to enable me to decide, I have excluded it. Three of the insurgents who were wounded in Paris, in June 1848, died during operations in which chloroform was administered. Two of the operations were amputation at the hip-joint, and the third was amputation at the shoulder. As the operators do not attribute the deaths to chloroform, there is no reason why others should do so. The death of a patient of M. Roux has been attributed, not by that surgeon but by others, to chloroform, although it is quite certain that this was not the cause. A woman had a cancerous tumour of the breast removed under the influence of chloroform; and, after she became conscious, M. Roux performed a protracted operation for the removal of some glands from the axilla, without the chloroform, and whilst the patient was sitting up to have a bandage applied, she fainted, and was dead. A death which occurred in the practice of Mr. Robinson, the dentist, I consider was not due to chloroform, because the patient showed none of the symptoms of its effects, and because the inhaler which was employed had not been approached nearer than an inch from the patient's face, whilst it might be held at that distance for a week without causing insensibility, much less death. On a former occasion² I expressed an opinion, that death was caused by syncope from mental emotion, occurring in a patient with great organic disease. Since that time, I have been present with Mr. Marshall, of Greek Street, at the *post-mortem* inspection of the body of a woman who died suddenly of fright, in consequence of a fire in the next house to that in which she lived, in Crown Street, Soho. We found in that case exactly the same diseases as in Mr. Robinson's patient, viz., fatty degeneration of the heart, and great enlargement of the liver, displacing the viscera of the chest. Dr. Aschendorf has attributed to chloroform³ the death of a child a year old, from whose face and neck he extirpated a large nævus, which extended from the zygoma to the os hyoides, and from the external auditory meatus to the maxillary fossa. No one else had been willing to undertake its removal. The operation lasted eighteen minutes, and only nine drops of chloroform were used in all. The child died suddenly at the end of the operation. As no chloroform had been applied for eight minutes before death, and then only three drops, it is quite impossible that this agent could have been the cause of the fatal result, and it only seems curious that the operation did not suggest itself to Dr. Aschendorf, as affording a sufficient explanation of the event.

¹ Traité de la Méthode Anæsthétique, p. 398.

² Edinburgh Medical and Surgical Journal, No. 180.

³ CASPAR'S Wochenschrift, September 6, 1850.

PART II.

ON looking over the list previously given, it will be seen that the accidents from the administration of chloroform nearly all occurred during, or preparatory to, minor operations. The case of extirpation of the eyeball, No. 13—that of amputation of the leg, No. 17, and the removal of the testis, No. 19, are the only operations of importance in the list. None of the accidents have happened in childhood or old age; and, except the subject of amputation, case 17, and the last case in the list, none of the patients were reduced to a state of debility. The general health also of the twenty-one patients who lost their lives was probably better than the average state of it in the thousands who have inhaled chloroform without accident; for the greater number of them are stated to have been in good health, and, except Patrick Coyle, No. 4, who was suffering from phthisis, and the patient with cancer of the uterus, No. 21, it has not been recorded that any of them were effected with serious disease of any internal organ. The reason of the accidents having happened under the conditions just named is probably that in large operations—in children and old people—in those much reduced by illness or affected with organic disease, an amount of care has been taken which has not always been observed under other circumstances; for, however faulty the method of administering the chloroform may be, the exercise of attention and care very much diminishes the danger, and it cannot be denied that there has been a want of care and attention in many of the cases in which accidents have happened. In the recent trial of a medical man at Strasbourg for homicide, by imprudence and want of precaution, in causing the death of a patient by chloroform, the President of the Tribunal made some very appropriate remarks on this point. He said, “When a patient is submitted to the action of chloroform, every attention ought to be fixed on the progress of the anæsthesia, and on the state of the pulse and respiration. Instead of that you extracted several teeth without having examined the state of your patient. You acted alone, whilst men of eminence constantly procure the aid of assistants.”¹ In some of the cases all the care was certainly employed that the operator had been led to believe was necessary, and the accidents were entirely due to the faulty method of administering the chloroform.

In order to show clearly the cause of the deaths which have taken place, it is necessary to give an outline of the phenomena which occurred at the time of dissolution, in the cases of which the particulars are related. In the first case, in the list previously given, about a fluid drachm of chloroform was poured on a tablecloth, and held to the nose of the patient. Dr. Meggison, the medical attendant of the

¹ L'Union Médicale, Jan. 29, 1852.

patient, said "in about half a minute I observed the muscles of the arm become rigid, and her breathing a little quickened, but not stertorous. I had my hand on her pulse, which was natural until the muscles became rigid. It then appeared somewhat weaker, not altered in frequency." The operation was now performed; and when the semicircular incision was made, the patient gave a struggle or jerk. Regarding the state of the girl immediately afterwards, Dr. Meggison continues: "Her eyes were closed and I opened them, and they remained open. Her mouth was open, and the lips and face blanched. I called for water and dashed some of it in her face. I then gave her some brandy, a little of which she swallowed with difficulty."¹ Other means were used with the hope of restoring the patient, but without effect; and she was dead within two minutes from the commencement of the inhalation. During the operation, at the time of the jerk mentioned above, the patient made a prolonged forced expiration, during which the tongue was protruded from the mouth, and the remaining expirations and inspirations were exceedingly feeble and few.² It will be remarked that the insensibility was induced so quickly in this case, that the air the patient breathed must have been charged with vapour of chloroform to a dangerous extent, and that the blood could not have been uniformly impregnated with the narcotic in so short a time as half a minute: the heart would therefore be liable to be paralysed by its direct action. The palor of the countenance renders it extremely probable that such was the case, although we have no direct proof of it, since Dr. Meggison and his assistant were too much occupied in endeavouring to restore the patient to ascertain whether there was any pulse after the alarming symptoms set in. I have often seen convulsive movements at the time of death in animals that were suddenly killed by chloroform.

Mrs. Simmons, of Cincinnati, the subject of the second fatal case, inhaled chloroform from an apparatus contrived by Dr. Morton, of Boston, for the inhalation of ether. It contained a sponge saturated with chloroform, and one-third filling the glass globe of four and a half inches in diameter. The breathing was at first slow, and the patient inhaled twelve or fifteen times, occupying from a minute to seventy-five seconds. She became pale whilst inhaling. As soon as the inhalation was left off four stumps of teeth were extracted: the patient groaned whilst this was taking place, and as the last stump came out, which was about two minutes from the commencement of inhalation, there was a kind of convulsive motion in the limbs and body. At this instant Mrs. Pearson, a friend of the patient, placed her finger on the pulse, and observed that it was very feeble, and almost immediately ceased to beat; respiration also ceased about the same time, according to her evidence, viz., about two minutes from the commencement of inhalation; but the dentists, who did not belong to the medical profession, considered that a longer time elapsed before death.³ It is probable from the palor of the face, which came on during inhalation, that the heart was affected by the direct action of the chloroform; but if the witness Mrs. Pearson was not mistaken

¹ *Lancet*, 1848, vol. i, p. 161.

² *Med. Gaz.*, vol. xli, p. 277.

³ *Med. Gaz.*, vol. xlii, p. 79.

about the pulse, the heart did not altogether cease to beat till about a minute afterwards.

In the third case, that of the young woman at Hyderabad, a drachm of chloroform was administered in what the operator called the usual way, *i.e.*, it was sprinkled on a handkerchief and inhaled. He described what occurred as follows:—"She coughed a little, and then gave a few convulsive movements. When these subsided, I performed the necessary incisions, which of course did not occupy more than a few seconds. Scarcely a drop of blood escaped." The operator, after mentioning the means which were used to recover the patient, without avail, continues, "I am inclined to think that death was almost instantaneous; for, after the convulsive movements above described, she never moved or exhibited the smallest sign of life."¹ In this instance also death was evidently caused suddenly by the action of chloroform vapour not sufficiently diluted with air; and it seems, from the brief account of the case, that the breathing and action of the heart were arrested at the same moment.

In the fourth case, that of Patrick Coyle, Dr. Warren, who relates it,² states that about thirty drops of chloroform were used, and that the time of inhalation, as also the lapse of time from the commencement of inhalation till death, was one minute. Speaking of the symptoms, he says that the patient "showed signs of pain, by putting his hand to the part; in a moment his pulse, which was full and natural, sank; death." The cause and manner of death were evidently the same as in the last case; and it is probable that the quantity of chloroform used was under-estimated.

In the fifth case, that of Mdle. Stock, of Boulogne, death took place in nearly the same manner as in the above cases. The surgeon said, "I placed over the nostrils of the patient a handkerchief, moistened with from fifteen to twenty drops at the most, of chloroform." It is necessary to remark, that a judicial examination of the bottle from which it had been taken, proved that from five to eight grammes had been used, a quantity equal to from 77 to 123 minims; and, as there are about four drops and a half of chloroform in each minim, the amount used was more than twenty times as great as first stated. The surgeon proceeds to say of his patient, "Scarcely had she taken several inspirations, when she put her hand on the handkerchief to withdraw it, and cried with a plaintive voice, 'I choke'. Immediately the face became pale; the countenance changed; the breathing embarrassed; and she foamed at the mouth. At the same instant (and that certainly less than a minute after the beginning of the inhalation), the handkerchief moistened with chloroform was withdrawn."³ The operation of opening the sinus was immediately performed; but the patient showed no signs of life, and the operator believes that she was dead when he made his incision.

The only information I have met with respecting the sixth case, is that contained in the table of Bouisson previously referred to. Chas. Desnoyers, aged 22, a patient in the Hôtel Dieu at Lyons, affected with scrofulous disease of the left wrist, having to undergo transcurrent cauterisation of the joint, inhaled chloroform from an apparatus

¹ Ibid. p. 84.

² Ibid. vol. xliii, p. 682.

³ Ibid. xlii, p. 211.

for five minutes, and died at the beginning of the operation. The only particulars which are generally known of the seventh case, also, are confined to a short paragraph, which appeared in the *Glasgow Herald*, and was copied into the medical journals. It was stated that the patient died almost instantly after inhaling the chloroform.

Of the next case in the list, we are furnished with particulars by Dr. Warren.¹ The patient was somewhat excited by the chloroform at first, but soon became tranquil; the operation of removing some hæmorrhoidal tumours was then performed. "At this moment," the surgeon says, "my attention was arrested by my assistant calling for a wet cloth: on examining the patient, I found his face and neck of a livid, leaden hue, the eyes turned upward, the pulse imperceptible at the wrist, and the whole body relaxed; after two or three gasps, he ceased to breathe." He likewise says, that "not exceeding three drachms was administered from a napkin", and that about ten minutes elapsed from the commencement of its administration before death took place."

A very precise account has been given of case number nine.² It occurred, like the sixth case, at the Hôtel Dieu, Lyons, the subject of it being also a young man. "As usual, a piece of fine gauze was employed; it was spread over the face, leaving a free passage for atmospheric air; the chloroform was dropped from time to time upon that portion of the gauze which was over the nostrils. . . At the end of four or five minutes the patient still felt and spoke; and at the end of another minute he spoke, and was somewhat restless. Up to this time, from a drachm to a drachm and a half of chloroform had been employed. The pulse was regular, and of the normal strength. All at once the patient raised his body, and struggled so that the limbs escaped from the hold of the assistants, who, however, seized them quickly, and replaced the patient in his position. Within a quarter of a minute, one of the assistants stated that the pulse at the wrist had ceased to beat. The handkerchief was removed. The countenance was completely altered. The action of the heart had altogether ceased; the pulse could not be felt anywhere; and the sounds over the region of the heart could no longer be heard. Respiration still continued, but it became irregular, weak, and slow: and at length ceased completely, in the space of about half a minute." Various stimulants were applied to the nostrils and skin, and finally pressure was made on the chest and abdomen. "After two or three minutes, respiration reappeared, and even acquired a certain degree of fulness; but the pulse nowhere returned. Frictions were continued. Respiration became again slower, and at length ceased." In this case, we have clear proof that the action of the heart was arrested by the chloroform whilst the breathing still continued, as in the experiments Nos. 3 and 5, on animals, previously related. In this instance, the air which the patient breathed must for some time have contained very little vapour; and then it evidently became charged with it to such an extent as to so saturate the portion of blood passing through the lungs at the time, that on reaching the aorta and coronary artery, the heart became paralysed, before the sensibility of those parts of the nervous system which preside over respiration was abolished.

¹ Med. Gaz. vol. xliii, p. 712.

² Ibid. vol. xliii, p. 745, from L'Union Méd.

In the case of Samuel Bennett, half an ounce of chloroform was "sprinkled on a handkerchief, and held over the mouth and nose. . . This quantity of the agent failed, however, to produce anæsthesia, having caused only the ordinary excitement and struggling". After a delay of two hours, more chloroform was procured, and half an ounce was again applied on a handkerchief, "care being taken to allow the entrance of air at short intervals". Insensibility was induced, and the toe was amputated; the chloroform being applied, as I was told, during part of the time of the operation. At the close of the operation, no blood escaped when the pressure was removed from the arteries; the patient was in fact dying, and in a short time expired. "A few inspirations were noticed after the pulse had ceased at the wrist".¹ In this, as in two subsequent cases, the first attempt to cause insensibility failed; a circumstance which illustrates the uncertainty of the method that was employed to give the chloroform, and which affords additional proof of the fallacy of the opinion which attributes the accidents to idiosyncrasy, or peculiar susceptibility; for it cannot be supposed that a patient could be the subject of two opposite idiosyncrasies, or could have a want of susceptibility on the first occasion, and a greater susceptibility than usual two hours afterwards.

Of the next case—that of Mdme. Labrune—we are told, "complete insensibility was not produced at the first trial: more chloroform was placed on the handkerchief, and she drew a full inspiration. Her countenance immediately became pallid; her features were visibly altered; there was dilatation of the pupils, with a convulsive rolling of the eyes; and no pulse could be felt. Every attempt was made to restore life, but without success. She died as if struck by lightning".² The instantaneous arrest of the circulation, on a full inspiration being taken, immediately after more chloroform had been placed on the handkerchief, is particularly worthy of notice. The heart was paralysed, in this instance, as quickly as in experiment No. 4, on the rabbit; and this accident, amongst others, illustrates and confirms the calculations which were made, in the former part of this paper, on the probable effects of 100 cubic inches of air, charged with ten per cent. of vapour, in the cells of the lungs.

The twelfth case occurred in St. Thomas's Hospital. The chloroform was administered by a non-medical person—a sort of surgery man. An inhaler was used, though, in my opinion, not one of the best construction. It was when Mr. Solly had just removed the toenail that the danger of the patient was perceived. "After struggling for about a minute, he became still, the skin cold, pulse scarcely perceptible, and soon ceased to be felt at the wrist; respiration became slow and at intervals, but continued a few seconds after the cessation of the pulse".³ The impropriety of entrusting the administration of chloroform to a non-medical person, however able the on-lookers may be, having, I believe, been generally admitted, I need not enlarge on that point, but would observe that in this, as in several other cases, it was whilst the attention of every competent person present was absorbed by the operation, that the dangerous symptoms commenced.

¹ Lancet, 1849, vol. i, p. 205.

² Med. Gaz., vol. xlv, p. 478, from L'Union Médicale, Sept. 8, 1849.

³ Ibid. p. 757.

In cases 3, 10, and 16, it was the absence of bleeding which called attention to the dangerous state of the patient.

I am not aware that full particulars have ever been published of the next case, that of a girl named Jones, who was about to undergo extirpation of the eyeball. It is stated, however, that a drachm of chloroform was used, and that she expired instantaneously.¹

In case fourteen, that of a young lady at Berlin, the chloroform was poured on a sponge, which was covered with a napkin. The dentist (not a medical man) made five unsuccessful attempts to get his patient sufficiently insensible; and when he did, what was most likely to happen under such circumstances, he committed an error in the opposite direction. His patient suddenly died, almost at the commencement of his sixth attempt, stretching herself out, and frothing at the mouth, at the moment of death. There is no account of the pulse or respiration.²

The case which occurred on board ship at the Mauritius, was included in a list of deaths I made out in 1850;³ but I am not aware that it has been otherwise published. A report of the case was sent to the Board of Ordnance, and also to the Admiralty. I had the opportunity of reading one of these reports, through the kindness of the nobleman at the head of the department to which it was sent, and I made a note of the chief particulars, as soon as I got home. As the report was a very able one, it is to be regretted that it has not been published. The accident occurred to an artilleryman, aged 24, who required to have the last phalanx of the middle finger removed. In other respects, he was considered to be in good health. Two scruples of chloroform were first poured on the handkerchief with which it was administered, and then one scruple more. It was observed that the face turned pale, and the pulse and breathing ceased, soon after the chloroform was discontinued. The measures which were employed to restore him were of no service. The lungs, after death, were found to be emphysematous; and, upon inquiry, it was ascertained that he had been short of breath on exertion. The reporter considered that the emphysema was the cause of death, by interfering with expiration, and thus detaining the vapour; and it must be admitted that, if the vapour were not sufficiently diluted with air, the emphysema would increase the danger. At the same time, I have had practical experience to show that, when it is sufficiently diluted, it may be safely inhaled, even in extreme cases of emphysema.

The case at Guy's Hospital, is one of those in which the first endeavour to cause insensibility failed; and also one of those in which the sudden cessation of bleeding was the means of calling attention to the danger of the patient. Mr. Cock said, in his evidence at the inquest: "The ordinary machine was used, and, as it had not the effect, witness directed that a napkin should be folded into the shape of a cone, which was applied with chloroform. The operation of removing a portion of the bone occupied one minute and a half; but before it was completed, the blood which was gushing out suddenly stopped, when witness directed Mr. Lacy to feel the pulse of deceased, and they found that deceased had expired."⁴

¹ Med. Gaz. p. 1007.

³ Med. Times, vol. ii, p. 230.

² Ibid. vol. xlv, p. 483.

⁴ Med. Gaz., vol. xlv, p. 89.

In case seventeen, which occurred at the Cavan Infirmary, a fluid drachm of chloroform was poured on a bit of lint, which was placed in a hollow sponge, and the sponge was enclosed in a towel. As there was some delay, half a drachm more was added. The patient had not taken more than fifteen inspirations after this, when the anæsthesia was said to be complete. The towel was removed from the face, a slight convulsive action of the left eyelid was observed, and there was some froth at the mouth. On a more minute examination of the patient, he was found to be dead.

There has been no full account published of the fatal case at the Stepney Workhouse. It was stated at the inquest that half a drachm of chloroform was administered without effect, and then half a drachm more was applied, when the patient suddenly expired. I was informed by a medical man, living in the neighbourhood where this case happened, that the handkerchief on which the chloroform was administered was tied behind the head of the patient; but, as my informant was not an eye-witness, I cannot state with certainty that such was the fact.

Case nineteen on the list is important, as having given rise to a prosecution. The medical man, an officier de santé, named Kobelt, was accused of homicide, by imprudence, want of precautions, etc. The chloroform was administered on a handkerchief, and the accident occurred as suddenly as any of the others. The husband of the patient stated that the whole process did not last a minute. "I observed attentively," he said, "during this time, and the character that her countenance took all at once made me apprehensive. I spoke of it to the operator, who tranquillised me, and continued to extract the teeth. After the third tooth, however, he partook of my apprehension, suspended the operation, and proceeded to adopt measures indicated by the circumstances."¹ Professor Sédillot, who had to pronounce an opinion on the case, after hearing all the evidence, expressed himself very nearly as I did, when alluding, on a former occasion, to the death which occurred in Westminster.² He said: "I do not think that M. Kobelt is guilty of imprudence or of rashness, because that officier de santé has followed a practice very habitually employed, and even recommended, by eminent practitioners, whose example and authority were sufficient to inspire him with security, and shade him from reproach." The accused practitioner was acquitted. The above remark of Sédillot applied to the plan of causing insensibility very rapidly, as first recommended by Dr. Simpson; and he added some observations, to the effect that, when used in a different manner, chloroform is free from danger.

In the case at the Dreadnought Hospital Ship, all the precaution seems to have been taken that is possible in giving undiluted chloroform on a handkerchief; and, if the quantities that are mentioned as having been poured on were actually measured, this case would strongly confirm the opinion that insensibility cannot be caused in this way, without some degree of danger. Twenty minims, it is said, were poured upon a linen cloth. At the expiration of a few minutes, this had been dissipated, producing only very trifling excitement; a second

¹ L'Union Médicale, 29 Jan. 1852.

² Edin. Med. and Surg. Journ., No. 180.

dose, of the same quantity, was then administered in the same way. Ten minims more were put on the handkerchief, and finally other twenty minims. When the patient was insensible, the operation was commenced; but it had proceeded only a very little way, when the flow of blood and the pulse ceased at the same moment. The breathing also stopped at the same time, but the man afterwards took one or two deep sighing inspirations.¹ It is evident that the last quantity of chloroform was inhaled in a too concentrated state, and that the heart was paralysed by the absorption of vapour which was present in the lungs at the instant when the inhalation was discontinued.

We have no account of the manner in which the breathing and circulation ceased in the last case of the list, for no one was observing the patient at the time. The chloroform was administered for the removal of impacted fæces from the rectum, a proceeding which would otherwise have been attended with great pain on account of cancerous disease in the neighbourhood. The medical attendant administered the chloroform on a handkerchief, and used altogether eight or ten drachms. He says: "When I found the arm fall after being raised (a very uncertain sign to rely on), I proceeded to and accomplished the operation. At this time she was not inhaling." On turning his attention again to the state of his patient he found that she was dead.²

Since the former part of this paper was sent to the press a fatal accident has unfortunately happened, in St. Bartholomew's Hospital, to a young man, aged 23, affected with aneurism by anastomosis of the right ear and surrounding soft parts. Mr. Lloyd, having tied the temporal artery the week before, under the influence of chloroform, with advantage, was proceeding to tie an artery between the mastoid process and ramus of the jaw, when the patient suddenly expired from the effect of the chloroform, which was administered by one of the dressers with an apparatus which had been used on the former occasion. In from five to ten minutes the usual effect was produced, the patient having previously struggled much. The operation was then commenced; but no sooner had Mr. Lloyd cut through the skin than it was stated that the pulse had suddenly ceased. The chloroform was at once removed, but in a few seconds the patient had ceased to breathe, and no pulsation could be felt in any of the arteries, or at the heart.³ Under the use of compression, percussion, and other means, the act of respiration was several times performed again, on two occasions, and it is stated that "the circulation was observed to be returning."⁴ I understand that the red colour returned to the face, but have not learnt whether the pulse or action of the heart was distinctly felt or heard. The respiration might cause the colour to return to the face without a true circulation, as I have seen whilst inflating the lungs of still-born children; for if a portion of red blood be mechanically displaced from the lungs by the motion of the chest, it will be sent on by the contractility of the arteries, which continues for some time after death. If the heart had recommenced to beat, complete recovery would most likely have taken place, for such has

¹ Med. Times, 1851, vol. ii, p. 98.

² Med. Times and Gaz., p. 203.

³ Ibid., 1851, vol. ii, p. 620.

⁴ Loc. cit.

been the result, under similar circumstances, in the observations I have made on animals.

I have been kindly informed by Mr. Paget of a death from chloroform, with which I was previously unacquainted. It occurred on May 22nd, 1850, in the practice of Professor Carl Santesson, in the Seraaphim Hospital at Stockholm. In this case also the heart was paralysed by the direct action of the chloroform, and the breathing continued after the heart had ceased to beat, as in some of the other cases. The patient, a man thirty years of age, was affected with hydrocele, and there was some suspicion of disease of the testicle. It was consequently intended to operate on the hydrocele by incision, in order that the testicle, if diseased, might be removed. The chloroform was administered in the same way that Professor Santesson had seen it exhibited by Dr. Simpson, except that it was poured on a little cotton, which was placed at the small end of the cone, into which the folded towel he made use of was rolled. About a drachm and a half was first poured on the cotton, and the patient was told to inhale in long and deep inspirations. This quantity being nearly evaporated in two or three minutes, a drachm more was added. After a few inspirations rigidity and struggling came on: these subsided, but in a little time returned more strongly than before, and the towel was removed from the face until the struggling ceased. The patient, however, not being sufficiently insensible to undergo the operation with the necessary quietness, the towel was reapplied, when, after a few inspirations, the pulse suddenly ceased. The face and the whole surface of the body turned pale, the eyes rolled upwards and inwards, and the breathing became very slow, but full and deep, the intervals between the inspirations becoming longer, until the respiration ceased altogether. The patient died before the operation was begun, and within five minutes from the commencement of inhalation. During the application of various means of resuscitation, including the dropping of cold water *guttatim* on the epigastrium, the breathing returned, and continued for the space of three or four minutes; but the pulse and sounds of the heart did not return.

The above particulars of the mode in which death took place in the various cases of accident, when considered in connexion with the experiments on animals described at the commencement of the paper, show clearly enough that in every instance the air breathed by the patient just before death, was too highly charged with chloroform to be consistent with safety; for if the air contain not more than about five per cent. of vapour, symptoms of danger would exist for a considerable time before death; and even should the inhalation be continued till the patient ceased to breathe, the action of the heart would survive the respiration—a circumstance which has not been observed in any of the fatal cases.

PART III.

I HAVE examined the viscera of the chest, and kept notes of the appearances, in thirty-seven animals killed by chloroform. They consisted of two dogs, twenty-two cats, one kitten, three rabbits, three guinea-pigs, two mice, two larks, and two chaffinches. Many of the animals were opened immediately after death, and the rest within a day or two. The lungs were not much congested in any instance. In seven of the animals they were slightly congested; but, in the remaining thirty, the lungs were not congested. They were generally of a red colour, but in a few of the cats they were quite pale. I ascertained the specific gravity of the lungs of two of the cats, in which they presented the amount of vascularity I have most usually met with. They were weighed first in air, and then in distilled water, and the specific gravity was found to be 0.605 in one instance, and 0.798 in the other. As many of the animals died in a way resembling asphyxia, the respiration ceasing before the circulation, it might at first be supposed that we should meet with the same congestion of the lungs; but, by the time that the respiration is altogether suspended by the action of chloroform, that agent has begun already to influence the heart, which does not inject the blood into the lungs with the same force as when the respiration is mechanically prevented, whilst it is in full vigour. Besides, in the gaspings which so often take place when the heart is ceasing to act, the animal inhaling chloroform draws air freely into the lungs, whilst the asphyxiated animal is prevented from doing so. Mr. Nunneley and Mr. Thomas Wakley met with congestion of the lungs in many of the animals which they killed with chloroform. I am unable to explain how this happened; but Mr. Richardson, who spoke lately at the Medical Society of London, when I read a paper on the subject of which I am now treating, said, "when animals had been killed by it, he had found that the red colour of the lungs was invariable, but those organs were not congested, neither was the brain."¹

As regards the condition of the heart, it was found in the two chaffinches that the right and left auricle were filled with blood, whilst the ventricles were empty. The condition of the heart in the larks is not mentioned, but in all the thirty-three quadrupeds the right auricle and ventricle were filled with blood. In ten of them, these cavities were much distended; and, in some of these instances, the coronary veins on the surface of the heart were distended also. The left cavities of the heart never contained more than a small quantity of blood, not exceeding about a quarter of what they would hold.

The head was examined in only ten of the animals. The substance of the brain was found to be of the natural vascularity, and the sinuses were not very much distended, except in two instances.

With respect to the state of the blood, it may be mentioned, that

¹ Med. Times and Gaz., vol. i, p. 253.

in every instance in which the chest was opened within an hour after death, the blood which flowed from the cut vessels coagulated immediately and firmly. In eighteen of the animals in which the blood was examined in the heart or large vessels, a day or two after death, it was found to be coagulated in ten, loosely coagulated in seven instances, and quite fluid in one instance.

I have not met with air in the blood-vessels, either in the thirty-seven *post-mortem* examinations of which I retain notes, or in any of the numerous other animals that I have opened after they have been killed by chloroform; nor have I met with it in animals killed with ether and various other volatile narcotic substances.

The appearances met with in the cases of accident in the human subject differ somewhat from those described above. In some of the cases, however, the *post-mortem* appearances have been modified by the artificial respiration and other measures employed with a view to restore the patient. The following is a brief summary of the inspection in the fatal cases in which an examination took place after death.

CASE I. Hannah Greener. *Lungs* congested; epiglottis reddened, as also mucous membrane of larynx. *Heart* healthy; dark fluid blood in both its cavities; very little in the left. *Brain*, externally and internally more congested than usual. Liver, kidneys, and spleen, congested¹.

CASE II. Mrs. Simmons. *Lungs* congested, crepitant, no extravasation; congestion of lining membrane of bronchi; great injection of pleura; six ounces of bloody serum in right, two ounces in left. *Heart* flaccid; cavities empty; inner surface of all the cavities deeply stained; six drachms of bloody serum in pericardium. *Brain*. General aspect, colour, and consistence, normal. A larger quantity of blood than usual flowed from the vessels of the dura mater. Superficial vessels of the brain moderately distended. Two or three ounces of fluid blood, intermixed with bubbles of air, flowed from the sinuses of the dura mater. *Blood*, quite fluid in every part of the body.²

The cavities of the heart had evidently been emptied after death by the artificial respiration which was employed; and if the bubbles of air met with in the sinuses of the dura mater did not enter during the dissection, they were probably introduced into the circulation by the rupture of the air-cells, whilst inflating the lungs.

CASE III. Patrick Coyle. *Lungs* studded with tubercles; abscess in each; lower part congested; pleura adherent. *Heart* enlarged, pale, and soft; two or three ounces of serum in pericardium; blood-vessels with dark fluid blood. *Brain*, with its membranes, natural and healthy.³

CASE IV. No inspection.

CASE V. Madlle. Stock. *Lungs* visibly engorged in the lower lobes, "pulmonary vesicles dilated by the air blown in during the last moments of life, with a view to reanimate the patient." *Heart* flaccid, of the usual size; cavities absolutely empty. *Brain* firm; no drops of blood escaped on cutting into it. *Blood* very black. Air was met with in the pulmonary veins, in the carotid arteries, in the veins and

¹ Lancet, 1848, vol. i, p. 161.

² Med. Gaz., vol. xlii, p. 81.

³ Ibid., vol. xliii, p. 683.

sinuses of the head, and in the veins generally throughout the body.¹

In this case also the cavities of the heart had been emptied after death by the artificial respiration. The air-cells were permanently distended by the same cause, and some of them must have been ruptured to allow the air to enter the pulmonary veins, from whence, being passed through the left cavities of the heart, it was forced by the contractility of the arteries into the veins of various parts of the body. Many of the French physicians who have written, or spoken, on this case, seem to have overlooked the circumstance that the arteries have the power of expelling their contents through the capillaries into the veins, after the heart has ceased to act.

CASES VI AND VII. I have met with no account of any examination.

CASE VIII. John Griffith. *Lungs* a good deal congested, and discharged, when cut, a large quantity of bloody serum. *Heart* large; its ventricles and auricles empty; its condition flabby; the substance of the left ventricle rather softer than natural. *Brain* healthy; no other appearances than in persons dying when in full health.² It is not stated whether artificial respiration was performed in this case, but it most likely was.

CASE IX. J. Verrier. *Lungs* of a very black colour, otherwise their tissue was healthy. *Heart* flaccid and empty, [artificial respiration had been performed.] *Brain* normal; sinuses of dura mater contained a considerable quantity of black uncoagulated blood. *Blood*, fluid, except a fibrinous clot on the Eustachian valve of the heart.³

CASE X. Samuel Bennett. *Lungs* of a dark venous hue throughout, a large quantity of blood escaping from them when cut into. Mucous membrane of trachea and bronchi congested. *Heart* rather large but flabby; auricles empty; each ventricle contained about an ounce of semi fluid blood; (the lungs had been inflated.) *Head*. Sinuses and veins contained blood, but not to any remarkable amount. But few bloody points occurred in cutting into the cerebral mass. *Kidneys* congested.⁴

CASE XI. Madame Labrune. No inspection reported.

CASES XII and XIII. No inspection.

CASE XIV. Young lady, Berlin. *Lungs* presented nothing morbid; the bronchi contained a little bloody froth. *Heart* was soft, flabby, and collapsed. Decomposition had commenced in it. Its cavities were empty. The blood was of the colour and consistence of cherry juice. *Head*. The membranes of the brain were slightly congested. The sinuses were not unusually full of blood. The substance of the brain was in its natural condition.⁵

CASE XV. Artilleryman. *Lungs* emphysematous. *Heart*. Its right cavities were filled with fluid blood. *Head*. The sinuses of the dura mater contained less blood than usual, and the brain was pale.

CASE XVI. Alex. Scott. *Lungs* extremely congested. *Heart* feeble and flabby, not particularly distended; about two ounces of fluid blood on the right side; not more than half an ounce on the left. *Head*.

¹ Med. Gaz., vol. xlii, p. 212.

² Ibid., vol. xliii, p. 684.

³ Ibid., p. 745.

⁴ Lancet, 1849, vol. i, p. 206.

⁵ Med. Gaz., vol. xlv, p. 484.

Much congestion of the dura mater; the grey matter of the brain was dark and congested; fluid was found in the subarachnoid space, and a considerable quantity of it in both ventricles. *Kidneys* congested.¹

CASES XVII and XVIII. No inspection.

CASE XIX. Madame Simon. *Lungs* somewhat congested, and emphysematous. *Heart* flaccid, of middle size. Right cavities filled with liquid dark-coloured blood, mixed with some fibrinous clots. The left cavities contained similar blood, in much smaller quantity.² Chloroform was detected in the blood, in the lungs, spleen, and various other organs, by a chemical process nearly the same as one which I employed about two years ago for the same purpose.³ It was detected in the blood even when it had become putrid. As chloroform cannot be perceived by its odour in the dead body, and as the *post-mortem* appearances it leaves are neither striking nor constant, its easy detection by chemical means is of considerable importance. Its presence does not prove, however, that death was caused by chloroform, but only that this agent was taken at or near the time of death; for it can be detected with great facility in portions of the body removed by surgical operation, when the patient is under its influence.

CASE XX. Thos. Hutton. *Lungs* much loaded with fluid blood, and containing a large quantity of serous infiltration. *Heart* flabby and soft; its cavities contained only a very small quantity of dark fluid blood. (The lungs had been inflated.) The muscular substance of the heart was examined with the microscope; "here and there a minute oil globule could be observed in the muscular fibrillæ, but nowhere did this amount to fatty degeneration." *Head*. Vessels of the dura mater, and on the surface of the brain, gorged with fluid blood. A considerable quantity of serous fluid in the cavity of the arachnoid, and a large quantity flowed also from the spinal sheath. The substance of the brain was very soft. (The weather was warm.) *Kidneys* congested.⁴

CASE XXI. No inspection.

CASE XXII. At St. Bartholomew's Hospital. *Lungs*. Their texture was healthy, but they appeared more than usually collapsed and dry. Their large blood-vessels were not over filled. The mucous membrane of the large bronchi and trachea was turgid. *Heart* healthy, natural in its texture. The right auricle and ventricle were distended with blood. The left auricle and ventricle contained very little blood. The blood was all fluid, and presented a brownish purple hue, like that which is usually met with in the spleen. *Head*. Some adhesions of the membranes of the brain, from disease at a previous period. Otherwise the appearances were healthy.⁵

CASE XXIII. At Stockholm. No report of any examination.

It will be remarked, that congestion of the lungs was more frequently met with in the above cases, and to a greater extent, than in the animals which I killed with chloroform; and, also, that the blood was more frequently fluid. A fluid state of the blood is very frequent in sudden death, in the human subject, from any cause, as I have had

¹ Lancet, 1850, vol. ii, p. 21.

² L'Union Médicale, January 29, 1852.

³ Med. Gaz., vol. xlv, p. 321.

⁴ Med. Times, 1851, vol. ii, p. 98.

⁵ Med. Times and Gaz., 1852, p. 319.

many opportunities of verifying; and the reason why it is less often met with in the smaller animals is, probably, because their bodies cool more quickly after death.

As regards the prevention of death from chloroform, it must be evident, from what was previously stated, that the chief means to be employed for this purpose, is to have the vapour sufficiently diluted with air. The methods of ensuring this dilution were previously alluded to; but I should like to observe, in this place, that it would be well if all those who do not feel confident that they can employ chloroform without incurring any risk to the patient, were to confine themselves to the use of sulphuric ether, an agent which is incapable of causing death in the sudden manner in which it has taken place in all the accidents from chloroform previously detailed.

Many persons at one time supposed that the deaths from chloroform were caused by a want of care in selecting the cases for its employment—an opinion natural enough in those who had not had the time or opportunity to study all the physical conditions connected with the exhibition and action of the agent. The particulars of the fatal cases which have occurred show, however, that the unfortunate results did not depend on any peculiarity of the patients; and the truth is, that whilst chloroform, if not well managed, may cause the death of the most robust and healthy person, it may, on the other hand, with due care, be safely administered to the most feeble and diseased, as I have had numerous opportunities of observing. It is, undoubtedly, both proper and desirable to take into consideration every circumstance connected with the condition of the patient, before administering chloroform; but, wherever there is severe pain to be prevented or removed, it may, according to my experience, always be employed without ill consequences, if sufficient care be observed.

There is a very general impression, that the use of chloroform is unsafe where disease of the heart exists, although no good reason has been given for this impression. I may remark, in the first place, that no great amount of disease of the heart has been met with in any of the fatal cases of administration of chloroform, in which the body has been examined; and, in the second place, that I have several times given this agent during surgical operations, when very marked disease of this organ existed, and to a great number of old people, in whom the arcus senilis in the cornea might lead to suspicion of its being affected with fatty degeneration. The fact of chloroform being able to arrest the action of the heart, might appear to indicate that it is prejudicial to that organ; this circumstance, however, does not arise from any peculiarity in the mode of action of this agent, but only from its physical properties being such that it is capable, under certain circumstances, of being absorbed in sufficient quantity to narcotise the heart. I find that sulphuric ether will produce the same effect, if the inhalation be continued by artificial respiration as soon as the natural breathing ceases; and that diluted alcohol will also arrest the heart's action, if it be injected into the coronary arteries immediately after death, whilst contractions are still taking place. The action of chloroform on the circulation, when sufficiently diluted with air, is that of a stimulant. It has a very marked effect in preventing syncope during

surgical operations; and, as syncope is attended with danger in diseases of the heart, there is reason to believe that the careful administration of chloroform is a means of safety to patients who, notwithstanding the heart disease, have to undergo an operation. Moreover, the pain of even a slight operation has generally the effect of accelerating the pulse to about twice its natural frequency; and it is well known that mental excitement, muscular exertion, or any other cause which has such an influence on the circulation, may occasion sudden death where there is disease of the heart; but, as the pulse usually remains of its natural frequency and force during an operation under the effects of chloroform, this circumstance further confirms the conclusion that the careful use of this agent is a source of safety, and not of danger, to the patient with heart disease. In these patients, however, I think it desirable to conduct the inhalation in such a manner that excitement and struggling may be avoided, and not to prolong the use of chloroform longer than is absolutely necessary, for protracted insensibility is sometimes followed by depression. I am happy to be able to quote the opinion of Dr. Sibson, who has paid great attention to the subject of chloroform, in favour of its employment under certain circumstances where there is disease of the heart. He says, "persons the subjects of heart disease, when the dread of a severe operation is great, may sometimes be peculiarly benefited by the careful and short production of anæsthesia during the cutting part of an operation."¹

It remains now to treat of the measures to be adopted in case of an overdose of chloroform; and it may be remarked in the commencement that, in any case in which the respiration and circulation both continue after the lungs have been emptied of the chloroform which was contained in them at the moment when the inhalation was discontinued, the patient will most likely recover, however alarming his symptoms may appear; for at this moment he begins to get rid of the chloroform, by its being exhaled from the blood as it passes through the lungs.

From the good effects of dashing cold water on the surface, applying ammonia to the nostrils, and using means of a similar character, for exciting respiration in certain cases of narcotic poisoning, it might at first be supposed that like measures would be very useful in accidents from an overdose of chloroform. It must be borne in mind, however, that in the ordinary and safe administration of this agent, when it is desired that the patient should lie without flinching during a surgical operation, the sensibility is often temporarily diminished to the extent that no reflex motions are caused by the strongest stimuli that can be applied; and it is impossible that a further dose of chloroform should restore the sensibility. I have dashed cold water on animals, and applied ammonia to their nostrils, without the slightest effect, whilst the insensibility was kept within safe bounds; and, on one occasion, Mr. Marshall and I found that the strongest ammonia produced no effect on a guinea-pig, at a time when it was still sensible to having the nose and feet pinched with the forceps. In cases in which the action of the heart might be arrested by the influence of a

¹ Med. Gaz., vol. xlii, p. 111.

few ounces of blood overcharged with chloroform, whilst the body at large was not insensible, these ordinary excitants of respiration might have some effect. There would, therefore, be no impropriety in trying such means, provided they were not allowed to occupy the time which ought to be employed in more important measures; and patients have recovered under their use, who appeared in danger; but it is most probable that these patients would have recovered spontaneously, if nothing had been done, for I have in numerous instances observed the unassisted recovery of animals that appeared dead from the effects of chloroform.

The most important measure in the treatment of a case of threatened death from chloroform is artificial respiration, which, I believe, would restore the patient in most instances, if it were put in force within half a minute after the natural breathing had ceased.

The following experiment, in which I was assisted by Mr. Marshall, shews the success of this measure on an animal, when promptly applied.

EXPERIMENT VII. A cat was made insensible by breathing chloroform in a large jar. An incision was then made in front of the neck, the trachea was opened, and a tube was introduced and secured. A bladder, filled with air containing four per cent. of vapour of chloroform, was attached to the trachea tube, by means of a stop-cock, with which it was armed. The stop-cock being opened, the cat breathed to and from the bladder. The capacity of the bladder was a hundred and twenty-five cubic inches, and five minims of chloroform had been introduced previously to filling it with the bellows. A fresh bladder, of the same size, charged with chloroform and air in the same manner, was substituted every three or four minutes for the former one. After a time, the breathing began to be feeble, and, twenty minutes after the inhalation from the bladder commenced, it ceased altogether. The action of the heart continued, however, to be very distinctly heard with the stethoscope for half a minute, when its pulsations were becoming slow. At this moment the stethoscope was removed, in order that I might assist in commencing the artificial respiration, which was performed by attaching a bladder filled with air to the tube in the trachea, and making gentle pressure on the bladder about thirty times a minute. On listening to the chest again, just after the artificial respiration had been commenced, the heart was heard beating with extreme rapidity. After the artificial respiration had been performed for about a minute, the cat was observed to breathe of itself. The bladder was removed, and it was allowed to breathe through the tube. It began to show signs of sensibility almost immediately, and in ten minutes it had recovered nearly altogether from the effects of the chloroform. At this time the cat was made to inhale air containing ten per cent. of vapour of chloroform; twelve and a half minims having been put into one of the bladders previously used. Both the breathing and the heart were soon affected, the breathing being at times very quick, and at other times feeble, and the action of the heart being rapid, and occasionally almost inaudible. At the end of about three minutes the bladder was changed for another, containing the same quantity of chloroform and air; and, in three minutes more, or six minutes after the beginning of the inhalation, the cat ceased to breathe. The heart's action had become almost inaudible before the breathing ceased. It was, however,

just perceptible afterwards, though very feeble and indistinct. Artificial respiration was set up as before, with a bladder full of air, within half a minute after the cat ceased to breathe. In a little time the action of the heart became more audible, and in a minute or two the cat breathed by its own efforts. In a very few minutes, and before the animal had recovered its consciousness and voluntary motion, the experiment of making it breathe air charged with ten per cent. of vapour was repeated in the same manner. Two bladders were used as before, and the breathing ceased again in six minutes. The sounds of the heart became very indistinct a little time before the breathing ceased, and, when the cat ceased to breathe, no sound of the heart could any longer be heard. Artificial respiration was commenced immediately, and, in about half a minute, feeble and rapid sounds of the heart could again be heard. In a minute or two the heart's action was very audible, but it was two or three minutes before the breathing recommenced by the muscular action. In two or three minutes more the cat was in a fair way to recover altogether from the effects of the chloroform, when it was made the subject of a different kind of experiment.

I believe that the breathing would have recommenced after the first inhalation, and that the cat would have recovered spontaneously, without the aid of the artificial respiration; but I consider that its restoration after the second, and more particularly after the third inhalation, was entirely due to the artificial respiration; for I have never seen an animal recover without assistance, when the breathing and action of the heart had been simultaneously arrested by chloroform. The success of the inflation of the lungs was, however, altogether owing to its being promptly performed. I have often opened the trachea of animals as quickly as I could after the breathing ceased from the effects of chloroform, and then performed artificial respiration, but without ever restoring them; for the short delay occasioned by having to open the trachea, has always prevented the success of the measure.

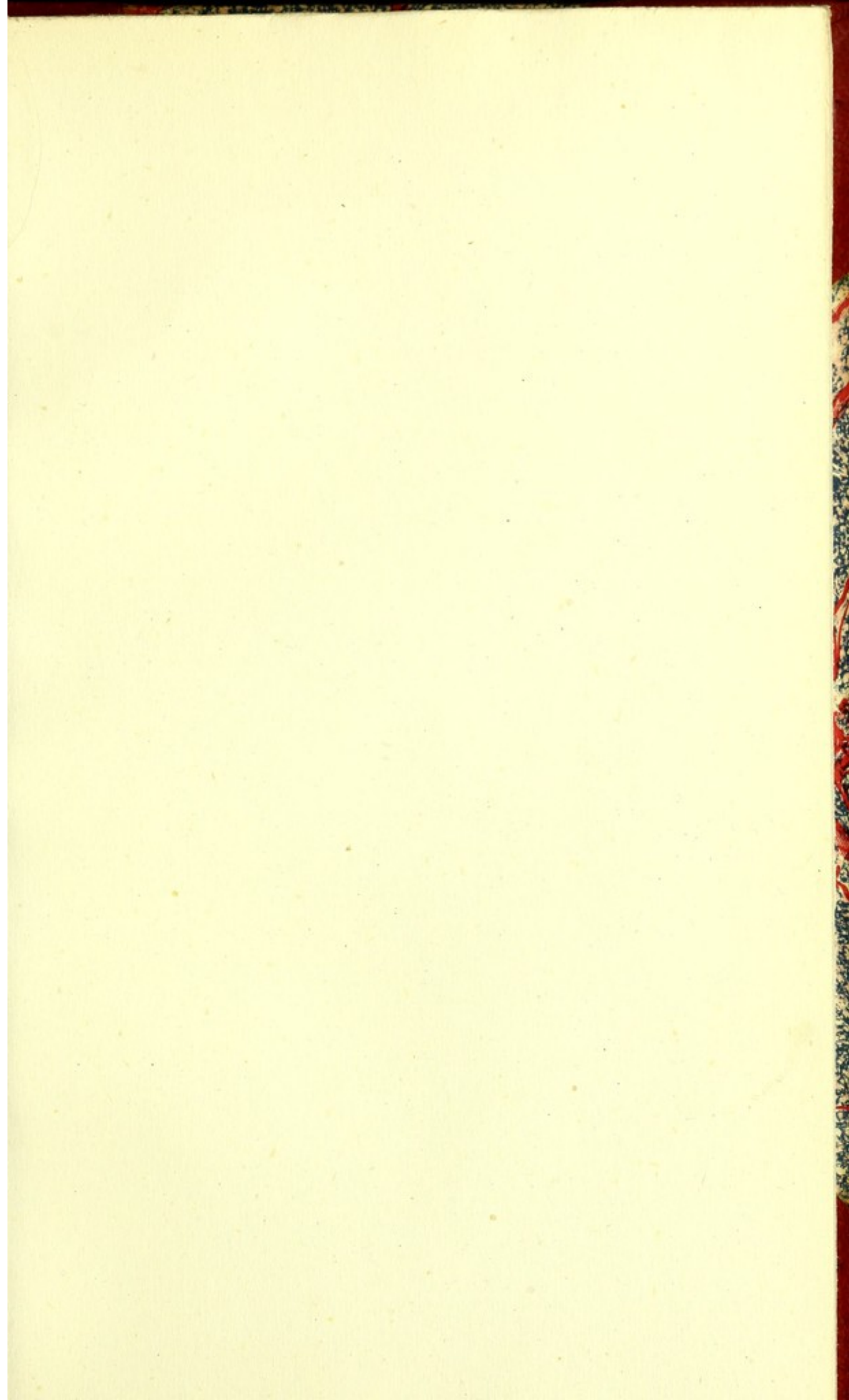
The only kind of artificial respiration that could be performed with sufficient promptitude, in cases of accident in the human subject, would probably be by applying the mouth to that of the patient, and either inflating the lungs, whilst the larynx is pressed back against the œsophagus, to prevent the air from going into the stomach; or else drawing as much air as possible from the lungs of the patient by a strong inspiration, and allowing them to be filled again by atmospheric pressure. In cases such as that of J. Verrier, at Lyons, the case at Stockholm, and some others previously related, where the breathing continued a little time after the heart had ceased to act, it is probable that the heart is so overpowered by the chloroform as to be past recovery, otherwise the breathing would restore its action: however, it would obviously be right to continue the breathing by artificial means after it should cease; and either in these, or in any other cases in which the artificial respiration should not restore the patient in a minute or two, it would be desirable to open the external jugular vein, and allow some blood to flow, whilst still keeping up the artificial respiration. We have seen that the right cavities of the heart generally become distended with blood in death from chloroform, and this distension may obviously offer an impediment to its returning action. I have not

succeeded in restoring any animal by opening the jugular vein after artificial respiration had failed; yet I have noticed in opening the chest immediately after death, that the feeble contractions of the heart which still continued, were improved in force and extent by opening a vein and relieving the distension of the right ventricle.

I have frequently tried to restore animals by electricity, but have never succeeded, except when it was probable that spontaneous recovery would have taken place. When the breathing has been arrested by the continued action of chloroform, and the heart has been still acting, electricity has always restored the animal; but, as was previously stated, spontaneous recovery is very apt to take place under such circumstances; a very little assistance in the way of artificial respiration is always successful; and, moreover, none of the accidents in the human subject have happened in this manner. When, however, the action of the heart has been arrested by chloroform, I have never succeeded in restoring animals by electricity. I have applied it by means of Neeves' electro-magnetic battery, sending shocks through the chest, and also applying one wire to the nostrils, or back of the neck, and the other near the insertion of the diaphragm, and breaking and renewing contact, so as to keep up some amount of respiration. Notwithstanding this want of success, electricity is one of the means which might be tried in case of accident to a patient; but it is obvious that the chief measure to be relied on is artificial respiration put in force very promptly, and that blood should be taken from the jugular vein, if the patient does not very quickly begin to show signs of returning animation.

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