

# SURGERY OF EXPERIMENTAL LESION OF SPINAL CORD EQUIVALENT TO CRUSH INJURY OF FRACTURE DISLOCATION OF SPINAL COLUMN

A PRELIMINARY REPORT \*

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## PREFATORY REMARKS

In two former papers I have dwelt at length on the mechanical considerations of injury to the spinal cord in cases of fracture dislocation of the spinal column.<sup>1, 2</sup>

In this communication, therefore, I shall limit myself to the discussion of the experimental work in which I have been engaged for the past year in the laboratories of the University of Pennsylvania.

I would accentuate the fact that this is a preliminary report and that I am fully aware of the amount of control experimentation necessary before an *ex cathedra* statement can be made as to applicability of this work in the human subject.

## MEASUREMENT OF IMPACT ON SPINAL CORD IN SPINAL FRACTURE DISLOCATION

In order to arrive at an adequate concept as to the amount of impact a spinal cord could receive and yet recover its function, I designed an instrument whereby a given weight could be dropped from a known height thereby producing a given impact (see the accompanying illustration).

A dog having been thoroughly anesthetized, a laminectomy is performed, the instrument placed in position and the weight dropped on the spinal cord. The resulting impact in gram-centimeters is the product of the height in centimeters and the weight in grams. The element of friction in the instrument is so inconsiderable that it may be regarded a negligible quantity.

## HYPO-IMPACT AND HYPERIMPACT

Instrument for producing a measured impact on the spinal cord.

In my work I have used dogs varying in weight from 7.5 kilos to 18 kilos. The laminectomy has been performed in the lower third of the thoracic region.

I have found that a weight of 30 gm. may be dropped on the spinal cord from a height not exceeding 11.5 cm.

\* From the Department of Experimental Surgery and the Department of Neurology in the University of Pennsylvania. Read at the thirty-seventh annual meeting of the American Neurological Association, Baltimore, May 11-13, 1911.

1. Allen, A. R.: Injuries of the Spinal Cord, *THE JOURNAL A. M. A.*, March 21, 1908, p. 940.  
2. *Am. Jour. Med. Sc.*, May, 1908.

with every expectation of an uninterrupted recovery on the part of the animal. The resultant of 339 gram-centimeters is one wholly in accord with complete autorestitution.

So soon as we exceed an impact of 340 gram-centimeters (to speak in round numbers) we obtain symptom pictures of more serious import.

Whereas an impact of 340 gram-centimeters will produce a complete paraplegia of spastic type, which, in course of a week or ten days, will have largely disappeared, so soon as we begin to use impacts of greater magnitude, we find the symptoms more severe and more lasting. Most animals injured by a 420 gram-centimeter impact will present a serious symptom picture; complete spastic paraplegia with scissor-like crossing of the hind limbs, emaciation, paralysis of the bladder and rectum and trophic lesions. An impact of 450 gram-centimeters will produce a symptom picture of complete transverse lesion of the spinal cord and the animal will die in the asthenic and toxic state so familiar to all who have had experience with fracture dislocation of the spinal column in the human subject.

I therefore term all impact below 340 gram-centimeters "hypo-impact," and all impact above this amount "hyperimpact."

## THE HYPOTHESIS OF SYMPTOM-COMPLEX OF TRANSVERSE LESION OF THE SPINAL CORD IN FRACTURE DISLOCATION OF THE SPINAL COLUMN

Without restating *in extenso* the views concerning pressure on the cord from fragments of bone or the intramedullary pressure of hemorrhage or edema, with which views I have dealt in previous articles, I would say that I consider it a very uncommon occurrence to find a passive impingement of bone on the spinal cord when the operation of laminectomy is performed for fracture dislocation.

We must assume one of two theories, or probably both, in the etiology of cessation of function in the spinal cord in those cases in which the cord has not been literally cut through: Either there is a destruction of axis cylinders directly consequent to the impact, or else, owing to the impact, there is an edematous and hemorrhagic outpouring into the cord tissue, which by its pressure and chemical activity inhibits temporarily all conduction function, or destroys permanently the spinal cord.

In suggesting a possible treatment to aid and abet an autorestitution, it is obvious that the hypothetical factor of direct injury to the axis cylinder by the impact is beyond our reach, and that we should better confine our attention to the amelioration of the heightened intramedullary pressure.

This has been tried in years past by various means, such as cupping and other antiphlogistic devices. But the amount of benefit obtained has always been open to much doubt and in the fortunate cases, where restoration has taken place, the surgeon has found himself unconsciously imbued with a *post hoc non propter hoc* feeling.

## THE SYMPTOM-CONTENT OF LONGITUDINAL SECTION OF THE SPINAL CORD

In order to ascertain the symptom-content of longitudinal section of the spinal cord, I performed laminectomy on a number of dogs. The dura mater was incised in the median line and held apart gently by means of traction sutures. Then with a very fine canaliculus knife longitudinal incisions from 2 to 3 cm. in length

were made. In some cases a single incision in the median line, in others, bilateral incisions from the emerging posterior roots forward and inward were made. The incisions were carried completely through the cord. When the dogs came out of ether, they were able to stand and walk, showing very little weakness or awkwardness in walking. There was very little, if any, exaggeration of the reflexes of the hind limbs. A few days sufficed for the animal to recover his normal motor capabilities.

This finding is at variance with the teaching of some of the older physiologists, who have reported paraplegia of spastic type after this procedure.

I cannot but believe that when paralysis ensues after this operation, it is most likely due either to cutting the cord obliquely owing to faulty technic, or else is secondary to inflammatory change from imperfect aseptic precautions. From this work I conclude that median longitudinal section of the spinal cord of the dog is provocative of no symptom of note.

#### EXPERIMENT OF MEDIAN LONGITUDINAL INCISION IN CASES OF HYPERIMPACT

Given, as the hypothesis, that there is a twofold factor after the impact: (1) the direct injury to axis cylinders from the impact; (2) the outpouring of serum and blood into the substance of the cord; given the condition of the closely investing pia-arachnoid and the inability of drainage; given the comparative absence of symptoms after median longitudinal incision into the cord—the corollary which presented itself was: What effect would a median longitudinal incision into the spinal cord have on subjects submitted to hyperimpact?

The factors suggesting this course were the need for spinal cord drainage, thereby accomplishing a spinal cord decompression, and the fact that the heteromeric neurons in the dog and in man are not of vital importance.

In five dogs I have used a hyperimpact of 540 gram-centimeters (30 gm. at a height of 18 cm.), and then made a median longitudinal incision from 1 to 1.5 cm. in length directly through the impact level and passing altogether through the spinal cord. These dogs made uneventful recoveries, in the worst instances showing only a slight spasticity and awkwardness in the hind limbs after recovery, but not enough to prevent running and jumping.

This impact would have led to the dire consequences which I have pictured above, had not the median longitudinal incision been made. The dogs would have died had not the spinal cord been drained.

#### DETAILED DESCRIPTION OF OPERATIVE PROCEDURE

An incision of about 6 cm. is made over the spinous processes down to the fascia. The fascia is incised and the muscles pushed well to the side by means of a periosteal elevator. Three spinous processes are cut off by means of bone forceps, and then the lamina of one vertebra is sawn through on each side and the fragment of bone elevated and removed. Further enlargement is obtained by means of specially fashioned rongeur forceps. It is necessary to have at least 3 cm. of the cord exposed so that careful observation can be made. The epidural fat is now wiped away, the impact instrument adjusted and a strong reading-glass focused on the segment of the cord to be struck. The blow is struck, and there is a single jerk of the lower extremities.

The instrument is instantly removed, when it is noted that instead of the cord being the natural color and the

dura mater showing as an almost transparent covering through which the small vessels are easily visible, we have now to deal with a dark bluish-purple, swollen mass. I now take a very fine curved needle, and clamping it in a pair of mosquito hemostats I use it as a tenaculum to lift the dura preparatory to incising it centrally. If this incision be carefully made, there at once bulges out of the opening of 2 cm. a dark, beefy-red mass. This is the greatly distended pia-arachnoid. This hyperdistention of the pia-arachnoid extends longitudinally about 4 cm., and when torn by means of a fine tooth forceps it subsides in a great gush of blood and cerebrospinal fluid. It will now be seen that the substance of the cord appears pinker than it should normally.

A median longitudinal incision of at least 1 cm. is made completely through the cord, following which there is a goodly outpouring of blood and serum from the cord substance.

After the active bleeding ceases, the muscles are brought together by a close row of buried Pagenstecher sutures. The fascia is closed by means of a continuous Pagenstecher suture and the skin wound by means of Michel clamps. The dura mater in the dog is too tight to warrant trying to suture it, as would most certainly be indicated in man.

The dog is completely paraplegic following the operation, and it may be three or four days before there is any indication of return of power. In a week's time he is standing and moving about his cage with a very spastic gait. Little by little the power returns and the spasticity diminishes. The end-result is a complete restoration of motor power. The animal is able to run and jump and has complete control of bladder and rectum.

The only point in the convalescence which may give trouble is the development of what I might term an artificial spina bifida. Owing to the difficulty of closing the dura mater in the dog, there is a leakage of cerebrospinal fluid upward forming a fluctuating tumescence, possibly the size of an egg, at the seat of operation. This it is my practice to evacuate by means of an aspirating needle under the most stringent aseptic precautions.

This experimental work has been carried out under full ether or chloroform anesthesia; and at no time have the dogs given evidence of suffering pain.

#### GENERAL CONSIDERATIONS; OUTLINE OF FUTURE WORK IN THIS FIELD

There are many steps between the results above mentioned and the adoption of the median longitudinal incision through the injured area as a desirable method of procedure in cases of spinal cord injury in fracture dislocation in the human subject.

The first important step to determine is: How long after the injury to the dog's spinal cord can one wait and still obtain the good effect of the drainage from median longitudinal incision?

I shall conduct a series of cases of hyperimpact in which the median longitudinal incision is made two, four, six and twelve hours after the impact; then a series in which a period of twenty-four hours elapses before the cord is cut.

I have already tried to aid the drainage by applying a Bier stasis-hyperemia cup over the laminectomy area the day after the impact operation of median longitudinal incision had been performed. This I applied for half an hour twice a day, but the result was most unde

sirable. The dog showed every symptom of complete transverse lesion shortly after the first treatment and died about four days later. On histologic examination, I found the gray matter of the cord greatly softened and hemorrhagic for a distance of 2 cm. above and 2 cm. below the impact area. It looked just as if the gray matter, naturally lacking in *Widerstandsfähigkeit* (resisting power) had given way to the negative pressure.

Of course, this is only one case in which the Bier's method was used. It is altogether possible that, with a more gentle suction, a better or favorable result might have been obtained.

I wish to call attention to a point which has impressed me greatly in all this work. I refer to the effect of severe hemorrhage during the operation on the period of convalescence.

Hitzig<sup>3</sup> has shown the baneful effect of exsanguination on the central nervous system. I also have noted in a previous work the great change in conductivity in the lateral columns of the spinal cord in animals (dogs) slowly exsanguinated.<sup>4</sup> There is no doubt to my mind that whenever I had much hemorrhage, the animal's convalescence was prolonged, his spinal cord symptoms more severe than the impact would warrant and the chances of an infection greatly augmented. I am convinced that this is an important element in the failure of operations on the brain and cord.

It is not my purpose to take up the histopathology of this work until a future communication. I shall only say that I have been surprised at the amount of ascending and descending degeneration that I have found by the Marchi method in the spinal cords of dogs which had recovered their motor power completely and which I had killed in order to make the histopathologic study.

My tentative conclusion is that in cases of fracture dislocation of the spinal column in the human subject, in which there exists the symptom picture of transverse lesion of the spinal cord, it were well to perform the operation of laminectomy at the earliest possible moment, and if the cord be not completely severed to make a median longitudinal incision through the area of impact by means of a fine canaliculus knife in order to drain the injured tissue of the products of edema and hemorrhage.

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**Protective Detention.**—Dr. Quinton, an English criminologist, is quoted by G. A. Auden (*Jour. Crim. Law and Criminology*) as saying: "Female offenders who are of weak intellect will gain incalculable benefit from the scheme of the royal commission, which provides for their removal from prison altogether. This class—a very pitiable one—never has been, and never can be, rationally dealt with under a short sentence system. Their vicious habits and criminal propensities soon alienate them from relations and friends who in despair of controlling them, abandon them to their fate—picking up a living on the streets. Petty thieving, drunkenness and prostitution bring them back to prison time after time, their only gain from imprisonment being the protection it affords them for the time being from the perils of the street, which, in the case of feeble-minded girls and women, are appalling. They need not only preventive but protective detention in some kind of institution other than the prison, for a much longer period than any term of penal servitude their offense would justify."

3. Hitzig: Physiologische und klinische Untersuchungen über das Gehirn, Berlin, 1904, part 1, p. 23.  
4. Allen, A. R.: Hemorrhage Into the Ventricles, THE JOURNAL A. M. A., July 18, 1908, p. 210.

## SEVERAL UNUSUAL JOINT CASES

THEIR TREATMENT AND THE RESULTS \*

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In reporting the following rather unusual cases I claim no originality, but simply aim to show what thorough asepsis, accuracy of adjustment and secure fixation will accomplish.

I make no reference to a rather large number of other fractures occurring in a field in which traumatism contributes greatly to the work of a surgeon, including fractures of the patella, nor to cases of delayed union, and ununited fractures occurring in the shafts of bone in which the open method and direct fixation have been called into use.

**CASE 1.**—The first case may be summarized as follows: Complete separation of the right olecranon, extensive injury of the soft parts, nailing, straight splint; complete restoration of function.

The patient was a male, aged 17, a pattern maker's apprentice. The injury was received by elbow joint coming in contact with a band saw; wound in soft parts 4 inches long across posterior aspect of elbow; olecranon severed  $\frac{3}{4}$  inch below upper end; trochlear surfaces of joint scratched by saw; fragment of olecranon retracted by triceps. Reduction was effected by placing the arm in a straight position; fragment secured in place by driving a cast-steel wire brad,  $1\frac{1}{2}$  inches, No. 16, through fragment and into shaft of ulna (Fig. 1); wound closed with interrupted silk sutures, skein of catgut for drain, and straight anterior splint applied; wound healed without suppuration; nail was removed when it became loose, probably in the third week. Figure 1 shows the nail in position. The operation was done in the boy's home on a common kitchen table, a range for a sterilizer, a dish pan for instrument tray, in which instruments, nails, tack hammer, all were thoroughly sterilized. Passive motion was begun at the end of five weeks; six months after the injury the functions of the joint were perfect. Figures 2 and 3 show the limb in straight position and full flexion.

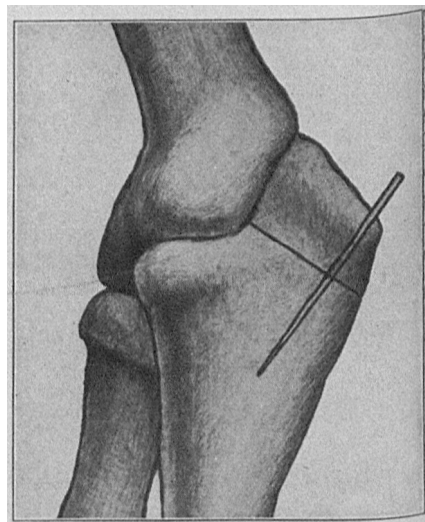


Fig. 1.—Method of fixing the broken fragment of the elbow joint in Case 1; the wire nail in position.

**CASE 2.**—The patient, a boy aged 10, was thrown from a horse while riding in the street; both condyles separated, probably an inch above the lower end of the humerus; distal end of proximal fragment thrust through soft parts in front of joint. Every precaution to produce an aseptic condition was taken. Complete reduction under anesthesia was effected by inserting fingers into the wound and securing perfect apposition of fragments, forearm was flexed on the arm and secured by a strip of adhesive plaster; the external wound was then dressed, and the upper extremity bound to the side of the body without a splint, as practiced by Mr. Robert Jones. Improvement was rapid and satisfactory; wound remained

closed.

\* Read in the Section on Surgery of the American Medical Association, at the Sixty-Second Annual Session, held at Los Angeles, June, 1911.