ACUTE injuries to the cervical spine with or without involvement of the spinal cord and/or cervical nerve roots continue to be a difficult therapeutic problem. Whether to use simple skeletal traction or open operation (lamineetomy) has been a controversial topic in neurosurgery for many years. Regardless of the method of treatment used, the percentage of salvage in these patients is not great.

Since the contribution of skull tongs for skeletal traction by Crutchfield7,8 in 1933, very little has been added in the way of new technique or methods of treatment in these cases. In the past 2 years, however, several reports have appeared on the treatment of lesions of the cervical spine by an anterior surgical approach.1,9,10,12,18 An original operation was developed independently by the writer in 1956.2 The anterior surface of the cervical spine is exposed through a small transverse skin incision and blunt dissection through the line of cleavage between the carotid sheath and the thyroid. Using a 14 mm. drill, a hole is made through the intervertebral space to the spinal canal, through which acute disk ruptures, osteophytes, tumors, etc. can be removed. The adjacent vertebral bodies are fused by inserting a cylindrical dowel into the hole. In the past 3 years over 200 patients with lesions of the cervical spine have been operated upon by this method. Included in this series were 11 patients with acute fractures or fracture-dislocations of the cervical spine.†

This new method of early surgical treatment has resulted in a complete change in our therapeutic program for these patients. The end results are far superior indeed to those obtained by methods used previously. Space will not permit a detailed description of these cases, which will be reported elsewhere.5,6 A statistical review is presented to show the degree of injury to the spine and nervous system, the treatment employed and results obtained. The advantages of this new method of surgical treatment over standard methods are discussed.

STATISTICAL REVIEW

Method of Injury. The 11 patients with acute injuries of the cervical spine treated from 1956 through 1959 were all males ranging from 14 to 60 years in age. The injury was the result of automobile accidents in 4 patients, 3 by collision; 1 of these was thrown from his car, and 1 patient rolled his small car over at high speed. Four patients received their injuries by a fall, 3 of whom were intoxicated. Swimming and diving accidents accounted for 2 injuries and 1 patient was struck by a falling limb of a tree.

Injuries to Cervical Spine. The patients were classified into three groups depending upon the nature of the injury to the cervical spine as demonstrated radiologically: (1)
acute dislocation; (2) chronic (or delayed) dislocation; and (3) compression fracture. Anterior dislocation or subluxation occurred in 10 of the 11 patients. Five of these (50 per cent) occurred at the C5-C6 level, 3 at C4-C5 and 2 at C6-C7.

(1) **Acute dislocations.** The roentgenogram demonstrated an anterior dislocation at the time of injury in 8 patients. The dislocation was classified as marked (Fig. 2A) in 3 (75 to 100 per cent), moderate in 3 others (25 to 50 per cent) and slight in 2 patients (10 to 20 per cent). Additional fractures of either spinous processes, facets or vertebral bodies were present in 6 of the 8 patients.

(2) **Chronic dislocations.** At the time of injury the roentgenogram in 2 cases showed no evidence of dislocation, although 1 patient had a linear fracture through the body of C5. Films taken at a later date (3 weeks in 1 patient and 4 months in the other), demonstrated a moderate and marked anterior dislocation respectively. In 1 patient, in a diving accident, there was a marked compression fracture of C4 with severe anterior angulation of the cervical spine but no dislocation (Fig. 1A).

Injury to Spinal Cord and/or Nerve Roots. In 10 of the 11 patients there was neurological evidence of motor or sensory impairment indicating involvement of the spinal cord and/or nerve roots. The spinal cord injuries with motor and sensory impairment involving all four extremities occurred in 7 patients. Three of these were quadriplegic on admission with complete motor and sensory loss below the lesion; 3 others were markedly quadriparietic and 1 patient was moderately so. Three of the 11 patients had motor impairment in the upper extremities only; and 1 patient had no motor involvement. All patients complained of pain in the neck and shoulders and in one or both upper extremities. The pain was recorded as severe in 8 cases and moderate in 3.

**Therapeutic Program.** All patients were treated the same, that is, with initial trac-

![Fig. 1.](image)

(A) A 19-year-old, 6'7" college basketball player thrown by a wave in heavy surf. Compression fracture of C4; laceration of posterior (intraspinous) ligaments (arrow). Quadriparetic on admission to hospital.

(B) Vertebral-body fusion of C3-C4-C5, 1 year after operation. Marked anterior angulation, asymptomatic and not apparent clinically. Complete functional recovery. Patient played varsity basketball 4 months after operation.
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Fig. 2. (A) Severe fracture-dislocation of C5-C6. A 52-year-old male, who fell down hill while intoxicated Quadriplegic. Laminctomy on admission to hospital. Traction for 7 weeks. Recovered function of lower extremities but upper remained paralyzed.

(B) Myelogram following removal of traction. Note posterior subluxation of body of C5 and defect in oil column caused by herniated fragments of disk (removed at operation; anterior decompression).

(C) Vertebral-body fusion (2 years postoperative). Complete recovery except for atrophy of small muscles of left hand.

tion followed by operation with reduction, anterior decompression and interbody fusion. The program varied from case to case because of the time of referral. Seven patients had been treated with skeletal or halter traction and 1 patient with laminctomy prior to referral (Fig. 2B). Skull traction was applied immediately at the time of injury in 7 patients and at a later date in 3, and halter traction was applied in 2. Traction was successful in reducing the dislocation in 8 of the 10 patients.

Pain was relieved by traction in 8 patients. Paralysis was improved by traction in 5 patients, unsuccessful in 5 and 1 patient was made worse. Dislocations not reduced by traction were reduced at operation. A decompressive laminctomy was done on admission on 1 patient, and a nerve-root decompression by a hemilaminctomy 4 months after injury on another. Operation was performed within 48 hours after injury on 2 patients and within 10 days on 5 patients. Operation was delayed in 3 patients 3-4 weeks, 8 weeks, and 4 months after injury.

All treatments of injuries of the neck are directed toward: (a) relief of pain; (b) restor-ing normal function to the spinal cord and nerve roots, and (c) reduction of dislocation and stabilization of the injured vertebral joint. Results obtained from the methods employed in these patients were excellent.

(a) Relief of pain. Pain in the neck, shoulder and arm present in all cases was completely relieved by operation in 9 of the 10 patients who survived. The severe preoperative pain disappeared immediately following surgery or by the time the patient was discharged from the hospital, an average of 10 to 12 days. One patient with severe weakness of muscles in the upper extremities still complains of pain in the neck, shoulder and arm. Several months after discharge this patient suffered progressive motor involvement in the left hand over the distribution of the ulna nerve. The pain was found to be caused by a ruptured disk below the level of the dislocation. It had been unrecognized at the time of injury.

(b) Clinical recovery. An unexpected and gratifying functional return occurred in those patients with injury to the spinal cord and cervical nerve roots following the anterior operation. Severe dislocation of the spine did not indicate a poor prognosis for return of motor function. For example, of 4 patients
with quadriplegia had marked dislocation of the spine (60 to 100 per cent). One patient made a complete recovery and 3 recovered with only minor residual deficits. In the 3 patients who had total quadriplegia, 1 whose spine was severely dislocated (50 per cent), made a nearly complete functional recovery; 1 patient had no return of function; and 1 died. In 8 patients with severe paralysis of the upper extremities (with or without involvement of the lower) recovery was complete in 2; there was moderate to slight residual deficit in 4; 1 patient showed no improvement and 1 died. The 3 patients whose initial weakness of the upper extremities was moderate, made a complete recovery. In summary, 5 of the 10 patients (50 per cent) with nerve root and spinal cord injuries recovered completely without residual neurological deficit, and 4 patients made almost complete recovery with only minor weakness of muscles. In only 1 of these patients was the residual deficit sufficiently severe to interfere with the patient returning to his normal livelihood.

Rapid recovery after the anterior operation was evident by the fact that 9 of the 11 patients were sufficiently improved to be discharged from the hospital an average of 11.8 days after operation. Six of these patients returned home and received physical therapy on an out-patient basis. Three patients were transferred to the Rehabilitation Center as in-patients. One with complete quadriplegia showed no improvement in motor function and was transferred to a Veterans Administration Hospital. One patient with quadriplegia died after 6 days from multiple injuries.

(c) Results of fusion. Roentgenograms were taken at monthly intervals to determine the progress of fusion of the vertebral bodies. A solid fusion occurred in every case. Roentgenographic evidence of bony fusion of the vertebral bodies occurred in approximately 2 to 4 months in 9 cases and was delayed for 6 months in 2. The first evidence of bony bridging was observed on the anterior surface of the bone graft by proliferation of bone from the periosteum of the vertebral bodies. Evidence of fusion of the bone graft is recognized by increased density of its cancellous portion with demonstrable bony trabeculations bridging the interspace. Over a period of several months the hard cortical surface of the dowel gradually loses its dense appearance, finally blending in with the remainder of the graft and adjacent vertebral body in a uniform homogeneous appearance. These roentgenographic changes in appearance of the bone graft were used to indicate fusion rather than the conventional method of demonstrating motion at the fused joint on films taken with the spine in a position of flexion and extension. This latter method cannot be used as a criterion for fusion with this operation since the tightly impacted dowel (bone graft) placed between adjacent vertebral bodies as a rule results in mechanical fixation of the joint, from the beginning.

After fusion is complete, alteration in the normal alignment of the cervical spine can be expected in 50 per cent of these cases. In 5 patients, the cervical spine was restored to its normal contour. But in the other 5 cases an anterior angulation resulted in a permanent spinal deformity. In 3 patients the deformity was extreme, resulting either in marked angulation (Fig. 1B) or what appeared to be severe encroachment of the lower vertebral body upon the spinal canal. From the appearance of the roentgenogram, serious impairment of function of the spine and/or the spinal cord might be expected because of the change in the weight-bearing angle of the vertebral column. However, each of these 5 patients is entirely symptom-free as far as his neck is concerned and the deformity of the cervical spine is not apparent clinically. The preoperative neurological deficit completely recovered in 2 of these patients and only minor motor deficits are present in the other 3. No new symptoms have appeared in 8 to 16 months since operation.

DISCUSSION

A. Pain. All patients with injury to the cervical spine complain of pain in the neck radiating into one or both shoulders. Pain
in the forearm, hand and fingers is rarely encountered although the patient may describe an aching sensation rather than a severe pain. The most frequent complaint referable to the forearm and fingers is that of numbness. Heretofore, pains in the neck and shoulder have been attributed to: 1) compression of the spinal nerve root as a result of the dislocation; and 2) involuntary spasm of the cervical muscles as a result of disruption of their attachments to the dislocated or injured vertebra. Since adequate skeletal traction in most cases will relieve the pain, it was assumed that reduction of the dislocation and widening of the intervertebral space relieved the nerve-root pressure while the pain from the muscle spasm was arrested by stretching the muscles. These theories as to the origin of pain were further strengthened by the observation that if pain was only partially relieved by traction, it could often be abolished merely by increasing the amount of weight. Also, if the weight was reduced or the traction released the pain frequently returned.

From recent stimulation experiments and experience with the cases described in this report, we can add a third and perhaps a much more important source of pain, that is, the intervertebral disk itself. It has been shown anatomically that the peripheral fibers of the annulus fibrosus and the longitudinal ligaments that surround it are richly supplied with sensory nerves that subserve the function of pain. Unfortunately, it has not been generally accepted that the intervertebral disk is a pain-producing tissue. It has been demonstrated, however, that a very mild superficial stimulation of the peripheral fibers of the cervical disk will cause the patient to experience pain located at the base of the neck and along the vertebral border of the scapula. This stimulation-pain was found by electromyography to be caused by involuntary spasm of the muscles of the neck and shoulder. It is often quite severe. It can be induced by injection of a ruptured disk for diskography with as little as 0.2 cc. of fluid. It is easy to conceive of the proportionate increase in the degree of cervical pain from spasm of the muscles when the entire disk is lacerated extensively as a result of the dislocation. Even the slightest movement of such an injured neck will irritate numerous lacerated nerve endings in the periphery of the disk producing widespread, severe spasm of muscles. Contraction of these muscles may narrow the interspace and distort the joint causing additional compression of the lacerated disk and more pain, thus establishing a vicious cycle.

This theory of the lacerated disk as the major source of pain was demonstrated conclusively in 2 patients in whom the area of most severe pain following injury was localized in one scapula. The pain was so severe as to justify a roentgenogram of the scapula on admission to rule out a fracture or other injury to the shoulder. Both patients were found at operation to have a unilateral anterior laceration of the disk. This would confirm our stimulation experiment in which pain from irritation of the anterior surface of the disk is always referred to the scapula.

The severe pain in the neck and shoulder was either improved markedly or relieved completely in 8 of the 11 cases by skeletal traction. If we assume that the primary source of pain is the lacerated disk, relief of this pain by traction is easily understood. Widening of the intervertebral space by traction stretches the peripheral fibers of the disk, thus restoring them to the taut anatomical position that exists in a normal disk when the nucleus pulposus is intact. If the weight of traction is released, the interspace is narrowed again and the disk fibers are compressed again with return of pain from spasm of muscles. In the past it has been observed that 6 to 8 weeks of continual traction is required for permanent relief of pain in these cases. This is probably the time required for invasion of granulation tissue into the lacerated disk and healing by scar-tissue formation.

The anterior operation used in our cases has been shown to accomplish in a matter of days the relief of pain that required weeks of treatment by traction. By surgical removal of the anterior surface of the injured disk
nearly half of the nerve endings responsible for the pain are eliminated. The bone graft (cylindrical dowel) inserted between the adjacent vertebral bodies while the interspace is spread wide apart, restores the remainder of the peripheral fibers of the disk to a taut position and immobilizes the joint, thus preventing further irritation of the painful sensory nerves in the disk. The relief of pain in the neck and shoulder and complete disappearance of all spasm of muscles in a matter of hours after operation was demonstrated strikingly in 3 patients. This experience would indicate that direct injury to muscle and compression of nerve root are probably responsible for only a small part of the pain of the dislocated cervical spine and that most of the pain originates in the lacerated intervertebral disk.

B. Spinal Cord and Nerve Root Decompression. Decompression of the spinal cord and nerve roots by the anterior surgical approach has been shown by these cases to be perhaps the most valuable contribution of this operation. In 5 patients, the operative exposure disclosed loose fragments of the disk material, some of them enormous in size, herniated into the spinal canal, severely compressing the anterior surface of the cord and adjacent nerve roots (Fig. 2A). The early removal of these fragments of disk resulted in prompt improvement in the paralysis. In the past we have had no knowledge of the existence of such lesions, since a myelogram is seldom performed on patients with broken necks. Manometric studies with lumbar puncture gave no information of the existence of such lesions unless the spinal canal was completely obstructed. If an obstruction was demonstrated, treatment usually consisted of a decompressive laminectomy with cutting of the dentate ligaments. As a rule no attempt was made to explore or possibly remove extradural lesions on the anterior surface of the spinal cord and nerve roots. As one surgeon expressed it, “All the laminectomy operation accomplishes is an attempt to remove the patient from his lesion.”

The existence of suspected intraspinal fragments of disk causing spinal cord or nerve root compression is determined by cervical diskography. Unlike myelography, this procedure can be performed without potentially hazardous manipulation of/or damage to the injured neck and the roentgenographic findings are far more informative as to the intraspinal pathology than a myelogram or any other diagnostic procedure. The technique of cervical diskography has been described previously.3 A needle is inserted into the intervertebral disk at the level of the dislocation from its anterolateral surface, the patient being in the supine position, on the bed, a cart of the operating table. A small amount of radiopaque solution (Hypaque) is injected into the interspace. If the posterior fibers of the intervertebral disk are lacerated by the injury, the opaque solution will escape into the spinal canal. Disk fragments herniating intraspinally may be sharply outlined by the dye on the anterior wall of the spinal canal. In fact, if the injected solution is seen to escape from the intervertebral space into the spinal canal, an extensive posterior laceration of the disk has occurred. This is an indication for a thorough anterior surgical decompression and a search for torn fragments of disk that may have escaped into the spinal canal.

One patient in our series was made worse by traction with the Crutchfield tongs. A sudden respiratory arrest developed following reduction of the dislocation by skeletal traction necessitating an emergency tracheotomy. There was marked increase in the paralysis of the extremities, although the severe anterior dislocation (75 per cent) had been completely reduced. At operation a large free fragment was removed from the extradural space behind the lower vertebral body. It had probably been drawn backward into the spinal canal when the dislocation was reduced by traction. Its removal resulted in rapid improvement of the paralysis. This experience of the patient being made worse by skeletal traction has been reported by others (Rogers,13 Fig. 7-B), but the
reason for it remained obscure until the development of the anterior decompression operation.

C. Reduction of Dislocation and Fusion. In patients with severe anterior dislocation (Fig. 3A) an occasional case will be encountered in which an attempt to reduce the dislocation by traction and manipulation results in a locking of the articular facets (Fig. 3B). There was 1 such case in our series. The severe dislocation could not be reduced by traction and manipulation, but was easily and readily accomplished by the anterior operation. After removing the intervertebral disk with a curette, a heavy blunt instrument was inserted into the intervertebral
space (Fig. 3C). By gently prying the vertebral body apart, the locked facets were lifted free and then with gentle backward digital pressure on the anterior surface of the upper vertebral body, the dislocation was reduced (Fig. 3D). In a subsequent similar case, an instrument used for lumbar interbody fusion, "the vertebra spreader" (handle), was used to separate the vertebrae, making the reduction easier. Subsequently a new instrument has been devised for this purpose.*

After interbody fusion had occurred, an anterior angulation of the cervical spine had developed in 50 per cent of the patients. The factors responsible for the anterior angulation have not been determined definitely. Slight anterior angulation has been observed in about 10 per cent of cases of cervical disk disease treated by interbody fusion. Its occurrence in 50 per cent of fusions for fracture-dislocations may suggest a possible etiology. Hadley has shown that collapse of a cervical intervertebral disk will cause reversal of the normal lordotic curve. In flexion injuries to the cervical spine the various posterior spinal ligaments may be extensively lacerated and disrupted (Fig. 1A-arrow). This obvious weakening of posterior supporting structures of the neck from dislocation may explain the greater frequency as well as the development of a greater degree of anterior angulation of the spine after interbody fusion. A second and perhaps a more plausible explanation for the angulation is the possible bony injury to the vertebral body. The compression force applied to the anterior half of the vertebral bodies may disrupt the cancellous bone resulting in a weakening of its ability to support weight in the vertical plane. The hard cortex of the bone graft drifts into this softened bone with weight-bearing and angulation results. The use of braces, collars or casts was ineffective in preventing the anterior angulation in the severely injured spine. Two patients in whom the most marked angulation developed wore a cervical collar following operation, 1 patient for a period of 8 months. On the other hand 1 patient with just as severe dislocation was discharged from the hospital 10 days after operation and did not use a cervical brace. His spine fused without angulation (Fig. 2B). From a functional standpoint, however, it does not seem to make much difference whether the spine heals in a normal straight position or is markedly angulated.

**SUMMARY**

Eleven patients with fractures and fracture-dislocations of the cervical spine have been operated upon by the anterior approach to the spine. The operation includes an anterior reduction of the dislocation, an anterior decompression of the spinal cord and nerve roots and a fusion of the vertebral bodies. A summary of the therapeutic procedure used in these cases, and recommended as the treatment of choice for injuries of the cervical spine, is listed as follows:

(1) On admission to the hospital, often in the emergency ward, the neurological status is evaluated, portable anteroposterior and lateral roentgenograms are obtained without moving the patient, Crutchfield tongs are inserted into the skull and skeletal traction of 20 to 30 pounds is applied.

(2) The anterior operation is undertaken as soon as the patient's general condition will permit, if possible within the first 24 hours. The operation is performed under local anesthesia with the patient in the supine position. A cervical diskogram is done immediately before operation, on the operating table, using portable radiological equipment. Prior to the withdrawal of the diskogram needle a drop of methylene blue dye is injected to identify the level of the lesion when exposed for operation. If the dislocation has not been reduced by traction, open reduction is accomplished with a blunt instrument placed in the intervertebral space after removal of the disk. The drill hole through the interspace is made with no traction on the Crutchfield tongs. After the drill hole is made and spinal decompression is completed, 40 to 50 pounds of traction

*The cervical vertebra spreader, manufactured by Codman & Shurtleff Co., Boston, Mass.*
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are applied for insertion of the bone graft. With the interspace thus pulled apart, very little pounding is necessary to "set" the dowel. When the traction is released the vertebrae spring back together, securely fixing the bone graft. The morbidity of this operation, which is often completed in less than an hour, is negligible compared to the hazards of a "decompressive laminectomy."

(3) Skull tongs are removed at the end of the operation or the following day. The patient is placed in a sitting position and physiotherapy is begun including ambulation as soon as return of function will permit.

(4) No plaster casts or braces are used or advised. Plastic cervical collars may be worn for a short time for residual discomfort in neck, shoulder and arm.

(5) Monthly progress roentgenograms will demonstrate interbody fusion within 2 to 4 months. Deformity of the spine with anterior angulation will occur in 50 per cent of the cases. Although some may have the appearance of a roentgenographic monstrosity, the deformity from a functional standpoint is entirely asymptomatic.

CONCLUSION

A new and revolutionary form of treatment has been developed for fracture-dislocation of the cervical spine by the use of the anterior approach and vertebral-body fusion. The extremely gratifying recoveries obtained in the treatment of 11 patients would indicate that this method of treatment can be expected to give far better results and a higher salvage rate in these serious injuries than we have been able to accomplish by therapeutic programs employed in the past.

REFERENCES