CONCUSSION OF THE SPINAL CORD
IN BATTLE CASUALTIES

MAJOR GEORGE S. BAKER, M.C., A.U.S.,* AND CAPTAIN FARRINGTON
DANIELS, JR., M.C., A.U.S.

Neurosurgical Section, Lawson General Hospital, Atlanta, Georgia

(Received for publication December 4, 1945)

In civil practice acute injuries of the spinal cord are almost invariably
associated with dislocation or fracture of the vertebral column, and the
clinical picture of transection and compression of the spinal cord from
these causes is well known. In all cases of acute injury of the spinal cord—
contusion, laceration, compression, transection, penetrating wounds or con-
cussion—the phenomenon of spinal shock develops immediately and lasts
for a few hours to months. According to Munro, as the result of the pres-
ence of spinal shock, "all reflex activity below the level of the injury becomes
chaotic, unpredictable, variable and devoid of any diagnostic or prognostic
significance." He also emphasized the possibilities of rehabilitation in these
otherwise discouraging cases by an aggressive course of good nursing, good
nutrition and the use of tidal drainage of the bladder.

Transient paralysis as the result of injury of the spinal cord may occur
under circumstances in which a direct blow or compression of the cord is
not evident, and may be followed by partial or complete recovery in a few
hours to a few months. These fortunate individuals represent spinal shock
from concussion, rather than laceration or contusion of the spinal cord.

Concussion has been more thoroughly studied in regard to the brain
than to the spinal cord. Experimentally it is shown to be a phenomenon
consequent to sudden change of acceleration or of pressure of the brain sub-
stance. It is therefore found in isolated form in the "closed" type of
head injury and may be minimal or absent in cases in which there is a
penetrating type of head wound. The concept that cerebral concussion is a
traumatic paralysis has been challenged by Walker, Kollros and Case, who,
on the basis of electroencephalographic and other delicate measure-
ments on experimental animals during the moment of impact, emphasized
the excitatory phase of the reaction. It is their contention that the paralysis
following injury is analogous to the depression following other types of
cerebral stimulation. A similar concept of concussion in peripheral nerve,
induced by an air blast, was presented by Krems and co-workers. Denny-
Brown expressed disagreement with this viewpoint and pointed out that
convulsive manifestations are rarely present in cases of cerebral concus-
sion. It is generally agreed that synaptic transmission is affected by less
intense injury than is the neuron as a whole.

The term "concussion of the spinal cord" has been used in two senses.

* Released from military service December 24, 1945. Consultant in Neurosurgery, Mayo Clinic,
Rochester, Minnesota.
Hassin\textsuperscript{5} described as cases of concussion some in which trauma led to no immediate dysfunction of the spinal cord but was followed in a few days by symptoms and pathologic changes, sometimes simulating degenerative changes encountered in cases of amyotrophic lateral sclerosis.

In the other definition, concussion of the spinal cord is considered to be "that which happens after a single violent impact to the vertebral column, when the function of the spinal cord is affected though no gross anatomical changes can be found." We shall adhere to the second definition. While subsequent investigation may prove this erroneous, we shall presume that "concussion" is a similar phenomenon throughout the nervous system and that comparison of concussion of the spinal cord to cerebral concussion is justified.

\textbf{EXPERIMENTAL CONCUSSION OF THE SPINAL CORD}

The quantitative effects of measured trauma to the spinal cord were studied by Allen\textsuperscript{1} in 1911. He made no attempt to distinguish the effects of contusion and concussion nor to evaluate the result in terms of acceleration but found that an impact of 340 gm.-cm. gave every expectation of uninterrupted recovery. By dropping a 30 gm. weight from a height of 11.5 cm. (impact of 340 gm.-cm.) onto the exposed spinal cord of dogs he produced spastic paraplegia, which largely disappeared in a week or ten days.

More recently, experimental concussion has been studied by Groat, Rambach and Windle.\textsuperscript{4} They produced concussion in cats by a blow over the spine with a blunt wood instrument. They used the threshold stimulus of a reflex arc to determine the severity of the reaction. The degree of functional interruption and longitudinal extent of involved cord was found to be correlated with intensity of the blow applied. Immediate and delayed cytologic changes were also found.

\textbf{CLINICAL OBSERVATIONS ON CONCUSSION OF THE SPINAL CORD}

We have had an opportunity to observe a number of injuries of the spinal cord in an Army general hospital designated as a neurosurgical center (Lawson General Hospital). These have included transections of the spinal cord, both from battle wounds and from fracture-dislocations of the spinal column. There have also been a number of partial lesions and lesions with varying degrees of recovery. It is recognized that this case material may be artificially selected as a result of the Army casualty evacuation system but the consistency of the clinical picture lends the suggestion of validity.

Of a total of 85 cases of injuries of the spinal cord assessed, a diagnosis of true concussion of the spinal cord appeared justified in only 8 cases. These presented a similar picture, in that the lesion was caused by through-and-through (perforating) bullet wounds, which passed transversely near the spinal cord, striking bone or barely missing the lamina, and in that paralysis of the extremities persisted from a few hours to a few weeks. Holmes,\textsuperscript{6} in the Goulstonian lectures near the beginning of the First World War, gave
the best clinical descriptions of concussion of the spinal cord that we have. The type of trauma that he found most frequently is similar to the type that we observed. He stated, "Spinal concussion is most commonly seen when the projectile has touched either a spinous or transverse process, which it may have fractured or not, but it may be also produced by a bullet which penetrates or perforates the body of a vertebra."

This is in accord with the statement of Munro that "concussion of the cord is associated only with bullet wounds of the bony wall of the canal." The through-and-through nature of the wounds in cases of concussion indicates high velocity and it is probable that only in this type of injury can the "shocking" effect be produced, which will cause the requisite abrupt acceleration or compression of fluid, without actual contact with the missile or bony fragments.

In the 8 cases vesical disturbances have been absent or minimal and recovery has been more or less complete. Residual neurologic findings six months after injury have consisted in "upper motor neuron lesions," manifested by clonus, hyperactive reflexes, spasticity and presence of Babinski and Hoffmann signs. In one case in which a decubitus ulcer had been present in a region of anesthesia, this had healed and the anesthesia had disappeared. We have not encountered any cases in which a complete physiologic transection has been followed by recovery. This observation agrees with the statement of Pilcher that "recovery from a complete transverse cord injury which takes place instantaneously never occurs." He emphasized that close examination of an apparently complete transverse lesion will reveal a little remaining sensation in the lower sacral distribution. However, discussion of this problem with medical officers who have seen large numbers of these cases near the combat area suggests that recovery under these circumstances may rarely occur. In looking back from the vantage point of a recovery, the best prognostic sign that can be found in the history is the minimal nature of vesical disturbance.

The following report is typical of the 8 cases of concussion of the spinal cord and is given in detail. Data on all 8 cases are given in Table 1.

**Case 1.** An infantry soldier, 31 years of age, was wounded in January, 1945, in Luxembourg by a sniper's rifle bullet, which perforated transversely from one side of the neck to the other at the level of the 4th cervical vertebra. Points of entrance and exit were on the lateral margins of the trapezius muscles. He had immediate paralysis in both arms and legs, associated with "numbness." He apparently did not require urethral catheterization but had persisting difficulty with constipation.

Laminectomy within 24 hours of injury showed a compound, comminuted fracture of the spinous process of the 4th cervical vertebra. The laminae were removed from the 4th and 5th cervical vertebrae. The dura was not injured and the cord was pulsating normally. A catheter was passed 10 cm. down and 7 cm. upward without encountering obstruction.

Ten days after injury, neurologic examination showed weakness of all four extremities. Reflexes of both legs were normal. Reflexes in the left arm were weak and sluggish. Cremasteric and abdominal reflexes were present. Fourteen days after injury the patient was described as using legs and feet but weakness of the arms persisted, the patient being able "almost to flex his forearm unaided." Electrical evaluation of muscles at that time showed
loss of muscle power of chiefly the median distribution on the left and the ulnar distribution on the right. One month after injury the patient was able to get his hands to his mouth to smoke. Two months after injury there was still moderate weakness, particularly of the left upper extremity.

On admission of the patient to Lawson General Hospital 3 months after injury all scars were well healed and there was no deformity or rigidity of the neck. There was no Horner's syndrome. There was disuse atrophy of all extremities, with weakness of both arms and legs. There was a bilateral Hoffmann's sign but no Babinski reflex. All deep reflexes were exaggerated. There was bilateral exhaustive clonus. Subjectively there were still regions of "numbness" on the legs and arms but objectively no anesthesia could be discovered. By 3½ months after injury the patient was able to perform skilled movements and was sent home on a convalescent furlough. Seven months after injury he was separated from the military service as having attained maximal hospital improvement and possessing good functional recovery.

**Comment on Clinical Cases.** It should again be emphasized that the first 7 cases presented identical trauma with directly transverse bullet wounds just dorsal to the lamina. Patient 2 showed Horner's syndrome and had a decubitus ulcer in a region of anesthesia over the right hip, which persisted for six months. He therefore probably had a larger element of contusion than the others. Cases 5 and 6 are noteworthy in that injuries of the thoracic vertebrae were associated with paralysis in the upper extremities.

In Case 8 the lesion was a thoracic wound, which differed from the others in that the vertebral body rather than the lamina was fractured. Furthermore, there was impairment of sensation below the level of the

<table>
<thead>
<tr>
<th>Case</th>
<th>Level of Injury (Vertebral)</th>
<th>Duration of Complete Paralysis</th>
<th>Duration of Vesical Distention</th>
<th>Fracture</th>
<th>Laminecotomy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>C-4</td>
<td>10 days</td>
<td>0</td>
<td>Spinous process</td>
<td>&quot;Dura and cord normal&quot;</td>
</tr>
<tr>
<td>2</td>
<td>C-7</td>
<td>14 days</td>
<td>3 wks.</td>
<td>Transverse process</td>
<td>Not done</td>
</tr>
<tr>
<td>3</td>
<td>C-6</td>
<td>8 days</td>
<td>0</td>
<td>Spinous process</td>
<td>Not done</td>
</tr>
<tr>
<td>4</td>
<td>C-7</td>
<td>25 days</td>
<td>0</td>
<td>0</td>
<td>Not done</td>
</tr>
<tr>
<td>5</td>
<td>T-10</td>
<td>14 days</td>
<td>0</td>
<td>Spine and lamina T-10 and T-11</td>
<td>&quot;Cord intact&quot;</td>
</tr>
<tr>
<td>6</td>
<td>T-5</td>
<td>14 days</td>
<td>0</td>
<td>Small defect lamina T-5</td>
<td>Not done</td>
</tr>
<tr>
<td>7</td>
<td>C-5</td>
<td>4–5 hours</td>
<td>0</td>
<td>Slight irregularity of spinous process on x-ray</td>
<td>Not done</td>
</tr>
<tr>
<td>8</td>
<td>T-6</td>
<td>7 days</td>
<td>1 day</td>
<td>Fracture body T-5</td>
<td>Not done</td>
</tr>
</tbody>
</table>
wound and paralysis was not present in the upper extremities. Motor function returned first in the left foot, then in the right foot, and gradually returned up to the level of injury. The recovery of sensation followed the same pattern.

Among the cases in which concussion of the cord could not be diagnosed, in 3 cases of perforating side-to-side bullet wounds there was complete paralysis without recovery. In one of these when laminectomy was performed the cord was observed to be “intact but injured.” Out of 15 cases of penetrating shell wounds and 7 of penetrating bullet wounds in which there were clinically complete lesions, observation at the time of laminectomy revealed anatomic transection in 9 cases and in 5 the spinal cord was described as intact but injured. A penetrating wound is considered to be a wound with entrance, but not exit, indicating a decrease of velocity to zero.

SUMMARY AND CONCLUSIONS

In examining patients whose spinal cords were injured we have found 8 cases in which a diagnosis of concussion of the spinal cord was justified. These are similar to those previously described, particularly in the literature of World War I. Injuries to the cauda equina have not been discussed. Recovery of both motor power and sensation generally begins in the lower extremities and ascends, the duration of dysfunction being greatest in the level of injury. The exact nature of the mechanism of concussion remains obscure. It is hoped that the clinical material presented can be correlated with future experimental work.

REFERENCES


RELEVANT ARTICLES NOT REFERRED TO IN TEXT

CONCUSSION OF SPINAL CORD