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## ORIGINAL MEMOIRS.

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### FRACTURE OF THE SPINE.<sup>1</sup>

A SUMMARY OF ALL THE CASES (244) WHICH WERE TREATED AT THE BOSTON CITY HOSPITAL FROM 1864 TO 1905.

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*Is the spinal cord irremediably damaged?* This is the question that immediately arises in the mind of a surgeon when he first sees a patient with a fracture of the spine. The utter hopelessness of the condition, when there is complete destruction of the cord, is universally accepted.

*Can we tell whether a spinal cord is irremediably damaged or not?* On the answer to this question depends in many cases whether or not an operation should be done.

In many cases it is perfectly clear that the cord is crushed. In other cases doubt exists as to whether the cord is irremediably damaged. In still other cases it is a fair presumption that the cord is not hopelessly damaged.

These questions are constantly presenting themselves to surgeons, and it is often impossible to answer them dogmatically in an individual case.

Prior to 1887 the expectant treatment of fractures of the spine was practically always used. The mortality was so

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large, and the suffering so distressing, that it led me to advocate immediate rectification of the spine and its fixation by a plaster-of-Paris jacket.<sup>1</sup>

Open operations on the spine have been done occasionally since Henry Cline operated at St. Thomas's Hospital in 1814, but all these operations were futile or followed by a fatal ending.

Antisepsis and a simple method of doing laminectomy have rendered it possible to open the spinal canal and to look at the cord. An open operation gives definite information as to the condition of the cord, and above all allows pressure to be removed in some cases. Naturally an open operation quickly superseded immediate rectification, which was at best a "hit or miss" method of relieving pressure on the cord.

The largest collection of fractures of the spine was made by Gurlt,<sup>2</sup> who reported 270 cases. Thorburn's<sup>3</sup> well-known work is of great value. Morton<sup>4</sup> considered the subject carefully. Lloyd<sup>5</sup> presented 227 cases and judiciously summarized the subject.

The writer has twice reported the fractures of the spine at the Boston City Hospital, through the courtesy of his colleagues. The first series (82 cases) was published in the *Medical Communications of the Massachusetts Medical Society*, vol. xiv, No. 1, 1887, p. 151. The second series (168 cases, which included the first series of 82 cases) was presented to the British Medical Society in August, 1894, and abstracts of the paper were published in the *Medical Press and Circular*, London, August 29, 1894, in the *British Medical Journal*, August, 1894, and in the *ANNALS OF SURGERY*, February, 1895.

The writer now presents a third series of 244 cases, which includes the two previous series. The details of the 244 cases are not presented, but a summary of the three series of cases is given, and a comparison of the different series is interesting and instructive.

These tables show the frequency of symptoms; the deaths and recoveries in the different regions; the mortality; the

duration of life in the fatal cases; and the results as to whether the patient is useful or useless in the recoveries.

FIRST SERIES.—1864-1887.

*Frequency of Symptoms.*—Total cases, 82. Crepitus, 51, 62.1 per cent.; deformity, 63, 76.8 per cent.; unconsciousness, 18, 21.9 per cent.; paralysis, complete, 67, 81.7 per cent.; paralysis, incomplete, 6, 7.3 per cent.; paralysis, none, 9, 11 per cent.; pain, 71, 86.5 per cent.; priapism, 18, 21.9 per cent.; delirium, 12, 14.6 per cent.; cystitis, 31, 37.8 per cent.; bed-sores, 27, 32.9 per cent.

*Regions.*—Total cases, 82. Cervical, 28, 34.1 per cent. Deaths, 25, 89.2 per cent.; recoveries, 3, 10.8 per cent. Upper dorsal, 12, 14.6 per cent. Deaths, 8, 66.6 per cent.; recoveries, 4, 33.4 per cent. Lower dorsal, 19, 23.1 per cent. Deaths, 18, 94.7 per cent.; recoveries, 1, 5.3 per cent. Lumbar, 23, 28.0 per cent. Deaths, 13, 56.5 per cent.; recoveries, 10, 43.5 per cent.

*Mortality.*—Total cases, 82. Deaths, 64, 78 per cent.; recoveries, 18, 22 per cent.

*Time.*—Total cases, 82. Total deaths, 64, 78.0 per cent. Within 5 days, 39, 60.9 per cent.; within 10 days, 8, 12.6 per cent.; within 1 month, 7, 10.9 per cent.; after 1 month, 10, 15.6 per cent.

*Results.*—Total cases, 82. Total recoveries, 18, 22 per cent. Useful, 9, 50 per cent.; useless, 9, 50 per cent.

SECOND SERIES.—1887-1900.

*Frequency of Symptoms.*—Total cases, 114. Crepitus, 30, 26.3 per cent.; deformity, 58, 50.8 per cent.; unconsciousness, 14, 12.2 per cent.; paralysis, complete, 93, 81.5 per cent.; paralysis, partial, 14, 12.2 per cent.; paralysis, none, 7, 5.1 per cent.; pain, 58, 50.8 per cent.; priapism, 37, 32.4 per cent. (106 male cases); delirium, 29, 25.4 per cent.; cystitis, 22, 19.3 per cent.; bed-sores, 23, 20.1 per cent.

*Regions.*—Total cases, 114. Cervical, 44, 38.5 per cent.

Deaths, 41, 93.1 per cent.; recoveries, 3, 6.9 per cent. Upper dorsal, 24, 21.0 per cent. Deaths, 22, 91.6 per cent.; recoveries, 2, 8.4 per cent. Lower dorsal, 34, 29.8 per cent. Deaths, 19, 55.8 per cent.; recoveries, 15, 44.2 per cent. Lumbar, 12, 10.5 per cent. Deaths, 7, 58.3 per cent.; recoveries, 5, 41.7 per cent.

*Mortality.*—Total cases, 114. Deaths, 89, 78 per cent.; recoveries, 25, 22 per cent.

*Time.*—Total cases, 114. Total deaths, 89, 78 per cent. Within 5 days, 67, 75.2 per cent.; within 10 days, 7, 7.8 per cent.; within 1 month, 8, 9.2 per cent.; after 1 month, 7, 7.8 per cent.

*Results.*—Total cases, 114. Total recoveries, 25, 22 per cent. Useful, 15, 60 per cent.; useless, 10, 40 per cent.

#### THIRD SERIES.—1900-1904.

*Frequency of Symptoms.*—Total cases, 48. Crepitus, 12, 25 per cent.; deformity, 37, 77 per cent.; unconsciousness, 9, 18.7 per cent.; paralysis, complete, 25, 52.0 per cent.; paralysis, partial, 7, 14.5 per cent.; paralysis, none, 16, 33.3 per cent.; pain, 42, 87.5 per cent.; priapism, 11, 23.9 per cent. (46 male cases); delirium, 2, 4.1 per cent.; cystitis, 13, 27.0 per cent.; bed-sores, 13, 27.0 per cent.

*Regions.*—Total cases, 48. Cervical, 14, 29.1 per cent. Deaths, 11, 78.5 per cent.; recoveries, 3, 21.5 per cent. Upper dorsal, 7, 14.5 per cent. Deaths, 3, 42.8 per cent.; recoveries, 4, 57.2 per cent. Lower dorsal, 22, 45.8 per cent. Deaths, 4, 18.1 per cent.; recoveries, 18, 81.9 per cent. Lumbar, 5, 10.4 per cent. Deaths, 0; recoveries, 5, 100 per cent.

*Mortality.*—Total cases, 48. Deaths, 18, 37.5 per cent.; recoveries, 30, 62.5 per cent.

*Time.*—Total cases, 48. Total deaths, 18, 37.5 per cent. Within 5 days, 11, 61.1 per cent.; within 10 days, 1, 5.5 per cent.; within 1 month, 3, 16.7 per cent.; after 1 month, 3, 16.7 per cent.

*Results.*—Total cases, 48. Total recoveries, 30, 62.5 per cent. Useful, 23, 76.6 per cent.; useless, 7, 33.4 per cent.

## SUMMARY OF THREE SERIES.—TOTAL CASES, 244.

*Frequency of Symptoms.*—Crepitus, 93, 37.8 per cent.; deformity, 159, 68.1 per cent.; unconsciousness, 41, 17.6 per cent.; paralysis, complete, 185, 71.7 per cent.; paralysis, partial, 27, 11.3 per cent.; paralysis, none, 32, 13.1 per cent.; pain, 171, 74.8 per cent.; priapism, 66; delirium, 43, 14.7 per cent.; cystitis, 66, 28.0 per cent.; bed-sores, 63, 26.6 per cent.

*Regions.*—Cervical, 86, 33.9 per cent. Deaths, 77, 85.7 per cent.; recoveries, 9, 14.3 per cent. Upper dorsal, 43, 16.7 per cent. Deaths, 37, 76.7 per cent.; recoveries, 10, 23.3 per cent. Lower dorsal, 75, 32.9 per cent. Deaths, 41, 56.1 per cent.; recoveries, 34, 43.9 per cent. Lumbar, 40, 16.3 per cent. Deaths, 20, 50.0 per cent.; recoveries, 20, 50.0 per cent.

*Mortality.*—Deaths, 171, 64.5 per cent.; recoveries, 73, 35.5 per cent.

*Time.*—Total deaths, 171, 64.5 per cent. Within 5 days, 117, 65.7 per cent.; within 10 days, 16, 8.6 per cent.; within 1 month, 18, 12.1 per cent.; after 1 month, 20, 13.3 per cent.

*Results.*—Total recoveries, 73, 35.5 per cent. Useful, 47, 62.2 per cent.; useless, 26, 37.8 per cent.

The writer recognizes that statistics may be very deceptive, and that they may be made to prove almost anything; yet certain generalizations may be drawn from them. The figures speak for themselves; but it should be remembered that the observations and the records were made by a constantly changing staff of surgeons.

I have purposely refrained from drawing deductions from these figures, for I find that Dr. Crandon, who has carefully gone over the records, arrives at one conclusion and I arrive at another. If two individuals can reach different conclusions from an analysis of the same cases, it shows clearly the fallacy of attempting to generalize from cases that have been observed and recorded by many different surgeons. For this reason the reader must critically analyze these figures and draw his own conclusions.

The most striking statistics are those of the mortality in the first series when compared with the mortality in the third series. In the first series there was 78 per cent. of deaths; in the third series there was 37.5 per cent. of deaths. This extraordinary difference in mortality is due to the inclusion of fractures of the spine which did not have paralysis, in the statistics of the third series. In the first series of cases, if paralysis was not present in some degree, the case was not considered to be a fracture of the spine. For this reason the mortality tables of the summary of the three series cannot be accepted at their face value. Injuries of the spinal column that were formerly considered to be wrenches of the spine are to-day known, in some instances, to be fractures of the spine without cord symptoms. These cases are brought to the hospital with what is thought to be a minor injury, and are sooner or later recognized as fractures of the spine. The nursing care of patients has greatly improved, and this has doubtless diminished the mortality.

The three types of cases that I recognize are the following: 1. Cases in which the cord is crushed. 2. Cases in which doubt exists as to whether the cord is irremediably damaged. 3. Cases in which it is fair to assume that the cord is not irremediably damaged.

1. Cases in which the cord is crushed. This forms by far the largest class of spinal injuries. I append autopsy reports (for which I am indebted to the Pathological Department of the Boston City Hospital) of several of the cases to show the mechanics of absolute cord destruction.

(1) Anterior portion of twelfth dorsal vertebra broken into fragments. Largest wedge-shaped 3 centimetres long, entire body pressed backward. Compressed so that intervertebral disks above and below have largely disappeared. Posterior portion of body forms a knuckle-like mass projecting towards cord, elevated over 1 centimetre above level of the other vertebræ; on the cord, corresponding to the projection of the posterior surface of the body of the twelfth vertebra, is an area of softening 1 centimetre in length. At the lower

border is a marked constriction, the anteroposterior diameter of the cord being reduced one-half. This occurs at a point 3.5 centimetres above the tip of the conus medullaris. The softened portion is grayish white and translucent on section.

(2) Arches of spinous processes of first and second dorsal vertebræ absent (operation). Cord at this point appears normal. No blood in spinal canal. On anterior aspect of spinal column, fifth cervical projects anteriorly 5 centimetres in front of cord, which is dislocated backward. Fourth is freely movable on fifth, and also fifth somewhat less degree on sixth. Body of sixth anteriorly is movable with crepitus, and spinous processes with a portion of arch of this same vertebra can also be moved freely from side to side. There is apparently fracture of transverse processes of fifth cervical vertebra.

(3) Examination of spinal column from anterior surface showed transverse fracture of body of seventh cervical vertebra. Small bony fragments projected into adjacent tissue. Arches of sixth and seventh cervical were comminuted. On posterior surface of dura, beneath arch of seventh cervical and to less extent beneath that of sixth, was a small amount of dark, red coagulated blood. No hæmorrhage within dura. Vessels on surface of cord were injected. Distinct softening of cord opposite point where sixth nerve is given off.

(4) Spines of seventh and eighth dorsal vertebræ not present. Opposite bodies of seventh and eighth cord is sharply compressed by knuckle from posterior portion of bodies. On opening dura the cord was found completely divided, the upper portion being separated from lower by space 4 centimetres. The torn ends of cord end blindly in mass of fibrous tissue. Body of eighth dorsal was seen to have been forcibly driven backward and crushed between seventh and ninth dorsal. Lower portion of ninth exhibited old line of fracture with new formation of bone at about middle of body. No evidence of articular cartilage between eighth and ninth dorsal. Ninth projected into spinal canal at a sharp angle, about 45 degrees. Above angle made by displaced ninth there was a new growth of bone along front of spinal canal, making angle less prominent.

(5) A sharp knuckle of bone is found pushing into spinal canal anteriorly and corresponding to upper portion of body of first dorsal vertebra. This knuckle represents body of first dorsal. The articular cartilage between first dorsal and seventh cervical having been crushed and ligaments torn, the body of vertebra was forced back, producing angle in canal. Cord over knuckle was found softened and discolored by hæmorrhage into it. Microscopically for about 2 centimetres above and below there was blood in posterior horn.

(6) Roughened area in region of first lumbar. Body of twelfth dorsal much narrower on left than on right, bone having been apparently crushed on left side. Irregular fracture body of first lumbar with a fragment projecting posteriorly into spinal canal. Cord degenerated from upper dorsal to cauda equina.

(7) Eighth dorsal vertebra divided by oblique fracture beginning about middle of body and extending on each side upward and backward through body, pedicles, and laminae. Cord for about 2 centimetres opposite site of fracture is narrowed and completely softened. Cord for about 1 centimetre above and below this shows central cavity partially filled with thick red fluid. This cavity corresponds in form and size with portion of cord usually occupied by gray matter. Fluid contains compound granular cells,—irregular nerve fibres.

(8) Upper lumbar displaced to left, dislocation forming marked angle with adjacent dorsal vertebra. Unnatural mobility here. Spines of twelfth dorsal and first lumbar were separated one inch, ligaments torn. Fracture of body of first lumbar. Portion of cord two inches long over displaced ridge of first lumbar distinctly softened. Over projection the cord was brown and diffluent, completely disorganized.

(9) There was a displacement between second and third dorsal vertebræ, body of the second being forced backward and to the right about one-fourth of an inch. This displacement was more apparent upon examination of spine posteriorly, spines and cord having been removed. Second and third spines were broken at their tips. Cord in this region was



overlaid by thin, soft clot, and there was a region of softness one-half inch long, which upon section displayed a considerable effusion of blood into cord. Whole cord at this level was disorganized.

(10) Spinous process of sixth cervical vertebra was broken, and there was a separation between the fifth and sixth, admitting tip of finger. There was also a separation between bodies of fifth and sixth through intervertebral disks, with rupture of ligament to such a degree as to permit displacement of fifth forward nearly one-fourth of an inch. No free blood in meninges. In immediate relation with vertebral injury, spinal cord shows a mass of softening through one-half of its length extending through entire thickness. The consistency and color of cord at this point are that of thick cream.

(11) Examination of spinal column anteriorly reveals nothing abnormal. Spinous processes of the fourth and fifth cervical were widely parted, and fourth was displaced slightly forward. Fracture through body of fourth and through cartilage below it. Cord at this point was compressed, soft, and red. No blood within dura, compression being wholly due to displacement of fragments.

(12) Abnormal mobility between fifth and sixth cervical with anterior displacement of fifth to extent of one-fourth of an inch. Fifth and sixth spines separated, following rupture of their ligaments. Fracture of intervertebral disks below fifth, with separation of articular surfaces of transverse processes. Little blood outside dura; within dura, around cord, very little. At point of fracture the cord was shrunken, soft, and red. The extent of the lesion was about three-fourths of an inch.

(13) Anteriorly, second lumbar presents fracture through its body. Considerable amount of effusion of blood in spinal canal outside dura. Section of dura shows cauda equina without lesion or surrounding hæmorrhage.

(14) Complete crushing of third, fourth, fifth, and sixth cervical vertebræ. Cord not removed, owing to complete destruction and crushing.

2. Cases in which doubt exists as to whether the cord is irretrievably damaged. These cases should probably always have an open operation, but will be considered later.

3. Cases in which it is fair to assume that the cord is not irretrievably damaged. This class is of great interest and importance.

Dr. L. R. G. Crandon, of Boston, has collected a series of seventeen cases of fracture of the spine without marked cord symptoms which have come under his personal observation. He has pointed out to me that if they are unrecognized they may end most disastrously.

#### FRACTURE OF THE SPINE WITHOUT MARKED CORD-SYMPTOMS.

1. Male, aged ten years. Buried by a cave-in of sand and gravel; brought immediately to hospital. Marked tenderness over lower dorsal and first lumbar spines, with swelling and kyphos. Reflexes normal and no evidence of paralysis. Patient put on Bradford frame and fastened to it by swathe. Twenty-two days later plaster-of-Paris jacket applied. One month after injury patient up with jacket, and two days later discharged, with marked knuckle in lower dorsal region and definite limitation of intervertebral flexibility, but no evidence of injury to the cord.

2. Male, aged six and one-half years. So far as can be learned, an iron pipe fell on patient's side or back. Patient semi-conscious; color good; pulse 130; slight bleeding from both nostrils; reflexes of eyes, trunk, and extremities normal. Crepitus and abnormal mobility of ninth and tenth dorsal spinous processes of second and third left ribs. Discharged in one month with no evidence of cord-injury, but with slight scoliosis.

3. Male, aged thirty-nine years. Fell into hold of steamer. Pale, conscious, apparently in pain. Sternum fractured. Back shows continuous curve from base of neck to first lumbar with marked kyphos at sixth dorsal. At this point is abnormal separation of spines and great tenderness. No crepitus made out. Abdomen, marked spasm of both upper quadrants. No paralysis, and reflexes all normal. Bradford frame. Retention of urine made catheterization necessary for three days. In eight days the kyphos still persisted, but sensation and motion of lower ex-

tremities were normal. In six weeks sat up with back carefully supported. Plaster jacket applied with spine hyperextended. In eight weeks sat up in chair and was without symptoms.

4. Female, aged twenty-six years. Fell one story, striking on back across an iron fence. Unconscious for an hour. Marked knuckle at twelfth dorsal vertebra. Knee-jerk present on left, absent on right. No paralysis or lack of sensation made out. Bradford frame. Two and one-half weeks, plaster jacket. Radiograph negative. In six weeks was up and about with jacket; no symptoms. Discharged at her own request.

5. Male, aged twenty-two years. "Jack-knifed" while driving through a low doorway. Unable to walk; legs paretic, but sensation normal. Severe pain across back and marked abdominal spasm. Distinct kyphos at twelfth dorsal, but this seems to consist of hematoma and of a loose spinous process, giving crepitus. Retention of urine called for catheterization for seventeen days. At end of two months was discharged with "stiffness of back," but no other abnormality.

6. Male, aged twenty-four years. Fell from a tree about fifteen feet. Conscious. Cyanotic. Pulse, 80; reflexes absent; Babinski on both sides. Both lower extremities delayed in sensation and paretic in motion for twelve hours. After that normal. Eighth dorsal spine unduly prominent; just below it a distinct gap; ninth process not felt. Patient got out of bed several times the first night without new symptoms. Bladder and rectum normal from the first. At the end of one month was discharged at his own request, with plaster jacket; no symptoms.

7. Male, aged twenty-three years. Fell three stories. Conscious; tender prominence over eleventh and twelfth dorsal vertebrae. No crepitus or disturbance of motion or sensation. Reflexes normal. Slight priapism. Bradford frame. In four weeks: priapism continues, but no other cord-symptom has been noted. In one month: patient up (on his own insistence) and walks about, without back support, somewhat stiffly. Discharged.

8. Female, aged twenty-six years. On the tenth day of typhoid developed delusions, and jumped from a second story window to the ground, about thirty-five feet. The patient was unconscious, respirations were rapid and shallow, slight cyanosis. There was marked prominence of the ninth, tenth, eleventh, and twelfth dorsal, and first lumbar vertebrae, with evident separation

of spines of twelfth dorsal and first lumbar. No paralysis or anæsthesia. Abdomen distended. Kyphosis persists. Death at end of three days.

9. Male, aged thirty years. "Jack-knifed" under a bale of cotton. Conscious. Crepitation and abnormal mobility of eleventh dorsal spine. No paralysis or anæsthesia. Discharged well.

10. Male, aged forty-seven years. Fell one story down elevator well. Slight kyphos at second lumbar vertebra. Reflexes, sensation, and motion normal. Sat up in twelve days, with no sign of injury except the persistent knuckle.

11. Male, aged thirty-two years. A mass of twenty-eight bricks fell on patient's bent back. Conscious. Marked separation of fourth and fifth dorsal spines, enough to admit tip of finger. Just above this, fourth spine is unduly prominent. No paralysis or other sign of cord injury. Up and about in fourteen days without symptoms.

12. Male, aged thirty-eight years. Fell down stairs. Conscious. Soft swelling in dorsolumbar region. Twelfth dorsal spine unduly prominent. Sensation, reflexes, sphincters, and other muscles not affected in any other way. Discharged in seventeen days against advice.

13. Male, aged sixty years. Was thrown down a flight of stairs. Conscious. Dyspnoea. Abnormal mobility, crepitus, and pain over third and fourth dorsal spines. Discharged without symptoms in four days.

14. Male, aged sixty years. Fell off a bridge. Conscious. Reflexes normal. No loss of motion or sensation made out, but a marked kyphos over eleventh and twelfth dorsal spines. Much abdominal spasm. No symptoms of cord injury developed during two months. At the end of that time, although the deformity persisted, patient was up and about in plaster jacket.

15. Male, aged thirty-two years. Fell thirty-five feet from an electric-light pole. Conscious. Reflexes normal. General abdominal spasm. No loss of motion or sensation, but a definite kyphos over first lumbar spine. Retention of urine first twenty-four hours. Discharged in two months with persistent kyphos and wearing plaster jacket.

16. Male, aged twenty-six years. Intoxicated and in a fight fell from a second story window to the ground. Conscious. Color good; breath alcoholic; pupils equal and react; tongue

protrudes straight; pulse 100, regular, good quality; fine tremor of both hands. General abdominal tenderness and spasm; no motor paralysis. Slight prominence of spine of first lumbar vertebra. Considerable tenderness over this region; some pain on motion; no crepitus or abnormal mobility of spinous processes; able to move legs without difficulty; sensation normal. Plaster jacket applied with lordosis. Discharged after seven weeks. Able to walk slowly, with great sensation of weakness in lumbar region and dependent upon plaster jacket.

17. Male, aged forty-one years. Tried to jump from one roof to another and fell four stories. Semiconscious. Apparently in great pain. Marked pallor. Pupils equal and react. Tongue not protruded on request. Pulse 120, regular, but of poor quality. Marked kyphosis, with apex of the knuckle at the junction of the tenth and eleventh dorsal vertebræ, where there is considerable separation of the spines. Marked abdominal tenderness and spasm. Knee-jerks absent. Cremasteric present. Patient grew worse through the day, and in five hours was in a state of collapse. A pint of adrenalin solution, 1 to 50,000, was introduced into the vein of the arm, and this was repeated twice at intervals of six hours. Pulse immediately responded and general condition improved. There was no motor paralysis at any time. The patient was kept on a Bradford frame, and was discharged at the end of four months with a plaster jacket. This man was brought into the hospital by the police in a chair, his head and the upper half of the trunk collapsed forward. A knuckle in his back presented, the whole picture being that of Pott's disease. Immediate rectification was done to the extent only of placing the man on his back, and there he remained until complete union had taken place. At no time were there any cord symptoms.

This series of cases is, I think, worthy of careful consideration. Presumably in the past these cases have not gone to a hospital. The injury to the vertebræ in some of these cases is assumed from the symptom-complex, not from the existence of crepitus and abnormal mobility. It must be remembered that in certain adult spines there is present a kyphos that is not dependent upon an obvious pathological lesion.

There can be but little doubt that cord symptoms may

develop from the displacement of a fracture of the spine where the cord has not been permanently injured. Dr. Crandon has seen one such case that deeply impressed him. It is as follows:

Male, aged fifty-five years. Fell down an elevator well and was brought immediately to hospital. There was marked tenderness over the seventh cervical and the three upper dorsal vertebræ, together with slight spasm of the neck. No crepitus made out. Pulse, 74; temperature, normal; respirations, 17. No paralysis or anæsthesia. Reflexes present and normal. Full control of sphincters.

Patient was put to bed, and cautioned not to sit up or to roll in bed, because there was injury to his back which might be more than was then apparent. Four days after injury, however, when unattended, *he sat up in bed and immediately complained of numbness of the limbs and body.* Examination then showed a paresis of all the skeletal muscles from the neck down and diminished cutaneous sensation from the clavicle downward. Reflexes increased. Abdomen somewhat distended. Bladder parietic and sphincter ani relaxed.

Two days later the plantar reflexes and the knee-jerks were absent; absolute paralysis of lower extremities. Right arm: very slight power of flexion and slight power of supination; extension of elbow lost; pronation of wrist lost; very slight power of deltoid; pectorals and latissimus dorsi lost. Sensation blunted to pin-prick over ulna half; sharp over ball of thumb; blunted over both sides of forefinger; lost over middle finger; sharp over deltoid; sharp over radial aspect of forearm. Left arm: flexion good; extension of forearm lost; deltoid, pectorals, and latissimus fair; pin-prick of limb diminished; radial aspect diminished; over deltoid normal; ulnar side diminished. Sensation absent from toes to level of fourth rib, and blunted from fourth to second rib. Pupils equal and not dilated. Diagnosis: Complete injury at seventh segment; sixth segment blunted.

Operation advised at the first onset of these symptoms. Not accepted, and patient died at the end of a month, with the usual picture of fractured spine and complete destruction of the cord. Autopsy showed fracture of the first dorsal and complete degeneration of the cord at that level, but without macroscopic change in the envelopes of the cord.

In the care of this class of bony injury of the spine, surgery can protectively be of great value. To the police, to hospital attendants, to house officers, and to medical students, the instruction for the care of injuries to the back should be "*hands off.*" Let the patient be transported to the surgeon, so far as is possible held fixed in the position in which he is found.

*Can we tell whether a spinal cord is irremediably damaged or not?* In some cases it is obvious from the character of the injury that the cord is severed or crushed. A total transverse destruction of the cord may be deduced from the *persistence* of the following symptoms: the total loss of all reflexes, complete insensibility to touch and pain, and motor paralysis below the level of the lesion.

Thomas,<sup>6</sup> whose work on the changes in the spinal cord following fracture of the spine is of great value, stated that the "factors in drawing the conclusion that there is a complete transverse lesion of the cord are:

- "1. Complete paralysis, usually of a flaccid type.
- "2. A complete loss of sensation in all its forms.
- "3. Absent reflexes, especially the knee-jerk, while the plantar reflex, on the contrary, is often retained.
- "4. Complete paralysis of the bladder and rectum, with priapism.
- "5. Vasomotor paralysis, with severe sweating in the paralyzed parts.
- "6. And, most important, absence of variations in the symptoms.

"7. Absence of irritative phenomena, such as pain."

Walton,<sup>7</sup> who has studied fractures of the spine, states, "There are no symptoms which establish (otherwise than through their persistence) irremediable crush of the cord." "While total relaxed paralysis, anæsthesia of abrupt demarcation, total loss of reflexes, retention, priapism and tympanites, if persistent, point to complete and incurable transverse lesion, the onset of such symptoms does not preclude a certain degree at least of restoration of function." He also states that we have no infallible guide to the extent of the lesion.

*Treatment.*—The treatment of fractures of the spine comes under the following headings: (1) Expectant; (2) reduction and fixation; (3) operation (laminectomy) which may be (a) primary; (b) secondary. The selection of the kind of treatment should depend on what injury to the cord exists or what injury to the cord is likely to occur.

(1) Expectant treatment. This mode of treatment is applicable to fractures of the spinous processes or even of other bony structures where there are no cord symptoms. The expectant treatment consists in having the patient fixed in bed, preferably on a Bradford frame, to facilitate his care. The nursing care is most important. The expectant method is one which manifestly holds out little hope of complete recovery in cases of definite cord injury.

(2) Reduction and fixation. The immediate, bloodless, rectification of a fracture of the spine, and its fixation by a plaster-of-Paris jacket, was the mode of treatment which I advised in selected cases in my first series. If a detailed local examination is to be made, the patient should be turned only as a whole. Rectification should be attempted very slowly, so far as is possible, in the axis of the spinal column. During every step of this operation it is desirable that the condition of the cord, as shown by sensation, motion, and reflexes, should be known. Should the slightest sign or symptom of cord injury or pressure develop, the rectification should stop and an immediate open operation be done. If the kyphos is very marked, or if upon extension it does not readily reduce, an immediate operation, unless there is some contraindication, such as shock, should be done, that the reduction may take place while the cord is under the surgeon's eye. The deformity may be corrected and the jacket applied, with the body suspended, or by the horizontal hammock suspension position. In short, the jacket should be applied after reduction has been attempted by firm even pressure at the site of the deformity, with enough hyperextension to open the narrowed canal to its normal limits.

In 1887 I collected sixteen cases of immediate rectifica-



tion of the spine and fixation with a plaster-of-Paris jacket. Of these, three died, three derived no benefit, and ten were greatly improved. The conclusions reached by the writer in 1887 were as follows:

“ First: That, in the *immediate* correction of the deformity and fixation with plaster-of-Paris jacket or other means, we have a rational method of treating a large number of cases of fracture of the spine. Second: That, considering the hopelessness of results in fracture of the spine when treated expectantly, almost any risk is justifiable. Third: That the *immediate* correction of the deformity is imperative, *if* softening of the cord can and does occur from pressure at the end of forty-eight hours. Fourth: That the suspension of the patient is only a means of rectifying the deformity; that certain fractures could be simply pressed into position while the patient lies prone or supine.

“ The objections to the treatment are,

“ 1st. That the expectant plan of treatment gives a small percentage of recoveries. 2d. That there are serious risks, especially in the cervical region, attending the suspension of a patient and the rectification of the deformity with a fractured spine, in the way of shock, collapse, and death. 3d. That in attempting to relieve pressure on the cord, by rectifying the deformity, we might either sever the spinal cord or make pressure upon it. This is a matter of chance.

“ My own belief regarding the status which the procedure should occupy in surgery is, that it will occasionally be a life-saving measure; that it should be applied under anæsthesia in all cases of fracture of the spine which are not conclusively known to be irremediable; and that, apart from the chance of recovery offered to the patient by this means, it will almost invariably make the patient more comfortable, in that he can be handled more easily.”

In 1894, in the second series (86) cases, the percentage of recovery was 33. The treatment had been influenced by the first paper in 1887. In the first series of cases, 18 patients recovered; 9 recovered “useful,” that is, could walk; and 9 recovered “useless,” that is, were bedridden. In the second series of cases (86), 28 recovered; 19 were “useful,” and 9

were "useless." Not all of the cases were treated by the immediate rectification of the deformity; in fact, it was applied during the year 1887 four times; during the year 1888 twice; during the year 1889 three times; during the years 1890 and 1891 twice; and only once in 1893.

More experience, as is usually the case, has brought more light; and I now believe that the indication for immediate reduction and fixation is for cases of fracture with no cord symptoms, and for cases not hopeless which refuse an open operation.

(3) Laminectomy. The technique of the operation that I use is practically described by Munro.<sup>8</sup> A single incision is made in the median line and is carried down to the lamina on either side close to the spinous process. The wound is packed and the lamina on the other side is exposed in like manner. The interspinous ligaments above and below the selected spine are cut with blunt scissors curved on the flat. The spinous process itself is bitten off with a rongeur, the laminæ are next cut near the middle line with small bone forceps, and the intervening piece removed, thus exposing the cord without even putting it in danger of injury. Successive laminæ should be removed until it is positive, without any chance of error, that all compression of the cord, above and below, or of spinal nerves still in the canal, is removed. The dura should be opened freely; spicules of bone should be removed; the dura should not be sutured, and drainage by a bit of rubber tissue may or may not be necessary.

In the open operation lies our hope,—a hope, unfortunately, and nothing more. The advocates of operative surgery of spinal cord injury are divided into those who favor immediate operation and those who advise a delayed operation. Relatively few surgeons are in favor of an operation within a few hours. The arguments against immediate operation are that an injury which has involved destruction of the cord is already done, and will get no worse in a few hours. The patient is still suffering from spinal and general shock.

I believe in immediate operation unless it is distinctly

contraindicated by shock. The reason I believe in immediate operation is that no one can positively state in what condition the spinal cord is until he looks and sees, and if pressure exists on the spinal cord, and it is allowed to persist for many hours, irreparable damage to the cord may result. I recognize that it would be advisable to exclude spinal concussion, which at times might simulate pressure on the cord, but while waiting for the spinal concussion to clear up, if pressure on the cord exists, irreparable damage may result. I agree largely with Walton and Lloyd in fearing delayed operation in cases which have recovered from their first shock and have in them anything objectively hopeful.

OLIVER<sup>9</sup> states that "a point which has been regarded as very important in these cases is the length of time that elapses between the receipt of the injury and the performance of the operation. The usual advice has been to operate as soon after the infliction of the injury as is possible, because of the fear that prolonged pressure may of itself produce degenerative changes in the cord from which the patient never recovers." Dr. Oliver states that "analysis of the statistics seems to throw some doubt upon the correctness of this dictum." He instances cases by Lauenstein, McCosh, Huss, Starr, Wyeth, and one of his own cases, where recovery had occurred from late operation on a fracture of the spine. Dr. Oliver says, "If the injury is not irreparable at the time of accident, it is unusual for bony or other pressure to cause a permanent abolition of function."

I recognize that the successful laminectomies for fracture of the spine have almost invariably been late operations. Notably this is the fact in Horsley's cases. If, however, the late operations are successful at times, it perhaps may be assumed that these same cases would have been successful if an operation had been done early; at least, they would not have been subjected to the risk of uncertainty as to whether pressure on the cord was producing irremediable damage. I cannot believe that pressure on the cord should be allowed to persist any longer than is imperative from the general condition of the patient.

THORBURN<sup>10</sup> is pessimistic. Speaking of seven cases of operation, he says, "In none of the cases did any real benefit result; all those in which the injury was in the cervical region died; all those in which it was below the cervical lived, but did not recover from paralysis." "The published cases, of which there are about 200, show to my mind no better results, if we exclude injuries of the laminæ, hæmorrhage, and operations upon the cauda equina. I have, indeed, not satisfied myself that there have been any successes, as regards recovery of function, save such as may be attributed to the regeneration of nerve roots only, or to the natural recovery of a cord which was but very slightly injured." "And, further, if it were shown that in one or two instances among the 200 published cases there had been a definite improvement or recovery, I should be inclined to regard such as the sequel of some error in the original diagnosis, rather than to allow a single instance to invalidate a rule based upon such extensive premises."

LLOYD<sup>11</sup> is more hopeful and, it seems to me, just in his estimate of the surgical results in these cases. He says, "It is, therefore, evident that if we operate immediately after the injury we will have failures that should not be charged against the operation itself, and, if possible, we should wait before operating until the question can be settled whether the patient will overcome the shock or succumb directly to the effects of the injury.

"There is another objection to immediate operation. In so-called concussion of the spine, there may be a certain amount of anæsthesia and paralysis. The recovery, however, will be complete, or at least so nearly so that no appreciable lesion can be made out. Immediate operations in these cases would be unnecessary, as they would have recovered spontaneously had they been left alone for a sufficient length of time. It is impossible, too, in the first few hours, to determine with any degree of certainty how severe the injury really is, nor can we absolutely localize the injury to the cord. In my opinion, therefore, we should wait until this period of shock has passed and until it is evident that there will be no spon-

taneous recovery complete enough to render life bearable. If, after this period has passed, the patient still continues to improve, no operative interference should be considered, but as soon as the symptoms begin to show retrograde phenomena or seem to have reached the end of the improvement operation should be undertaken.”

LLOYD<sup>12</sup> published the following table of laminectomies in 1902:

Cervical Region.	Immediate Operation.	Later Operation.
Deaths .....	21	2
Recovery .....	0	2
Improved .....	2	1
Not improved .....	0	4
Subsequent death .....	4	3
	—	—
	27	12
Dorsal Region.	Immediate Operation.	Later Operation.
Deaths .....	23	5
Recovery .....	4	10
Improved .....	9	18
Not improved .....	6	16
Subsequent death .....	7	16
	—	—
	49	65
Lumbar Region.	Immediate Operation.	Later Operation.
Deaths .....	4	4
Recovery .....	1	6
Improvement .....	1	6
No improvement .....	0	4
Subsequent death .....	0	2
	—	—
	6	22
Sacral Region.	Immediate Operation.	Later Operation.
Deaths .....	0	0
Recovery .....	0	1
Improved .....	0	3
Not improved .....	0	0
Subsequent death .....	0	0
	—	—
	0	4

He states that “these statistics are decidedly against immediate operation, and we must urgently advise never operat-

ing until it is evident that the patient will not succumb to the direct effects of the injury. As soon, however, as he has recovered from the shock and his exact physical condition is known the operation should be performed."

VICTOR HORSLEY'S cases, reported to the British Medical Association in 1895,<sup>13</sup> are the most brilliant. Of the seven cases reported, three were fractures of the spine. They are as follows:

1. "There was a fracture of the cervical spine, with paralysis of all four limbs, which had lasted eight months. The paralysis began to extend. Analgesia was present, and this always points to an affection of the central gray matter of the cord. The laminæ of the fifth and sixth cervical vertebræ were removed, and the thick fibrous tissue was dissected off the dura mater. The patient steadily improved, and only wasting of the interossei remained."

2. "The patient had fallen from a cart, striking his head and right shoulder. He walked about for a week, but gradually lost power in all his limbs. When admitted to Queen's Square Hospital, fracture of the sixth cervical vertebra was diagnosed. The left optic disk was swollen. Laminectomy of the fourth, fifth, and sixth cervical vertebræ removed a ridge which had been pressing on the spinal cord. Power began to appear on the twelfth day. He has since recovered completely."

3. "The patient sustained a fracture of the sixth cervical vertebra; the onset of paralysis was gradual. There was marked contracture and well-marked anæsthesia of the postaxial border of the upper limbs. The arches of the sixth and seventh cervical vertebræ were removed when a projecting ridge was felt, but on extension this disappeared. He is recovering slowly."

The last case may have been a fracture of the spine, and is reported as follows: "The patient had struck the fore part of his head, and after walking 200 yards rapidly became completely paralyzed. After partial recovery spastic paraplegia appeared, with postaxial anæsthesia of the upper limbs. The laminæ of the sixth and seventh cervical vertebræ were removed. Permanent recovery commenced three weeks after the operation. He can now walk a mile."

The following is a list of some of the laminectomies that have been collected from the literature of the subject since Lloyd published his table. It must be recognized that it is not common for surgeons to publish their unsuccessful cases:

VAN ENGELEN<sup>14</sup> reports three operative cases.

1. Paraplegia as the result of a fresh fracture. The cord was found crushed to a pulp; death in fourteen days.

2. Fracture of skull and spine, apparently dying. After trephining both skull and spine consciousness returned, motor and sensory power in the lower extremities reappeared, but patient died three weeks later from tetanus.

3. A young woman after fracture of the spine suffered paraplegia and pains of the legs. Since sensation was retained, operation was done. Paraplegia was not relieved.

HAHN, E.,<sup>16</sup> reports four cases.

1. Man, aged fifty-one years. Fell three stories; much shock, paralysis of both legs. Sensation doubtful because drunk. Next day pulse better, paralysis persisted, reflexes gone, incontinence, complete loss of sensation from Poupart's down. Operation three weeks later. Fracture third lumbar up to twelfth dorsal. A fragment of twelfth dorsal narrowed the canal, pressing along 1 centimetre of the cord. The dura was opened and the wound drained. Pain was relieved and sensibility improved for a time.

2. Man, aged thirty-eight years. Fell twenty-five feet; conscious, with pain, paralysis of right leg and bladder; some power in left leg, which disappeared in twenty-four hours. Reflexes lost, sensibility of legs much diminished. Retention of urine, incontinence of fæces. Operation in six days. Fracture of the first lumbar, change in canal noted anteriorly. The cord compressed slightly but not torn; wound drained. Some sensation returned, but patient died in one week.

3. Man, aged forty years. Fell three stories; paralysis of both legs; sensation lost from pubis down. Operation nine weeks later. First and second laminæ removed. A bit of bone was driven under the cord and compressed it from behind, forward. Fragments were removed. In one week bladder and rectum improved. The wound healed. Four months later the patient was discharged, with mobility and sensation not improved.

4. Man, aged twenty-two years. Fell twenty feet into water, and his horse fell after him; swam ashore with arms only; had pain in the back and was numb in the legs. Sensation of legs gone, mobility from hips down lost. Operation three days later. Fracture of last dorsal and first lumbar, compression of cord by fragments, dura not open, the cord seemed normal. Died without improvement.

WINNETT<sup>16</sup> collected six cases which may be called successful, and to these added one of his own on which Peters operated. The cases are as follows:

1. Surgeon, McCOSH. Man, aged thirty-three years. Eighteen months previously sustained a fracture or dislocation of the fourth, fifth, or sixth cervical. For nine months bedridden. Caused by shackle falling on his head and doubling him up. Completely paralyzed below the clavicles. At time of operation, atrophy of muscles, but stands with

assistance. Spastic paralysis of left arm. Some use of right arm, but not of hand. Constant pain in upper limbs. Operation. Fourth displaced one and a quarter inches to left. Removed arch of fifth; dura very vascular and attached to arch. Not opened. Result: Gets about, uses arms, walks four miles, and writes with left hand.

2. Surgeon, JOHN A. WYETH. H. A., aged twenty-one years. September 1, 1889, thrown from a cow-catcher to track. Loss of motion from pelvis down; bladder and rectum paralyzed. Operation, April 30, 1890. Removed laminæ, last two dorsal, and upper two lumbar. Bodies found crushed, and cord partly divided. Undivided part compressed by laminæ of vertebra above and body below. Compressing bone was removed and dura closed. Result: Immediate slight improvement in motion, especially in feet. In 1894, good use of legs and feet, but uses cane.

3. Surgeon, RIDENAUR. M. N., aged twenty-eight years. December 11, crushed by an overhead beam in such a manner as to crush centre of his back forward at an acute angle, frightfully lacerating and crushing parts. Seventh dorsal depressed one inch, and eighth absent. Lamina of seventh dorsal broken and separated. Transverse processes of seventh torn off. Intervertebral disks of seventh forward one inch. Spinous process of eighth penetrating cord. Body of eighth fractured. Membranes punctured and lacerated, and hæmorrhage into arachnoid space. Operation: Removed roof from sixth and ninth dorsal. Sensation returned at once. Motion in recti at end of fourth day. Catheter required till seventh day. Sphincter ani restored at end of first week. Knee-jerk restored at end of second week. Lift limb from bed at end of fifth week. Walk with crutches at end of three months.

4. Reported in *American Journal of the Medical Sciences*, April, 1892. Fracture dislocation between tenth and eleventh dorsal. Opened five hours after, and large extra-theccal clot washed away; vertebræ reduced, and spines held together by silk. Paralysis and hyperæsthesia passed away.

5. Surgeon, BOYLE. S. M., aged twenty years. Struck in back by train May 8. Loss of motion and sensation below hips. Reduction failed. For first week catheterization. Pain and hyperæsthesia in both legs. Operation: July 12. Dislocation backward between ninth and tenth, above and forward of last dorsal, and first lumbar below. All arches removed and bodies grooved. Second day after operation slight movement in toes, also sensation. At present has good sensation and motion.

6. Surgeons, CHURCH and EISENDRATH. Fracture dislocation of tenth dorsal, with complete paraplegia. Extra-dural hæmorrhage found, clot removed, and vertebræ reduced. Result: Cured.

7. Surgeons, PETERS and WINNETT. Male, aged twenty-nine years. Dived into four feet of water, his head doubling under him. Physical examination: Mind clear, sensations normal down to nipples. Tactile sensation present, but indistinct over the remainder of the surface, with



the exception of the forearms and hands. Contact of clothes was hot and painful. No other pain since. Retention of urine. Paralysis of rectum. Contraction of pupils. Irregularity of fourth and fifth cervical spines. All muscles below the neck, except the diaphragm, paralyzed. A small spicule of bone was found in the membranes over the fourth left lamina. The spine of the fourth was bent to the left. The membranes were opened, blood and spinal fluid escaped, and pulsation returned. The case was discharged the nineteenth week, with bladder normal, and patient able to move left hand.

The writer presents the following conclusions :

*First.* That fractures of the spine may well be divided into two classes : first, fractures of the spine with injury to the cord ; and, second, fractures of the spine without injury to the cord.

*Second.* That it is not best to decide what the treatment of an individual case of fracture of the spine should be from the statistics, because the lesion varies so widely.

*Third.* That in many cases of fracture of the spine it is impossible to primarily state whether the cord is crushed or pressed upon by bone, blood, or exudate, except by an open operation.

*Fourth.* That only by the *persistence* of total loss of reflexes, complete insensibility to touch and pain, and motor paralysis below the level of the lesion, can total transverse destruction of the cord be diagnosed.

*Fifth.* That if pressure on the cord is allowed to remain for many hours, irreparable damage to the cord may take place.

*Sixth.* That unless it is perfectly clear that the cord is irremediably damaged, an open operation to establish the condition of the cord and to relieve pressure is imperative as soon as surgical shock has been recovered from.

*Seventh.* That in certain cases of fracture of the spine, when the cord is not injured but is liable to injury from displacement of the fragments of a vertebra, rectification of the deformity and fixation of the spine may be used.

*Eighth.* That if the cord is crushed, no matter what treatment is adopted, there will, of necessity, be a high rate of mortality.

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