

# Chronic Neurological Sequelae of Acute Trauma to the Spine and Spinal Cord\*

## Part I

### THE SIGNIFICANCE OF THE ACUTE-FLEXION OR "TEAR-DROP" FRACTURE-DISLOCATION OF THE CERVICAL SPINE

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Certain chronic neurological sequelae to be described may result not uncommonly from an isolated acute injury to the spine and spinal cord. Often this neurological pattern may arise from repeated minor traumatic insults to the spinal cord and develop so insidiously that a diagnosis is made of chronic degenerative disease of the spinal cord. Early recognition and verification of the lesion which is responsible is important so that proper corrective measures can be instituted before irreversible neuro-anatomical changes occur.

The lesions involved include those caused by fracture-dislocations, compression fractures, unbridged penetrating wounds of the spine with retained foreign bodies, herniated intervertebral discs, and chronic hyperextension injuries of the spine. Since such a discussion is too extensive for one paper, it has seemed advisable to divide the material into two reports on the basis of etiology. Part I concerns one of the causes of this syndrome, the acute-flexion or "tear-drop" fracture-dislocation. Part II will include the remaining types of causative lesions noted above. The sequelae of the acute-flexion or tear-drop fracture-dislocation are probably best illustrated by case reports.

#### THE SIGNIFICANCE OF THE ACUTE-FLEXION OR TEAR-DROP FRACTURE-DISLOCATION

Among the acute injuries of the cervical spine, the acute-flexion, tear-drop type of fracture-dislocation has received only scant attention. This lesion is characterized by crushing of one vertebral body by the vertebral body superior to it in such a manner that the anterior part of the involved centrum is not only compressed but often is completely broken away from its major portion (Fig. 1). In most of these cases, this fragment has resembled a drop of water dripping from the vertebral body and it has been associated with dire circumstances so frequently that the terms "tear-drop" and "acute-flexion" fracture-dislocation of the cervical spine seemed to describe the lesion and to suggest the mechanism of the injury. The most important feature of this injury is the displacement of the inferior margin of the fractured vertebral body backward into the spinal canal, which often causes compression or destruction of the anterior portion of the cervical spinal cord. Recognition of this lesion is important from the standpoint of treating the immediate sequelae of the initial injury and for the prevention of a chronic neurological deficit which may occur years after the traumatic episode if proper treatment is neglected.

In 1951, one of the authors (R. C. S.) described a syndrome in acute injuries of the cervical spinal cord for which early operation was advocated<sup>6</sup>. In the past year, a more comprehensive review of this problem was presented under the title "The Syndrome of Acute Anterior Spinal Cord Injury".<sup>7</sup> This syndrome is characterized by immediate complete motor paralysis, hypo-aesthesia and hypo-algesia to a level consistent with the lesion, preservation of the sense of motion and sense of position but partial loss of the sense

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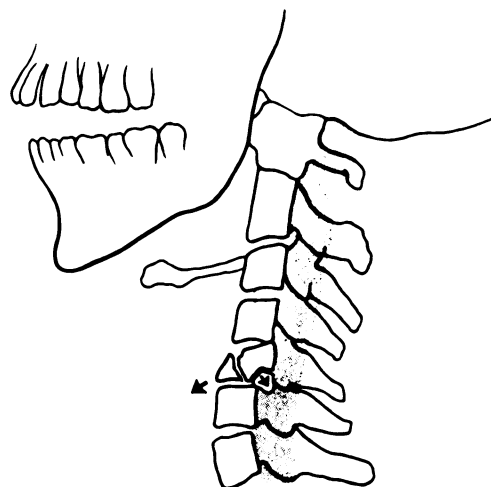


FIG. 1

Fig. 1: Diagram of acute-flexion or tear-drop fracture-dislocation. The body of the involved vertebra is compressed and the anterior inferior fragment is displaced downward and forward. The posterior inferior portion projects posteriorly into the cervical spinal canal.

Fig. 2-A: Case 1. A typical acute-flexion or tear-drop fracture-dislocation of the fourth cervical vertebra in a seventeen-year-old tumbler. (Reproduced by permission from the *Journal of Neurosurgery*, 12: 103, 1955.)



FIG. 2-A

of touch and vibration. This neurological pattern was found in cases of acute injury to the cervical spinal cord associated with destruction or compression of the anterior portion of the cord by extruded intervertebral discs, compression fractures, and fracture-dislocations. When compression was a factor, the production of this syndrome was believed to be an acute phase of the syndrome of chronic compression caused by calcified lesions lying anterior to the cord. This was described by one of the authors<sup>4</sup> and will be discussed.

Recognition of the syndrome caused by acute injury of the anterior portion of the cervical spinal cord is important. It is impossible to distinguish between compression and destruction of this portion of the cervical spinal cord without surgery, therefore early laminectomy is advisable with sectioning of the dentate ligaments at several levels to decompress the cord and to enable exploration anterior to it in order to determine if a lesion amenable to surgical treatment is present.

The roentgenograms and case reports of two of the twelve patients with injury to the anterior portion of the cervical spinal cord which were previously published are reprinted here to show the similarity of the fracture-dislocations and to demonstrate their important role in the syndrome of the acute injury to the anterior portions of the cervical spinal cord (Cases 1 and 2, Figs. 2-A through 3-C).

In one of the patients the injury to the cervical spine resulted in a compression fracture of the centrum of the fifth cervical vertebra with posterior displacement of the entire vertebra but without avulsion of the anterior portion. With more force, separation of the fractured anterior portion undoubtedly would have occurred.

Fig. 2-B: The cervical roentgenogram made two and one-half years after injury demonstrates apparent fusion between the fourth and fifth cervical vertebrae with a posterior bony protrusion projecting into the cervical spinal canal. Compare with Fig. 2-A, which was made after the initial injury. (Reproduced by permission of the *Journal of Neurosurgery*, 12: 103, 1955.)

Figs. 2-C and 2-D: Myelograms indicate marked encroachment on the spinal canal by a bony overgrowth at the interspace between the fourth and fifth cervical vertebrae. (Reproduced by permission of the *Journal of Neurosurgery*, 12: 104, 1955.)



FIG. 2-D

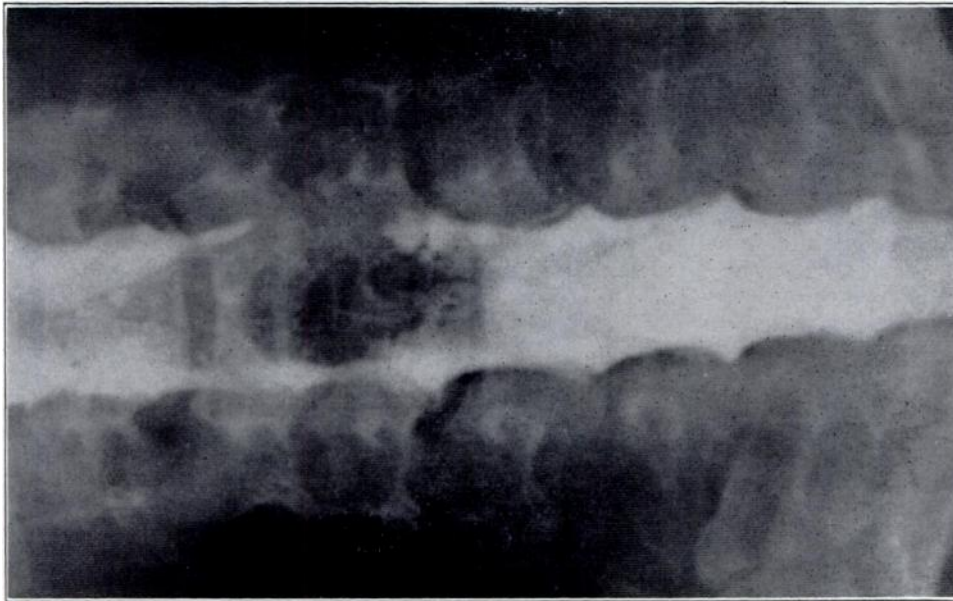


FIG. 2-C



FIG. 2-B

This boy had been placed in traction at another institution for six weeks without recovering motor function; he was then referred to University Hospital merely for physical rehabilitation. When the syndrome of acute injury to the anterior portion of the cervical spinal cord was recognized on admission, decompressive laminectomy was performed with section of the dentate ligaments. Within twenty-four to thirty-six hours he began to move his fingers and toes. This improvement may have been purely coincidental, but it suggests that the surgical intervention may have been of some value.

The problems associated with the acute flexion or tear-drop fracture-dislocation are not completely resolved by laminectomy and section of the dentate ligaments to decompress the spinal cord. Subsequent spine fusion is frequently indicated to prevent the sequelae of chronic compression of the anterior portion of the cervical spinal cord.

The following cases are presented as illustrations:

CASE 1. M. S., a seventeen-year-old tumbler, fell March 29, 1951, striking on the vertex of his head. Complete paralysis resulted in all four extremities, except for equivocal movement of his right great toe. There was headache, pain in the neck, and numbness from the neck downward over the trunk and extremities.

Upon admission to a Detroit Hospital there was hypo-aesthesia and hypo-algesia to the level of the fourth cervical dermatome, but the sense of position and the sense of touch were preserved bilaterally throughout the entire body. There was complete motor paralysis in both lower extremities. The patient could move his arms at the shoulders and extend his wrists but he had no active motion in any of his fingers. There was generalized hyporeflexia with no extensor plantar reflexes.

Roentgenograms of the cervical spine revealed a compression fracture-dislocation of the body of the fourth cervical vertebra with a 30 per cent collapse in its vertical height (Fig. 2-A). The vertebra was posteriorly displaced three to four millimeters.

Crutchfield tongs were applied and an indwelling catheter was inserted. On March 31, 1951, a lumbar puncture was performed and on jugular compression there was an equivocal partial block to the flow of cerebrospinal fluid. The cerebrospinal-fluid protein was 63 milligrams per 100 milliliters. On April 14, 1951, a second lumbar puncture revealed similar cerebrospinal-fluid dynamics. At this time the cerebrospinal-fluid protein was 110 milligrams per 100 milliliters.

Three and one-half weeks after injury the level of hypo-algesia and hypo-aesthesia was gradually receding; there was recovery of motion in the lower extremities and the patient was able to flex the fingers of both hands. A plaster body jacket was applied on April 27, 1951, and, on June 14, a back brace replaced this appliance. On August 3, 1951, it was discovered that the level of hypo-algesia and hypo-aesthesia, which had receded to the first lumbar dermatome, had risen again to the eighth thoracic dermatome. There was a wrist-drop on the left and foot-drop on the right. Bilateral extensor plantar reflexes and ankle clonus were elicited. Bladder control and bowel function were good.

As a student at the University of Michigan, he was under frequent neurosurgical observation. By August 1953, he began to have increasing spasticity in the lower extremities and was admitted to University Hospital for studies. Roentgenograms of the cervical spine are shown (Fig. 2-B). A cervical myelogram, made September 1, 1953, demonstrated a marked compression of the anterior portion of the cord (Figs. 2-C and 2-D).

At the time of the decompression laminectomy on September 2, 1953, the spine was extremely unstable. The laminae of the fourth and fifth cervical vertebrae, which had been fractured bilaterally, were healed but they were thin and osteoporotic. These laminae were removed bilaterally with a portion of the lamina of the third cervical vertebra. The dura mater was incised in the mid-line, and the very weak dentate ligaments were sectioned at two levels. At the interspace between the fourth and fifth cervical vertebrae there was a central bony protrusion, three to four millimeters in height, which could not be chiseled away for fear of injuring the ribbon-thin cord. The dura mater was left open, the cerebrospinal fluid being contained by the intact arachnoid membrane.

Inverted V-shaped bone grafts were inserted bilaterally from the spinous process of the third to the sixth cervical vertebrae. The wound was closed in layers.

Postoperatively the patient was able to walk with the aid of a cane and a spring kick-up brace. There were spotty areas of hypo-aesthesia and hypo-algesia extending to the level of the dermatome of the tenth thoracic-nerve root on the right side. Temperature sense was not clearly defined over the lower extremities, particularly on the right side. The sense of motion and the sense of position were intact bilaterally. Pyramidal-tract signs were present bilaterally with increased tonus in the upper and lower extremities; ankle clonus and the Babinski sign were present bilaterally. The patient's condition has continued to improve; the degree of spasticity present preoperatively has diminished somewhat, and the patient is able to attend college again.

This patient had a typical syndrome of acute injury to the anterior portion of the cervical spinal cord combined with the acute-flexion or tear-drop vertebral fracture-

dislocation. It is particularly interesting to note that the jugular-compression test did not reveal a complete subarachnoid block on two occasions, five days apart, and yet cerebrospinal fluid protein was definitely elevated at the first test and had increased by the time of the second lumbar puncture, five days later, although there was no blood in the specimen. This would suggest irritation of the spinal cord, possibly caused by bony pressure upon the oedematous anterior surface of the cord, and shows that an elevated cerebrospinal-fluid protein may be present even when the patient does not have a complete subarachnoid block or hemorrhage. Perhaps increase of the cerebrospinal-fluid protein merely indicates contusion of the spinal cord, but in that case the protein level should not have become progressively elevated. Although the patient showed a remarkable improvement at first, his condition began to deteriorate one and one-half years after injury and he had increasing spasticity. Because of the degree of narrowing of the cervical-spine canal, myelography was extremely dangerous. In retrospect, the patient should have been operated upon as soon after injury as his condition permitted and then, either primarily or secondarily, have had a spinal fusion.

CASE 2. H. P., a sixteen-year-old tumbler, sustained a severe injury to the cervical spine on May 14, 1948. According to the patient he suffered immediate complete motor paralysis of all four extremities with loss of sensation below the neck. Roentgenograms of the cervical spine revealed a compression fracture-dislocation of the fourth cervical vertebra and minimal posterior dislocation of the fourth cervical vertebra with relation to the fifth (Fig. 3-A).

Approximately twelve hours after injury, he was transferred to University Hospital. Areflexia and tetraplegia were confirmed by clinical examination, and hypo-algesia and hypo-anaesthesia were present to the level of the dermatome of the fourth cervical-nerve root. A lumbar puncture and jugular-compression test revealed an incomplete subarachnoid block.

As there was no progression of signs and only a partial block on the jugular-compression test, the patient was not operated upon. However, no improvement occurred during the next four years.

The patient was re-admitted to the University Hospital four years after injury, because of involuntary contractions of the fingers. Hypo-algesia and thermanaesthesia were present bilaterally to the level of the dermatome of the sixth thoracic-nerve root, and hypo-anaesthesia was found to the level of the sixth cervical-nerve root bilaterally. The sense of motion and sense of position were present throughout the body and the sense of vibration was present except over the right lateral malleolus. The sense of touch was present everywhere except in the left lower extremity where responses to touch were irregular. There was generalized spasticity and hyperreflexia in all extremities. Frequent spasms caused the legs to be extended rigidly, and hyperreflexia of the fingers caused them to be contracted into fists. Occasionally the patient's spasms were sufficiently severe to precipitate him out of bed onto the floor. Clonus of both wrists and of the patella on the left side was elicited.

Roentgenograms of the cervical vertebrae at this time revealed a loss of the interspaces between the third and fourth and between the fourth and fifth cervical vertebrae. There was posterior displacement of the fourth cervical vertebra on the fifth, and the third cervical vertebra had apparently fused in a position of slight anterior displacement on the fourth cervical vertebra (Fig. 3-B).

Lumbar puncture showed no subarachnoid block, but cervical myelograms revealed mid-line defects at the interspaces between the third and fourth and between the fourth and fifth cervical vertebrae (Fig. 3-C). After the myelography, the sense of motion, the sense of position, and the sense of vibration were further impaired.

On May 19, 1952, a laminectomy was performed from the third cervical vertebra through the sixth.



FIG. 3-A

Case 2. A tear-drop lesion of the fourth cervical vertebra in a sixteen-year-old tumbler. (Reproduced by permission from the *Journal of Neurosurgery*, 12: 101, 1955.)





FIG. 3-B

Fig. 3-B: The lateral cervical roentgenogram four years later showing loss of the interspaces between the third and fourth and fourth and fifth cervical vertebrae with projection of bone posteriorly into the spinal canal. (Reproduced by permission of the *Journal of Neurosurgery*, 12: 101, 1955.)



FIG. 3-C

Fig. 3-C: The cervical myelogram shows mid-line filling defects at the sites of bony overgrowth. (Reproduced by permission from the *Journal of Neurosurgery*, 12: 101, 1955.)

Although the roentgenograms had demonstrated what appeared to be fusion of the third and fourth cervical vertebrae marked instability of both the third and fourth cervical vertebrae and no evidence of fracture were found at operation.

There were marked adhesions between the arachnoid membrane and the dura mater laterally at the interspace between the fourth and fifth cervical vertebrae. After cutting the dentate ligaments bilaterally at four levels, gentle retraction of the cord revealed the bony projection demonstrated on the roentgenograms. No herniated disc material could be found. There was a definite variation in the levels of the insertion of the dentate ligaments, the spinal cord being displaced more posteriorly at the levels of the interspaces between the third and fourth and between the fourth and fifth cervical vertebrae than at the levels of the other two exposed interspaces. At the end of the procedure the dura mater was sutured and the wound was closed.

Postoperatively the wrist clonus which had been present preoperatively was no longer demonstrable and the tonus in the upper extremities had decreased about 50 per cent; however, the mass reflexes in the lower extremities were slightly accentuated. Finally, in June 1952, an anterior rhizotomy was performed, and the spasms of the lower extremities were adequately controlled. Marked spasticity and clonus were still present in both upper extremities.

When the patient was admitted to the Hospital at the time of injury, he had the syndrome of acute injury to the anterior portion of the cervical cord. There was no progression of signs and only a partial block on the jugular-compression test; consequently the patient was not operated upon. Over a period of four years there had been no regression of symptoms. The cervical exploration should have been performed as soon after injury as the patient's condition permitted. The pronounced instability of the fourth and fifth cervical vertebrae found at operation four years after injury suggests that it is important to perform early fusion of the damaged segments of the cervical spine in these incomplete lesions of the cervical cord. This case also demonstrates that roentgenograms may be misleading in determining stability of the cervical spine. This is a case of the syndrome of the



FIG. 4-A



FIG. 4-B

Fig. 4-A: Case 3. Roentgenogram made in 1947 of an acute-flexion or tear-drop fracture-dislocation.  
 Fig. 4-B: Roentgenogram of the lesion made eight years later showing spontaneous fusion of the third, fourth, and fifth cervical vertebrae and bony impingement on the anterior surface of the spinal cord.

acute injury to the anterior portion of the cervical spinal cord without complete block, which did not show recovery even after four years.

Another tear-drop fracture-dislocation with persistent spinal instability is demonstrated in the following case:

CASE 3. F. Z., male, twenty-four years old, dove into two feet of water on July 7, 1947. On admission to a local hospital he was not unconscious, he had no respiratory difficulty, and he could speak. He experienced sharp pains in the cervical region upon movement of the neck. There was no motor paralysis of the arms or legs, no difficulty in voiding, and no impairment of sensation. The patient had moderate pain in the left lower extremity.

However, on the following day, there was paralysis of all four extremities and of the bladder and the bowel. The pupil of the right eye was dilated. Roentgenograms of the cervical spine revealed a typical acute-flexion injury, a tear-drop fracture-dislocation (Fig. 4-A). A Thomas collar was applied forty-eight hours after injury. A short time thereafter the patient recovered bowel and bladder control. He continued to improve rapidly so that nine weeks after injury, he was permitted to walk a few steps and was discharged from the hospital on August 27, 1947. For six years, his physical condition continued to be good.

In March 1954, the patient presented himself for examination (while an inmate at the South Michigan Prison). He complained of increasing weakness and "jumping" in the left upper and lower extremities for the past year.

On examination, tenderness was found over the mid-portion of the cervical spine with a slight limitation of hyperextension of the neck. Weakness was present in all muscle group movements of the left upper and lower extremities, the most marked impairment being in the left deltoid muscle. Atrophy of one and one-half inches was demonstrated in the left arm and of one and one-quarter inches in the left forearm. Atrophy of one and one-half inches was present in the left thigh, but the left calf showed no atrophy. Muscle tone was markedly increased in all of the muscles of the left upper and lower extremities. The patient was unable to open and close the left hand quickly. Sustained clonus of the left ankle and wrist was elicited. On the right side hypo-algesia and hypo-thermanaesthesia were present to the level of the dermatome of the fourth

cervical-nerve root. The sense of motion, sense of position, and sense of touch were unimpaired bilaterally. Hyper-reflexia was demonstrated in both lower extremities but was more marked in the left patellar and Achilles-tendon reflexes. The reflexes of the triceps and biceps and the radial periosteal reflex were more active on the left than on the right. An extensor plantar reflex was present bilaterally but this was more marked on the left side. A positive Hoffman sign was elicited on the left side. Roentgenograms of the cervical spine now showed fusion of the third, fourth, and fifth vertebral bodies with almost complete obliteration of the interspaces, a kyphosis and a marked bony overgrowth posteriorly impinging on the cervical spinal canal (Fig. 4-B).

It was the examiner's impression that there was a marked compression of the anterior portion of the spinal cord and that a cervical laminectomy, section of the dentate ligaments, and excision of part of the bony exostosis anterior to the cervical spinal cord should be performed. It was also his opinion that a spine fusion should probably be performed at the same time. Since the patient was to be paroled soon, the operation was to be deferred until after his release.

This patient exhibited the typical acute-flexion or tear-drop fracture-dislocation at the time of his first hospital admission on July 7, 1947. Transient complete tetraplegia developed, probably because of inadequate immobilization. There was a progression of neurological signs which suggested that surgical intervention was indicated. However, after an interval of stabilization in a Thomas collar, spontaneous improvement occurred. Immobilization was incomplete, and although the patient made a good initial recovery, the prognosis now is extremely grave because there is chronic compression of the anterior portion of the cervical spinal cord similar to that noted in Case 1. Early operation with decompression of the spinal cord and either primary or secondary spine fusion might have prevented this.

CASE 4. J. W., a retired Navy lieutenant, thirty-six years old, was first seen in consultation on November 1, 1954, because of weakness in his left hand and arm. He complained also of severe pain radiating into all four extremities on merely flexing his neck or on coughing and sneezing.

Twelve years before, during World War II, he was aboard a destroyer which sustained a direct hit. He had been thrown upward, striking his head against a steel beam. Upon falling to the deck, he sustained a severe contused laceration of the left lower extremity and a tear of the cruciate ligaments of the left knee. He jumped from the bridge of the listing destroyer into the water, a distance which he estimated as fifty feet, and had clung to a life raft for eighteen hours under shore fire before being picked up by a friendly vessel.

Aboard a hospital ship, six days after injury, a roentgenogram of the cervical spine showed a severe compression fracture of the body of the fifth cervical vertebra. There was no weakness or numbness of the extremities and no incontinence of the bladder or bowel. A plaster collar was applied for three weeks and then replaced by a neck brace for another three or four weeks.

In November 1953, a year before consultation, he began noting progressive weakness in the finer movements of the left hand and forearm as well as numbness in the left thumb and index finger. In November 1954, he first noticed that when he sneezed or forcibly flexed his neck there was a sharp, shooting pain radiating into all four extremities.

At this time, twelve years after injury, there was tenderness on percussion over the fifth and sixth cervical spinous processes with no radiating pain. There was marked weakness in the grip of the left hand. The interosseus muscles were atrophied and abduction and adduction of the fingers were impaired. The strength of the left biceps muscle was diminished. No weakness was found in the muscles of the right upper extremity and the muscles of both lower extremities had normal strength. Sensation was normal except for hypo-algesia and hypo-anaesthesia in the dermatome of the sixth cervical-nerve root on the left and around the margins of the scar on the left leg and thigh. All reflexes were equal and active except in the left biceps. The remainder of the neurological examination was normal.

Roentgenograms made in 1948, six years after injury, showed a healing compression fracture of the body of the fifth cervical vertebra (Fig. 5-A). Recheck roentgenograms made in 1954, twelve years after injury, revealed an increase in bony overgrowth at the interspace between the fifth and sixth cervical vertebrae (Fig. 5-B).

Review of the roentgenograms suggests the presence of an old, healed tear-drop fracture-dislocation. At the present time there is not only evidence of compression of the cervical-nerve roots at the fracture site, but also a history suggesting chronic compression of the anterior portion of the cervical spinal cord. A cervical myelogram is indicated. It is probable that findings in this test would suggest that laminectomy and decompression of the cervical spinal cord should be performed.





FIG. 5-A



FIG. 5-B

Fig. 5-A. Case 4. Cervical roentgenogram made in 1948 of the cervical spine of a Navy lieutenant injured six years before during World War II. The roentgenogram shows healing of the typical tear-drop fracture-dislocation of the fifth cervical vertebra on the sixth cervical vertebra.

Fig. 5-B: Roentgenogram of the same lesion twelve years after the injury.

CASE 5. J. S., a nineteen-year-old male, dived into shallow water on July 1, 1954. He sustained a scalp laceration and was rendered unconscious for a brief interval. There was no numbness or paralysis of the extremities. Roentgenograms of the cervical spine demonstrated an acute-flexion or tear-drop fracture-dislocation of the fourth cervical vertebra on the fifth (Fig. 6-A). Three days after the application of skeletal traction by Crutchfield tongs, there was marked improvement in the alignment of the cervical spine (Fig. 6-B). Unfortunately, after four weeks, the skeletal traction had to be discontinued because one of the tong points had penetrated the brain in the left posterior parietal area. This had caused a Jacksonian seizure on the right side which had its onset in the right arm. Fixation in a plaster cast replaced the cervical traction and, after two months, the cast was replaced by a Forrester collar for a period of three months.

Six months after the injury, the patient was examined at University Hospital because of recurring episodes of numbness in both hands for intervals of five minutes. These symptoms appeared when the patient was in the sitting position and were apparently confined to the areas in the hand innervated by the median nerve. Recheck roentgenograms of the cervical spine revealed telescoping of the body of the fifth cervical vertebra into that of the sixth with encroachment on the anterior portion of the cervical spinal canal (Fig. 6-C). On December 17, 1954, a myelogram showed a mid-line filling defect at the level of the fifth and six cervical vertebrae. Skeletal traction by Vinke tongs was begun on December 24, 1954, and three days later a laminectomy of the fifth and sixth cervical vertebrae was performed. The dura mater was incised and the dentate ligaments were cut. No bony protrusion was noted anterior to the spinal cord, but this was probably due to the fact that during the operation the traction was applied so that the patient's neck was maintained in the plane of the body rather than in flexion. The dura mater was closed and the spine was fused from the fourth to the seventh cervical vertebra with an autogenous-bone graft removed from the right ilium (Fig. 6-D). A wound infection developed postoperatively, but this was cleared up readily after incision and drainage and antibiotic therapy.

The patient was last examined on February 8, 1955, when he was found to be asymptomatic with no abnormal neurological signs.

Study of the serial roentgenograms suggests that the best time for spine fusion would have been shortly after the injury when the cervical spine was in fairly satisfactory align-



FIG. 6-C

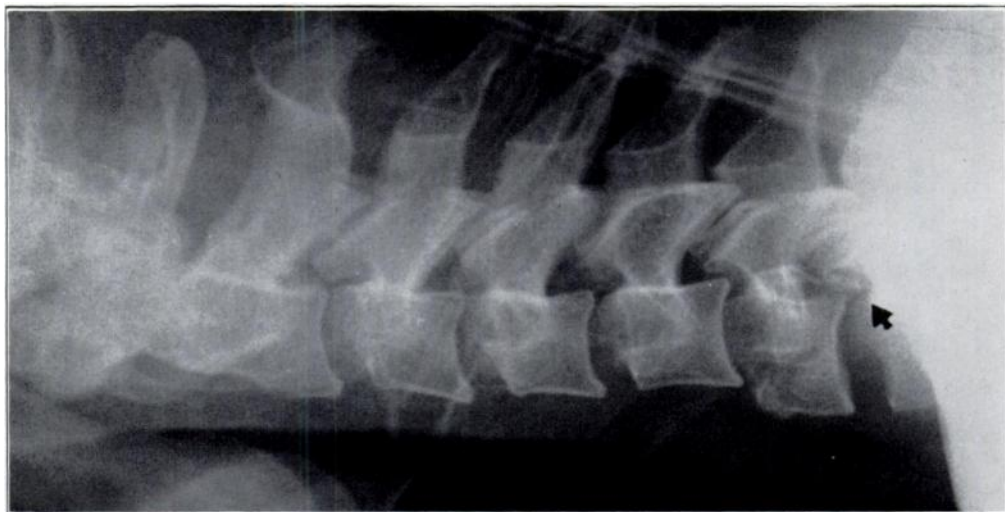


FIG. 6-B

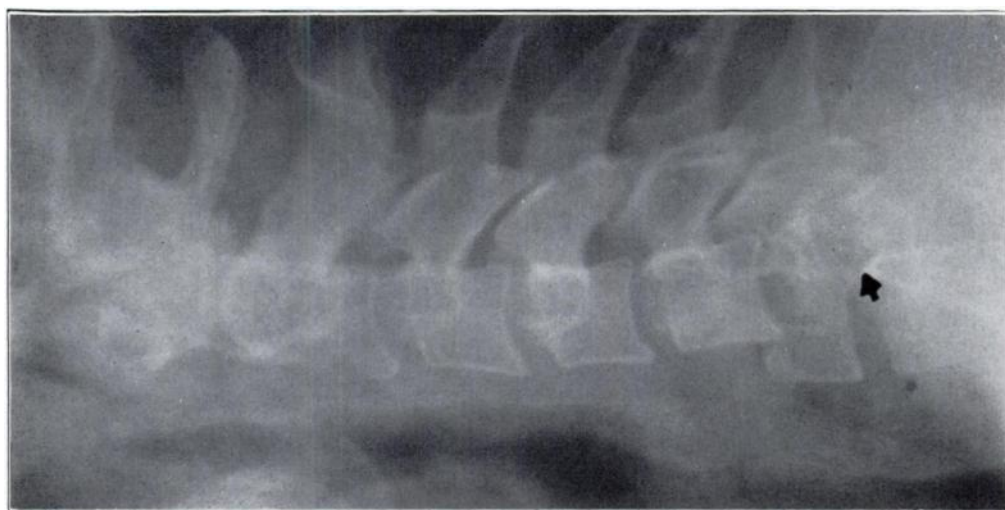


FIG. 6-A

Fig. 6-A: Case 5. Cervical roentgenogram exhibiting initial lesion and dislocation of the sixth vertebral body on the seventh cervical vertebra in a nineteen-year-old diver.

Fig. 6-B: Roentgenogram made after three days of skeletal traction.

Fig. 6-C: Roentgenogram of the lesion six months after injury. Inadequate fixation permitted redislocation and the formation of a bony overgrowth which encroached on the spinal canal.

Fig. 6-D: Cervical roentgenogram made after partial reduction with skeletal traction, laminectomy of the fifth and sixth cervical vertebrae, section of the dentate ligaments, and spine fusion of the spinous processes and facets of the fourth cervical vertebra to the seventh.

ment as the result of traction. The improper stabilization of the spine, which permitted movement for six months after injury, allowed telescoping of the vertebral bodies and was responsible for the creation of the hyperostosis anterior to the cervical spinal cord as visualized in the roentgenogram. This might eventually have led to chronic compression of the anterior portion of the cervical spinal cord. It was hoped that the application of traction preoperatively with re-alignment of the spine and a spine fusion would prevent future disability. A more complete reduction prior to spine fusion would have been desirable.

Since there were no abnormal neurological findings in this patient, spine fusion alone would probably have been adequate without prior laminectomy and section of the dentate ligaments.



FIG. 6-D

#### DISCUSSION

All of the patients with the acute-flexion or tear-drop fracture-dislocation have shown marked instability at the site of the lesion apparently due to changes in the ligaments and in the intervertebral disc. The ligaments torn at the time of dislocation and imperfectly healed by scar tend to stretch and become relaxed. The intervertebral disc is disrupted by the dislocation at the time of injury. The associated fractures of one or more of the adjacent vertebral bodies extend through the vertebral plates. The ensuing hemorrhage, replacement fibrosis and degenerative changes cause thinning of the disc with loss of its resiliency. As pointed out by Luck it is this narrowing and loss of resiliency which stimulate the formation of marginal osteophytes. Repeated episodes of minimal trauma consequent to the abnormal mobility lead to increasing degenerative changes and the formation of larger spurs. Eventually these spurs encroach upon the spinal canal posteriorly leading to pressure on the anterior aspect of the spinal cord.

All five of these cases demonstrate various phases of this problem and indicate the varying degrees of chronic compression of the anterior portion of the cervical spinal cord that may occur.

A quarter of a century ago, A. S. Taylor stressed the importance of recognizing the

chronic compression of the anterior surface of the cord resulting some time after an acute injury to the cervical spine and spinal cord. He stated: "When the cord has escaped entirely, or almost entirely, and has recovered, but the bone deformity has not been corrected and prevented from recurring by proper treatment, after a period varying from a few months to a year, there is likely to develop a transverse pressure myelitis of the segment of cord which rides over the backward-projecting upper margin of the body of the lower vertebra, with corresponding loss of cord function." It is indeed regrettable that this important suggestion in the literature has been overlooked.

In 1947, one of the authors (E. A. K.)<sup>4</sup> called attention to the role played by the dentate ligaments and by the nerve roots, with their surrounding dural sleeves, in anchoring the spinal cord over calcified lesions of the cervical area. This fixation was found to result in chronic compression of the anterior portion of the cervical spinal cord. Patients with such lesions were mistakenly diagnosed as having primary lateral sclerosis. In describing the mechanism involved, it was stated: "In anterior spinal cord compression I believe that, with pressure over a period of time, the pyramidal tracts, because of the greater stress on them and the large size of their fibers, have more disturbance of conductivity than the pain fibers of the spinothalamic tracts, even though the latter are closer to the compressing mass, be it midline herniated nucleus pulposus or tumor. Touch is preserved because, even though the touch fibers of the ventral spinothalamic tracts may fail to conduct, there is still sufficient sensation carried in the more protected posterior columns to prevent the clinical detection of touch disturbance. Postural sense is preserved because the attachments of the dentate ligaments prevent the posterior columns, which are farthest from the compressing mass, from being pressed against the unyielding laminae. Thus may be produced a clinical though not necessarily a pathological picture of lateral sclerosis with pyramidal tract disturbance and little or no sensory change"<sup>4</sup> (Fig. 7). Since this publication, there have been a number of papers published dealing with the problem of the neurological sequelae of cervical spondylosis<sup>1, 2, 3, 5</sup>.

In order to prevent the complications associated with calcified lesions lying anterior to the cord which result from recurrent trauma and which cause chronic compression of the anterior portion of the cervical spinal cord, patients with this special acute-flexion tear-drop fracture-dislocation which results in neurological deficit should be treated by traction; surgical exploration by laminectomy should be performed with the patient in traction, and the dentate ligaments should be sectioned. Finally, but extremely important, fusion of the involved portions of the cervical spine in good alignment should be performed. This may be done either at the initial surgical procedure, or, preferably, at a secondary operation. If this type of fracture is present without neurological deficit in the acute phase of the injury, then spine fusion without laminectomy and section of the dentate ligaments is justified.

#### SUMMARY

The acute-flexion or tear-drop fracture-dislocation associated with injuries of the cervical spinal cord warrants special attention. It is characterized by the separation and downward and forward displacement of the anterior inferior margin of the involved vertebral body. The posterior inferior margin of this same vertebral body is displaced posteriorly into the spinal canal.

Acute injuries of this type may be associated with the syndrome of damage to the anterior aspect of the cervical cord. This syndrome may be due to either destruction of this portion of the cord or to compression by displaced bone or disc material. If due to compression, this may be relieved by a surgical procedure.

In these cases surgical exploration with the patient in traction and section of the dentate ligaments are indicated, if neurological signs are present. Spine fusion should then be performed at the primary operation, or at a secondary procedure. This will prevent



## HERNIATED DISC (Diagram of Stress Analysis)

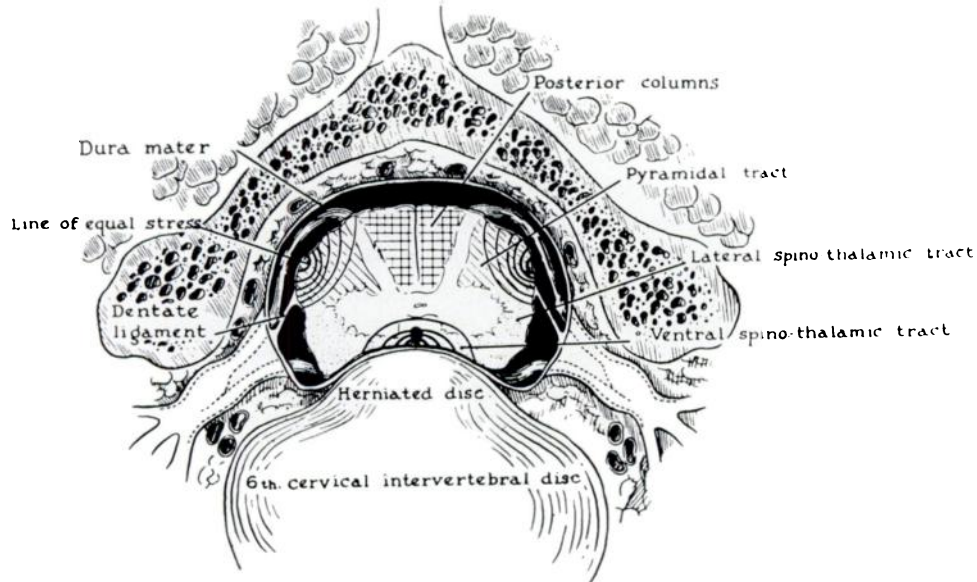


FIG. 7

Diagram showing lines of stress produced by compression of the anterior surface of the spinal cord. Greatest stress is on the anterior tracts, the ventro-spinothalamic tracts, disturbance of which would not be demonstrable by clinical tests. There is slighter stress directly on the pyramidal tracts, while the tracts affecting the hand, being located more centrally, receive the least stress or no stress, which explains why there is frequent sparing of the hands. (Reproduced by permission from the *Journal of Neurosurgery*, 4: 195, 1947.)

instability of the spine, and the fractured cervical vertebrae will heal in good alignment without the formation of a bony bulge posteriorly. Such bulging may cause chronic compression of the anterior portion of the cervical spinal cord with neurological sequelae. If the tear-drop fracture is present without neurological signs, spine fusion without laminectomy should be performed after spinal re-alignment by cervical traction.

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