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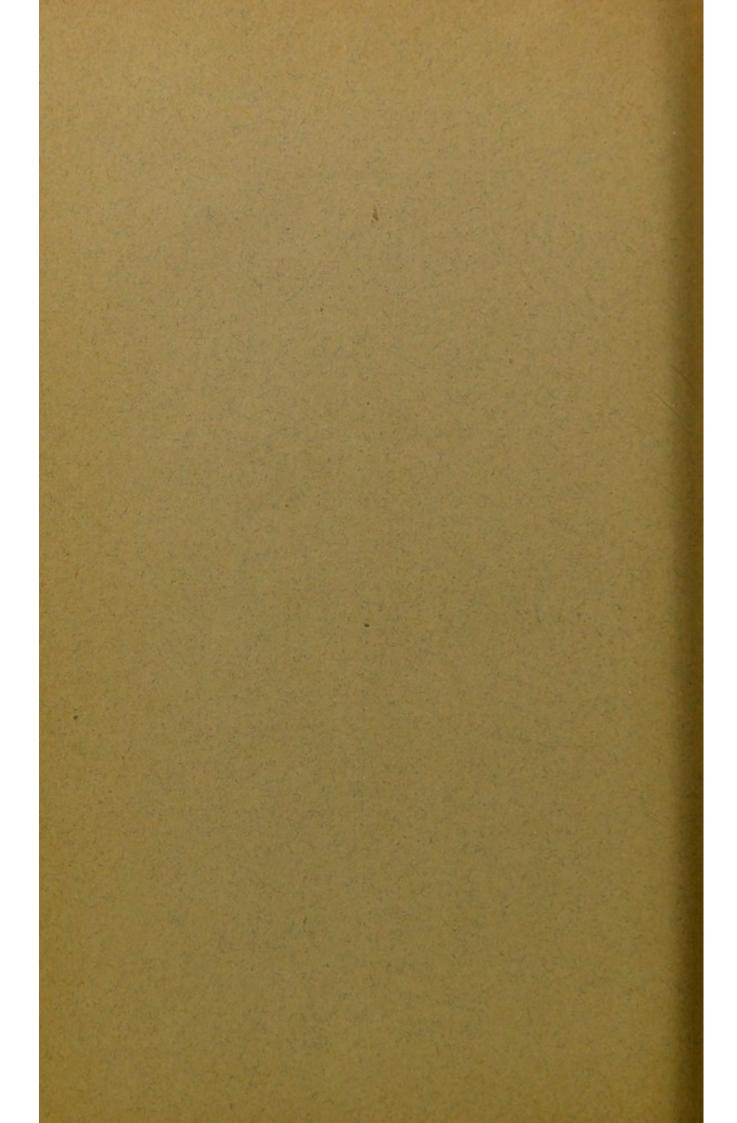
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CONCUSSION OF THE SPINAL CORD, BRAIN, ETC.

The term "concussion of the spinal cord" is commonly used in a very loose and indefinite manner. In some instances its use is restricted to those cases in which the functions of the cord are temporarily disturbed, independently of any discoverable lesions ; while in other instances it is made to include cases in which there are hæmorrhagic extravasations into the substance of the cord, or even a contusion of its membranes. Mr. Erichsen has employed the term in even a broader sense than that which includes the punctate hæmorrhages, etc., since he embraces the following conditions: 1. A functional disorder. 2. Compression of the cord from extravasation ; compression of the cord by inflammatory exudations ; nutritive cord alterations. It is therefore apparent that Mr. Erichsen, when he employs the term "concussion of the spine," intends to include all morbid conditions arising either primarily or secondarily from traumatic injuries not connected with fractures or dislocation of the vertebræ. In our consideration of "Concussion of the Spinal Cord, Brain, etc.," we shall include all those morbid and pathological conditions arising from the application of concussive force to these organs. By concussive force we mean that agitation communicated to one organ by a fall or blow upon another. For the purpose of illustrating this idea, let the force be applied to

the nates while the spinal column is maintained in an erect position, then there will be carried along this bony structure a vibratory motion which will also be imparted in varying degrees to the adjacent soft parts. A careful study of the anatomical structure of the spinal column and cord, their relation to each other, and likewise their relation to other organs, especially the brain, lungs, liver and kidneys, when examined in connection with the seat of the application of the concussive force, possesses a very high degree of interest. It will be readily observed that the normal curves of the spinal column cannot fail to exert an influence on the localization and character of the pathological lesions produced by a concussive force applied to the nates. It is likewise true that these curves exert a modifying influence on *all the lesions* resulting from concussive force; but the same can only be intelligently studied when the surgeon fully understands the nature of the power employed and the locality to which it has been applied. In order to illustrate this subject more clearly the reader's attention is directed to the following cut, in which the antero-posterior curves of the spinal column may be studied. These curves correspond to the different regions of the column, and are designated cervical, dorsal, lumbar and pelvic.

The examination of this figure makes it readily apparent that if the concussive force is applied to the nates while the spinal column is maintained in the erect position, the greatest power will be brought to bear on the sacro-vertebral articulation. The chief factors entering into this calculation are leverage and the superincumbent weight of the body. It likewise logically follows that if the centre of gravity be thrown either forward or backward the resulting traumatisms may

be materially modified. I am now prepared to show by the results of numerous experiments that the conclusion which I have expressed is strictly correct.

In a brochure which I have recently published, entitled, "An Experimental Study of Lesions Arising from Severe Concussions," there will be found a report of 141 experiments. In 135 of these experiments the concussive force was received on the nates, and besides the other traumatisms thus produced there were eleven cases of rupture of the spinal ligaments, and ten of this number occurred at the sacro-vertebral articulation, and the other between the fifth and sixth cervical vertebræ. It was still further observed that in six cases there was a considerable amount of blood extravasated within the pelvic cavity, and in five cases there were ecchimoses in the psoas muscles. The examination of the report of these experiments also shows that there were four cases of fractures involving the spinal vertebræ, and two of these were located in the lumbar region. I think it will now be readily admitted that true concussive force exerts the highest possible degree of potency on the spinal cord when applied to the nates while the body is maintained in the erect position; and, furthermore, that the most marked and numerous traumatic lesions observed in these cases are associated with injuries of the spinal column in the lumbar region. Let us now enter on the consideration of several important questions bearing on the etiology of spinal concussion.

1. Are there any cases of this morbid condition arising from concussive force in which the functions of the spinal cord are temporarily disturbed, independently of any discoverable lesions?

2. Are any of the following pathological conditions, viz.: punctate hæmorrhages, hyperæmia, blood in the perivascular spaces of the gray matter, etc., ever produced by concussive force while the bony walls of the spinal column and the ligaments of the same remain in the normal state?

3. How, and by what sort of force, are these morbid conditions most frequently caused?

Let us here attempt a seriatim reply to these queries. I therefore think it wise to inform my hearers that in my consideration of these questions I shall view my subject from the standpoint of a surgeon, rather than that of an alienist. The essential difference between the surgeon and the alienist is that the former presents his views from the standpoint of demonstrated facts, while the latter accepts a theory and then attempts to make all else conform to the god which he has erected. In other words, surgery is to-day essentially an exact science, while insanity rests entirely on a speculative basis, and, therefore, it can only be regarded as a pseudo science.

It will be here observed that when this question is examined from a pathological standpoint there *can be only negative evidence adduced*, and this would scarcely justify an affirmative answer. My experimental studies have added nothing in the affirmative, but, on the contrary, have materially strengthened the negative side of the question. I am therefore constrained, by the want of space, to answer this question negatively, although it is quite possible that by so acting I open myself to the charge of dogmatism.

In attempting an answer to the second query I shall preface my efforts by calling attention to the anatomical structure of the spinal column and cord, and their relations to each other, and afterwards bring forwards the results of my ex-

perimental studies for the further elucidation of this important question.

It can be readily seen that no part of the human skeleton plays a more important rôle in the preservation of life by protection of vital organs than the spinal column. Within this bony column is situated the spinal canal, beautifully and perfectly arranged for the reception of the spinal cord. This highly important structure is composed of thirty-three vertebræ, and these are artistically and strongly fitted together in such a manner as to allow every necessary movement, since the spinal column is both flexious and flexible. The articular surfaces of the vertebræ are covered with cartilages exactly suited to their wants. The various bony processes projecting from the vertebræ serve as the point for the attachment of muscles, and at the same time as a *cheval de frise* in warding off blows from the citadel. The numerous heavy muscles of the back serve to cushion externally, and thus protect the spinal column. In addition to this they afford a support and protection to the deeper seated tissues, and likewise give the required motions.

The segmentation of the spinal column possesses, in some cases, when the concussive force is applied in certain directions, a highly important modifying effect. The cartilagenous coverings of the articular surfaces, and also, to some extent, the osseous structure of the vertebræ themselves, act as cushions or buffers, by which the concussive force is greatly diminished at each articulation. This principle has been long understood, and is now generally applied to all the passenger trains on railways. Let us now present a few practical points connected with the anatomy of the spinal canal and the spinal cord, without entering into a full consideration of the anatomi-

cal structure of these parts, which can be readily
examined by a reference to the text books on this
subject. The spinal canal serves for the passage
of the spinal cord, and presents everywhere a
markedly smooth and even surface, which is lined
by the medullary membrane. It is also so large
that the spinal cord and its membranes are at no
point adherent or in contact with it ; in fact they
do not nearly fill it. The bony wall of this canal
is everywhere cushioned with connective or adi-
pose tissue, and the intervening space is filled
with spinal fluid. The spinal cord is wrapped by
the spinal membranes, and this is surrounded by
the spinal fluid, and every vertebral nerve is so
placed as to act as a most efficient stay, thus pre-
venting any swaying or other motion. Dr. Byron
Bramwell, of Edinburgh, says : "The relation-
ship of the cord and the nerve roots to the spinal
membranes (dura, arachnoid and pia) is of great
practical importance, and is as follows : The
spinal dura mater is a dense, tough membrane,
which is loosely attached externally to the bones
of the spinal canal, being separated from the
periosteum by loose areolar tissue, fat cells and
blood vessels, which forms a loose covering or
sheath for the spinal cord and its nerve roots,
surrounded by the pia, arachnoid and spinal
fluid."[1] The following illustration, it is thought,
will greatly facilitate the study of the relationship
of the cord and nerve roots to the spinal mem-
brane, while it also affords a very correct idea of
the relation of the spinal cord to the spinal col-
umn and other important parts.

Let us now turn our attention to certain ana-
tomical peculiarities which possess important
relative bearings on concussion in these organs.

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[1] " Diseases of the Spinal Cord," p. 14 *et seq.*, 2d edition, 1884.

We have already observed that the spinal cord is wonderfully protected against any injury from concussive force. It will now be seen that the anatomical peculiarities of the surroundings of the brain especially endanger the safety of this organ from that force. It is stated in the standard text books on human anatomy that the weight of the spinal cord is about thirty-three per cent. of the weight of the brain.

The weight of the brain, being so much greater than that of the spinal cord, increases greatly the liability of this organ to injury from concussive force. All the advantages arising from the buffer action, which has been previously mentioned, is lost, in case the concussive force is applied to the cranium, and the whole momentum of the blow will be transmitted directly from the skull to the encephalon.

Furthermore, we have called attention to the fact that the spinal canal is everywhere cushioned with areolar and adipose tissue, and likewise that the space intervening between this bony wall and the spinal cord is filled with spinal fluid. The encephalon, on the contrary, possesses no such protection against concussive force. In this case the membranes of the brain are placed in immediate contact with the bony walls of the cranium, without the intervention of soft tissue cushions or the presence of a water bed. The following cut presents a view of a portion of the encephalon, and likewise the entire spinal cord in its relation to the spinal nerve roots and some of the other surrounding parts.

Our own experimental work was done on dogs; and, therefore, that the anatomical peculiarities of these animals may be compared with those of man, we have here introduced the following illustration, which presents both the anterior and

posterior view of the spinal cord, spinal nerve roots, etc.

The whole number of these experiments were 141, but there were only 46 of these cases in which pathological lesions were produced in the cerebro-spinal axis or its membranes.

There were twenty of these forty-six cases in which the post mortem examination distinctly revealed a want of continuity in the spinal column, and these complicating injuries were as follows: Rupture of the vertebral ligaments, 11; fractions involving the bodies of the vertebræ, 5; stretching of the vertebral ligaments, 4. It will now be observed that there are twenty-six cases in which the spinal column apparently remained uninjured. There were four cases in these twenty-six which were complicated with lesions which quickly terminated in death. It will likewise be seen by a reference to the accompanying explanatory notes[1] that there are six other cases included in our total of cerebro-spinal lesions where the question of the causation of these pathological changes justly raises the query—shall they not be excluded in this enumeration ?[2]

Notwithstanding all this it must be admitted that these experiments have conclusively shown that pathological changes in the spinal cord, corresponding to those mentioned in the second query (2), may be produced by concussive force, while the bony walls of the spinal column and its ligaments remain in their normal state. The answer of the second query likewise includes in some degree the reply to the third question, since it shows that in the spinal cord concussive force may produce pathological changes. In fact, it must be self-evident to us that these pathological changes occurring when there is neither

a fracture of any portion of the spinal column, a rupture of the spinal ligaments, or a stretching of the same can only be caused by a true concussive force.

The next point demonstrated by our experimental studies is, that the force required for the production of these lesions must be comparatively very great, since only a limited number of these injuries resulted from a large number of experiments, although the force employed was highly efficient, as is shown by the production of severe and numerous traumatisms in the other organs (4).

In this connection it seems quite proper to call attention to the fact that the more limited the area to which the concussive force is applied, while the force remains otherwise unchanged, the more concentrated and destructive will be the effects produced by it, especially on animal bodies. It may therefore be logically assumed that the same concussive force when applied only to the nates will be much more effective than it would be if distributed over the greater portion of the posterior surface of the body. Bearing directly on this point is the fact that I made six experiments in which the blows were delivered on the posterior surface of the body—along the course of the spinal column, which produced no evidence of any concussion.

I will here affirm that my anatomical and experimental studies of this subject have rendered me absolutely skeptical in regard to the production of pathological lesions in the spinal cord by any concussive force applied evenly over the greater portion of the posterior surface of the body. It must, however, be admitted, that if the concussive force be complicated with any other power which destroyed the continuity of the spi-

nal column, then pathological changes in the spinal cord would be very likely to follow, although this is not an invariable result. True concussive force when thus applied would invariably produce death by traumatic lesions in other organs before its pathological effects would be manifested in the spinal cord. It may therefore be confidently asserted that these pathological changes in the spinal cord are commonly produced by a compound force.

Let us suppose for the purpose of illustrating our views, that the spinal column has been struck by a musket ball which has in some degree impaired its external continuity without producing any lesion in the osseous tissues of the canal; but there are discovered numerous pathological changes in the cord, how are these to be explained?

It will readily be admitted that these lesions are produced in many casss by a direct and concentrated concussive force applied to the spinal column which has been transmitted to the spinal cord.

It will not, however, be claimed by any one that this injury done to the spinal column resulted from concussive force. It will here be acknowledged by all that the injury done to the bony structures was caused by the projectile force given to the bullet by the explosive compound. In other cases a sudden wrench or strain, complicated or not with concussive force, may give rise to similar lesions in the spinal cord.

Here, again, he who carefully studies the anatomy of these parts will be compelled to acknowledge that great force, even of this sort, will be required to produce pathological changes in a healthy spinal cord. Observe the wonderful interlocking and bracing of these bony segments or

vertebræ which form the spinal column. Behold the bony processes or projections thrown out in various directions from the bodies of the vertebræ to protect them from direct force! In addition to all this, contemplate the protection afforded by surrounding and covering these with heavy muscular cushions. It now becomes apparent to us that no trivial jar, twist or strain can result in any injury to the healthy cord; but, on the contrary, it is self-evident that an extraordinary force will be required to produce pathological changes in this centre, a power which can never fail to do serious injury to other organs which are not so well protected. This point is clearly brought out in my experimental work, where I made 141 experiments especially directed to the production of lesions in the cerebro-spinal axis, studiously avoiding, so far as possible, the production of injuries in other parts of the body. The traumatisms were carefully delivered on that part of the body where the greatest portion of the force would be expended on the spinal columd; and what was the result? There were more than three times as many lesions produced in the other organs of the body as in the cerebro-spinal axis. The query suggested by these results is, that if severe traumatisms inflicted especially for the purpose of producing lesions in the spinal cord give us so small a ratio, how frequently might pathological changes be expected to occur in this centre in injuries arising from miscellaneous accidents? It is true that no reply approximating to a mathematical correctness can be here attempted; but it may be reasonably inferred that their occurrence will be very rare, even exceptional, unless the force applied has involved the continuity of the spinal column. In the examination of these accidents the surgeon's

attention is first directed to the nature of the force employed, and, secondly, to that part of the body on which it was expended.

It is by careful attention to these factors that this search for lesions will be primarily directed. Thus far we have only studied the effects of concussive force when applied to the nates and the posterior regions of the body. It therefore remains for us to consider the probable effects which arise from the application of concussive force on the other regions of the body. The statements already made while describing the effects of concussive force when applied to the nates are applicable, within certain limits, to the same force when it is applied to the feet while the lower extremities and body are maintained in a fixed and erect position. But even under these circumstances there would be a considerable loss of power, referable to the buffer action in connection with the articulations in the lower extremities.

However, a much more important subject for our contemplation in this connection is contained in the following question: Will not flexion occur at the articulations in the lower extremities with so much promptitude, under these circumstances, as to wholly obviate all danger? I think there is very little doubt on this point, and, therefore, feel strongly inclined to believe that no pathological changes can ever be produced in the spinal cord by concussive force applied to the feet. Furthermore, it may be boldly asserted, on the basis of correct anatomical knowledge and experimental research, that no amount of concussive force can ever be applied to the anterior or lateral regions of the body, which will be attended with the slightest danger to the spinal cord; since that amount of force which would disturb in the

slightest degree the functions of the cord *could not fail* to destroy life by injury to some of the abdominal or thoracic organs on which the power of the blow must be primarily received.

Having completed our study of the so-called "concussion of the spinal cord," from an anatomical and experimental standpoint, I am thoroughly convinced that neither pathological lesions, nor even functional disturbances, are ever produced in this centre, in a healthy cord, without the application of very great force. It is foolishly absurd to presume that these morbid conditions can have their origin in a slight jar, wrench, or even the application of a moderate concussive force.

My distinguished predecessor, Dr. N. P. Dandridge, Chairman of this Section at the last meeting, gave us an elegant paper modestly entitled, "Surgical Interference in Fractures of the Spine;" but the principles enunciated in it are equally applicable to the treatment of nearly all spinal injuries. I cannot refrain, at this point, from citing a portion of this paper, on which my experimental experience seems to have a very important bearing. Dr. Dandridge informs us: "It is well known that not only a considerable number of these cases escape death, but entirely recover all their functions, even after the existence of paralysis, incontinence and bed sores, existing for a variable length of time. In a valuable paper Burrill has investigated the results of all the cases which have occurred in the Boston City Hospital, eighty-two cases in all, of which eighteen survived. Divided into regions, we find twenty-eight cases of fracture of the cervical vertebræ gave two recoveries ; twelve cases of fracture of the upper dorsal vertebræ, six recoveries ; nineteen cases of fracture of the lower dor-

sal, one recovery; twenty-three cases of fracture of the lumbar vertebræ, ten recoveries. Of the sixty-four fatal cases thirty-five died within five days, eight in from five to ten days, and seven in from ten days to one month. Five of these cases were submitted to operation, all of which were promptly fatal. In the eighteen who survived, the result was good in nine, and in nine complete disability remained permanent. The especial value of Burrill's paper is that it is based on the entire number of cases treated in a single institution, and gives, therefore, more reliable data for deductions than statistics made up of isolated cases."

The statement made in this quotation, that not only a considerable number of cases of fracture of the spine escape death, but actually recover after having developed grave symptoms, is certainly not in accordance with the old preconceived notion. It has long been urged by many distinguished surgeons, among others, Abercrombie, Sir Ashley Cooper, Sir Charles Bell and John Hunter, that even slight injuries of the spinal cord were very apt to lead to fatal terminations. Mr. Erichsen[2] has asserted, in this connection, that "in many of the cases in which sensation is more affected than motion, or in which the principal lesion consists in a modification of sensation coming on immediately after the receipt of a blow on the back, there may be reason to suspect laceration of the gray matter, with extravasation of blood into it. Hammond mentions two cases in which incurable paraplegia followed supposed spinal hæmorrhage. Speedy death, however, most usually occurs as a consequence of such an injury."

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[2] "Concussion of the Spine, Nervous Shock, etc.," by John E. Erichsen, pp. 71 and 74. Wm. Wood & Co., New York, 1875.

The same author has also added that "Boyer had long since noticed the very interesting practical fact that when the interspinous ligaments were ruptured, in consequence of forcible flexion of the spine forwards, no fatal consequences usually ensue, the integrity of the parts being restored by rest; but that when the ligamenta sub-flava are torn through and the arches separated, paraplegia and death ensue. This he attributes to stretching of the spinal cord." Sir C. Bell, however, with great acuteness, has pointed out the error of this explanation, and states that "it is the progress of inflammation to the spinal marrow, and not the pressure or extension of it, which makes these cases of subluxation and breach of the tube fatal." . . . . "There can be no doubt that this explanation is the correct one, and that when once the spinal canal is forcibly torn open, fatal inflammation will spread to the meninges and to the medulla itself."

It will be observed that these quotations from Mr. Erichsen's work are not in harmony with the statements made by Dr. Dandridge. In fact we discover here about the same difference which marks the writings of the first half of this century on abdominal surgery, and those of the present day on the same subject. My own experimental studies have an important bearing on this matter of difference between Dr. Dandridge and Mr. Erichsen, and therefore I shall here state briefly some of my observations. Permit me, therefore, to transcribe from my brochure the following:

February 11. Experiment 4. Normal condition; mongrel, bull, male, æt. about five years; weight, 51½ pounds; temperature, 102.2°; pupils natural; traumatized. The animal walked with some difficulty, apparently weakened in the hind legs. Pupils were slightly dilated.

Feb. 12. Temperature, 102°; pupils normal; the symptoms more marked to-day than yesterday. The animal stood on his hind legs with much difficulty; walked with an unsteady gait; toilet neglected; eyes dull; ate and drank, and was evidently suffering from incomplete paraplegia.

Feb. 13. Temperature, 101°; pupils normal; some slight improvement in other respects.

Feb. 14. Temperature, 100.5°; pupils normal; ate and drank fairly well.

Feb. 15. Temperature, 101.8°; pupils normal.

Feb. 16. Temperature, 99°; pupils normal. There had been some improvement in the paraplegia.

Feb. 17. Temperature, 100.6°; pupils normal.

Feb. 18. Temperature, 100°; pupils normal.

Feb. 19. Temperature, 102°; pupils normal.

Feb. 20. Temperature, 100.7°; pupils normal.

Feb. 21. Temperature, 100°; pupils normal.

Feb. 22. Temperature, 101°; pupils normal.

Feb. 23. Temperature, 100.8°; pupils normal.

Feb. 24. Temperature, 101.6°; pupils normal.

Post mortem.—This autopsy was made promptly after the examination recorded on the 24th. There was found a simple fracture of the body of the last lumbar vertebra, external to which was a large blood clot, some part of which had evidently been absorbed, while the cauda equina showed signs of pressure from the coagulated blood, but none of an inflammatory character. There was also congestion of the cortical substance of both kidneys and the lining membrane of the bladder.

Microscopical report.—The brain was incised in several places, and it was found to be moderately hyperæmic; otherwise normal. There was general hyperæmia of the cord. The ganglionic

cells were less distinct than in normal cords, less defined from their surroundings. The nerve ends were less sharply defined in the anterior and posterior columns, near the median commissure, than in the rest of the cord. This was more marked in the lumbar region.

Observations.—It is highly important to observe that in the case of this animal, the improvement was steady after the third day of the receipt of the traumatism until his death. In fact, so marked had been the progress, that I am fully assured, that had the dog been left to unaided nature, he would have entirely recovered. I will also add to the above record a few extracts from the same source, which will include *all the other cases* of fractures involving the spinal column which occurred in my 141 experiments. . .

First Series.—Experiment 3—traumatised—complete paraplegia. The hind legs absolutely powerless, but the animal drags himself, with much effort, over the floor with his fore legs.

Post-mortem.—This examination revealed a comminuted fracture of the spinous process and body of the seventh dorsal vertebra. The spinal cord was exposed, and found to be completely crushed at this point, showing the result, likewise, of inflammatory action in the congested and softened condition, which extended in both directions away from the seat of injury one inch or more.[3] . . .

Microscopical Report.—There was a break in the dorsal region of the cord. Above and be-

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[3] The above record will, it is thought, enable the reader, to form his own opinion in regard to the causation in these cases, while the whole number interrogated is limited to six. The total number which terminated quickly in death were eight, while there were only four of these, in which there were found any lesions in the cerebro-spinal axis. See brochure, page 71, for complicating lesions.

low this break the cord was softened and intensely hyperæmic. The central canal was dilated with blood. The cord was intensely hyperæmic throughout. In the cervical and lower lumbar regions no special change was noticed except the hyperæmia.

Second Series.—Experiment 2. . . . Traumatised—Paraplegia. . . . Post-mortem.—This examination revealed the following: A simple fracture in the body of a vertebra, in the upper half of the lumbar region; the injury to the spinal cord was very marked at this point. There was likewise found within the peritoneal cavity about two ounces of coagulated blood directly over the psoas muscles; these muscles were ecchymosed, the right more than the left. Both kidneys were congested. Meninges of the brain congested, especially over the occipital region; spinal cord in a similar condition. . . .

Microscopical Report.—Brain intensely hyperæmic otherwise normal. The cord was hyperæmic throughout. It had not hardened well, and the outlines of the fibres were indistinct, whether cut longitudinally or transversely. The ganglionic cells were perfectly distinct.

Experiment 5.—Traumatised—Incomplete paraplegia; pupils moderately dilated. Post-mortem. —This examination revealed the following lesions: Congestion of both kidneys; in the pelvic cavity there was a quantity of extravasated blood, a deep ecchymosis involving the whole of the left psoas muscle, marked congestion of the meninges covering the vertex of the brain, and a slight congestion over other portions, the brain itself somewhat hyperæmic, cranial fluid increased in quantity. The spinal cord was likewise hyperæmic. A comminuted fracture of the body of the last lumbar vertebra and the

presence of a blood clot within the canal at this point. . . .

Microscopical Report.—"The material was not received." The injuries described in Experiment 3, First Series, would have sooner or later caused the death of the animal; but in the other cases recovery would have been the final termination in each instance. It would be very interesting in this connection to take up separately the eleven experiments in which there was a rupture of vertebral ligaments, in order to show the nature of the pathological lesions in each case, and likewise the other complications; but space will not permit; and therefore it is sufficient for me to say, that in each instance the improvement had been so marked before the animal was killed, as to justify me in asserting, that all of these animals would ultimately have recovered.

There still remains a single point connected with fractures and other lesions of the spinal column, to which I desire to call especially the attention of surgeons. My experimental studies have conclusively shown that in all severe injuries of the spinal column, cord, etc., there are complications involving more or less seriously, the organs within the thoracic, abdominal or pelvic cavities. I know of no reason why there should not be found similar complications in the human subject. In fact, I think it will be discovered when sought for in connection with spinal lesions.

EXPLANATORY NOTES AND REFERENCES.—A brochure entitled "An Experimental Study of Lesions Arising from Severe Concussions," by B. A. Watson, M.D., p. 67 *et seq*. Philadelphia: P. Blakiston, Son & Co.[1] The report of these cases may be found by a reference to Nos. 20, 22 and 35, First Series, and No. 64, Second Series. The immediate cause of death in case "No. 20 was a rupture of the aorta." . . . . In 22 it was "chiefly due to deep lacerations in the lungs, injury of the liver, etc."
"The cause of death in the 35th Experiment existed in the rupture of the right auricle and left pulmonary artery." "In the 64th

Experiment the cause of death was the laceration of the liver, which gave rise to a profuse hæmorrhage, although there were hæmorrhagic infarctions in the lungs and a pre-existing pneumonia ;" . . . . "The spinal and brain complications in the above-mentioned cases were as follows : In Experiment 22 there was intense hyperæmia of the brain and spinal cord, while in the 20th and 35th Experiments there were found small hæmorrhages into the gray matter of the cord. The complication in the 64th Experiment consisted of distension of the vessels of the membranes of the spinal cord, which had ruptured in several places, and hæmorrhages of small size had occurred in the surrounding tissue."

These forty-six cases of pathological changes involving the various parts of the cerebro-spinal axis occurred as follows : (1) brain, 1 ; (2) brain and spinal cord, 12 ; (3) spinal cord, 15 ; (4) cauda equina, 2 ; (5) membranes of the brain and spinal cord, 3 ; (6) Brain and spinal cord ? 2 ; (7) brain and cauda equina ? 1 ; (8) spinal cord ? 2 ; (9) brain ? 1 ; (10) spinal cord and the membranes of the brain, 5 ; (11) membranes of the spinal cord ? 1 ; (12) membranes of the brain and spinal cord ? 1.

The attention of the reader is here called to the fact that in my brochure I have stated that there were fifty cases in which pathological changes occurred in the cerebro-spinal axis, but a more careful examination of these reports justify me in limiting the number to forty-six.

[2] It will likewise be observed in the above classification of these pathological changes that in some instances the interrogation point has been placed after the classification clause. In the cases thus marked the author thinks there is a reasonable doubt whether the pathological changes observed were due to the traumatism or other complicating factors. Thus, in Experiment 10, First Series, the following facts are recorded : Post mortem.— " Visceral organs of the thorax and abdomen healthy, with the exception of the kidneys, which are both in a state of cystic degeneration. The meninges of the brain seem to be congested. The quantity of cerebral fluid apparently somewhat increased. No softening (apparent to the unaided eye) of the brain and spinal cord. . . . .

Microscopical Report.—Brain moderately congested. There are a few punctate hæmorrhages in the anterior horns of the lumbar region of the cord. The cord is hyperæmic throughout, but less so than in experiment 22." The record in the 17th Experiment, Second Series, reads as follows : Post mortem.—" This examination revealed the following lesions : Rupture of the bladder, abdominal cavity distended with urine, the organs contained within it all more or less inflamed, lungs contained numerous hæmorrhagic infarctions and were considerably inflamed. The meninges of the brain were markedly congested, blood clot of considerable size beneath the dura mater, spinal cord seemed congested. . . ."

Microscopical Report.—" The brain is intensely hyperæmic ; there is no lesion of the nerve cells or fibers. There are hæmorrhages in the meshes of the fibrous tissue of the dura mater and upon its inner surface. The vessels of the cord are very greatly distended with blood, but there are no hæmorrhages and no lesions that can be distinguished in the ordinarily stained sections."

FIG. 1.—Lateral view of the spine.

FIGURE 2.

FIGURE 3.

FIGURE 4.