Lateral extracavitary approach to traumatic lesions of the thoracic and lumbar spine

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The lateral extracavitary approach to the spine was used for resection of displaced bone and disc located anterior to the dura in 62 patients with traumatic lesions of the thoracic and lumbar spine. Fifty-two patients had closed vertebral fractures and 10 had gunshot wounds. The spinal cord was involved in 44 patients, and the cauda equina in 18. A spinal subarachnoid block was demonstrated in 17 of 57 preoperative gas myelograms. Evoked potential recordings, although related to perception of joint rotation, tended to reflect the overall neurological condition and had some prognostic value. Significant improvement followed surgery in 46 patients with incomplete neurological lesions, and one was transiently worse. Before operation 18 patients were able to walk; nine with assistance and nine without. After operation 47 patients were able to walk; 12 with assistance and 35 without. Adequate bladder function was present in 17 patients before surgery, and in 44 after surgery. A laminectomy had been done previously in 16 patients, 11 of whom improved significantly after anterior resection. Spine fusions were required in 26 patients, five of whom had a prior laminectomy. The major factor in the pathogenesis of the incomplete neurological deficit appeared to be distortion of the cord and roots by displaced bone and disc. Consequently, the primary object of treatment was the restoration and maintenance of normal anatomical relationships between the spinal cord or cauda equina and the spinal canal.

Key Words • spinal injury • spinal fusion • spinal cord injury • spinal nerve root • myelography • evoked potential

The lateral extracavitary approach to the thoracic and lumbar spine was developed for the management of tuberculous spondylitis with neurological involvement. Capener also suggested it be used in the surgical treatment of nontuberculous diseases of the vertebral bodies including "certain types of traumatic paraplegia." We have performed this operation in 62 patients with incomplete myelopathy or radiculopathy following injury of the thoracic or lumbar spine (Fig. 1).

Clinical Material and Methods

Fifty-two patients had closed fractures of the thoracic and lumbar vertebrae and 10 had fractures from gunshot wounds which did not penetrate the dura. Thirty-six of these patients were admitted to our hospitals on the day of injury, while 21 were admitted more than 4 weeks afterward. Of the latter group, the interval between injury and admission was more than 6 months but less than 1 year in seven, and more than 1 year in eight.
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FIG. 1. Lateral approach to the thoracic (left) and lumbar (right) spine. The shaded areas indicate the extent of bone removal. Usually the rib is transected 8 cm lateral to the costotransverse joint.

For evaluation the patients, all of whom had incomplete lesions, were assigned to functional categories A to G as follows:

A. Walking without assistance, normal micturition
B. Walking with assistance, normal micturition
C. Walking without assistance, abnormal micturition
D. Walking with assistance, abnormal micturition
E. Unable to walk, some motor and sensory function, normal micturition
F. Unable to walk, some motor and sensory function, abnormal micturition
G. Paraplegic, sensory perception only, abnormal micturition.

Adequate bladder function was defined as voluntary control of micturition with a residual urine volume of less than 100 cc. Some of the patients considered able to walk without assistance had residual disability. Patients considered able to walk with assistance required support varying from one cane or one short leg brace to a long leg brace and two canes. Patients using two long leg braces were considered unable to walk. Where bed rest was required because of the character of the vertebral injury, a patient was considered able to walk with assistance if the strength of the lower limb muscles was rated as fair (Grade 3), and able to walk without assistance when rated good (Grade 4) or better. Categories A through G were selected as the minimum number necessary to describe the functional state of the patients before and after treatment. A more precise definition of function would be desirable but there were too few patients to justify a larger number of categories and too many for individual description.

Before surgery, gas myelography with polytomography was performed in 57 patients and Pantopaque myelography in four. Selective spinal arteriography was performed in four patients; identification of a radiculomedullary artery at the level of the lesion was made in two. Somatosensory evoked potentials were recorded using computer averaging techniques before and after operation in 28 patients.\textsuperscript{19-15}

Indications for surgery were deterioration of the patient’s neurological condition, his failure to improve, or initial neurological improvement followed by stabilization short of adequate functional recovery. The lateral approach\textsuperscript{15} was selected when the tissue deforming the spinal cord was located anterior to it. Forty-eight patients were operated on from the left side and 14 from the right. The highest level approached was T-3, and the lowest S-1. Of the vertebral bodies exposed, 60% were between T-9 and L-2. In the thoracic region, the approach is extrapleural (Fig. 1 left). The paravertebral muscles are retracted medially and not divided. It is usually necessary to resect at least two ribs, the corresponding transverse processes, pedicles, and apophyseal joints. In the lumbar area (Fig. 1 right), the plane of dissection lies between the erector spinae muscles and the quadratus lumborum. Consequently, problems associated with working in the retroperitoneal space do not arise. To provide adequate access to the floor of the spinal canal, it was necessary to divide the segmental artery at each level exposed if this had not already been accomplished by the fracture. The spinal column was approached from the left side to facilitate access to the aorta if necessary. An approach from the right was reserved for those patients whose neurological findings indi-
cated predominantly right-sided cord or root injury. In the two patients with arteriographically demonstrated radiculomedullary arteries, the approach was made from the side opposite the vessel. Steroids, hypothermia, and osmotic diuretics were not used.

Illustrative Cases

Case 1

This 31-year-old man was admitted with multiple injuries including a tension pneumothorax and fracture of T-12. Except for trace contractions in the left quadriceps and adductors, muscle function was absent in the lower limbs, as was perception of joint rotation. Perception of touch and pain were reduced below T-12 and absent below L-5. He could not detect bladder filling and was unable to void. Two days after injury gastrointestinal bleeding developed but after blood transfusions his condition stabilized. The neurological findings were unchanged. A gas myelogram demonstrated compression of the terminal portion of the cord and a complete spinal subarachnoid block at T-12. A selective spinal arteriogram done by right femoral artery catheterization 1 week after admission did not demonstrate radiculomedullary vessels at the T-11, T-12, and L-1 levels.

At 4 AM on the day after angiography, the patient developed a rapidly progressive hypotension secondary to retroperitoneal bleeding on the right, went into shock and became unresponsive, but was successfully resuscitated. Laboratory findings were consistent with a disseminated intravascular coagulopathy. The subsequent course was complicated by an acute surgical respiratory distress syndrome, acute tubular necrosis with renal failure, and a Klebsiella septicemia. He was treated with antibiotics, volume ventilation with positive end expiratory pressure, and hemodialysis. Two weeks later he was weaned from the respirator and renal function was recovering. He was intermittently febrile but the temperature gradually became normal. The neurological status was unchanged, with saddle anesthesia and only trace function in the left quadriceps and adductors.

Seven weeks after admission, a lateral resection and interbody fusion was done with placement of Harrington rods posteriorly. The following morning he was able to flex and extend the toes of the left foot, could raise the left knee from the bed, and could adduct the left thigh. Two weeks later, function was rated as fair to poor in all muscles of the left lower limb, and trace in those of the right lower limb. He was able to detect bladder filling and could initiate micturition with a voiding volume of 250 cc and an approximately equal residual. Two months later, strength was good in all muscle groups of the left lower limb and fair to poor in muscles of the right lower limb. He had voluntary control of micturition but residual urine volumes were still more than 200 cc.

Case 2

A 27-year-old man was admitted to the hospital 30 minutes after injury. He was intoxicated, had compression fractures of T-3 and T-4, and a flaccid paraplegia, but some preservation of sensory perception below the level of injury. One hour after admission, he regained feeble voluntary movement of the toes on the right. Perception of pain had improved but he could not detect joint rotation. Five hours after admission, strength in the right lower limb muscles was rated as Grade 3 (fair) but the left lower limb remained paralyzed. Perception of joint rotation, although abnormal, had improved. Twenty-four hours after admission, strength of the right lower limb muscles was unchanged but very weak movements were present on the left. Sensory perception remained the same. An indwelling catheter was required. The neurological condition became stable. A gas myelogram performed 3 days after injury demonstrated angulation of the spinal cord with occlusion of the subarachnoid space anterior to the cord at the level of fracture.

An anterior resection and interbody fusion was done the next day. Within 48 hours, strength in the left lower limb had significantly increased, and within 1 week normal control of bladder function was regained. One month after injury he was walking with the help of a cane and after 2 months he was functionally normal.

Case 3

A 23-year-old man fell 40 feet, sustaining a compression fracture of T-12 and abdominal injuries. The neurological examination was normal. A laparotomy was done shortly after admission for removal of a lacerated spleen.

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He remained normal neurologically until the seventh postoperative day when he began to get out of bed to sit in a chair and to walk. Within 2 days he developed urinary retention, became paraparetic, and was unable to stand without assistance. A gas myelogram demonstrated angulation of the spinal cord and occlusion of the subarachnoid space at the twelfth thoracic vertebral level. The patient was operated on and subsequent improvement was rapid. After 6 days he could void normally, after 10 days could walk without assistance, and 3 weeks later was neurologically normal.

Summary of Cases

Preoperative Course

The opportunity to personally evaluate the neurological findings from shortly after injury onward was available in the 36 patients admitted directly to our hospitals from the scene of the accident. Of these, 27 remained unchanged before operation. Four patients had some improvement that stopped short of adequate functional recovery, as, for example, in Case 2. In the other patients with incomplete and arrested recovery, the interval between injury and operation was 10, 17, and 22 days. Each had been neurologically unchanged for at least 1 week before surgery and in each, definite neurological improvement was noted within 24 hours after surgery.

Five of the 36 patients became worse a week or more after admission. Each had remained stable while in bed, but shortly after getting up developed a progressively more severe paraparesis. Case 3 is an example. In the other 26 patients (those admitted after the day of injury), 21 of whom were admitted more than a month after injury, the neurological condition had either been stable or had deteriorated before admission and none of these patients improved between admission and operation.

Gas Myelography

A spinal subarachnoid block was present in 17 of 57 patients who had a gas myelogram before operation. The subarachnoid space posterior to the spinal cord at the level of involvement was patent in 23 of the 40 patients who did not have a block. Other than transient headache, there were no complications associated with gas myelography. In two patients gas was visible outside the spinal canal, suggesting meningeal laceration.

Results of Surgery

Considering the group as a whole, 50 patients improved, 46 significantly. Before operation, 18 patients were able to walk; nine with assistance and nine without. After operation, 47 patients were able to walk; 12 with assistance and 35 without. Before surgery, adequate bladder function was present in 17 patients and after surgery, in 44. One patient was worse after an inadequate resection at L5-S1. This patient recovered after a second operation.

Objective improvement, defined as significantly increased strength in a paretic muscle, or return of function to a paralyzed muscle, began within 24 hours after surgery in 21 patients, and between 2 days and 1 week in 16 patients. In both groups, the interval between injury and operation varied between 1 day and more than 1 year, with a median interval of approximately 4 weeks. In most of these patients the interval between injury and surgery was substantially greater than the interval from surgery to onset of improvement (Fig. 2). In eight of the nine patients in whom onset of improvement was observed more than 1 week after operation, adequate control of micturition was recovered.

A comparison of pre- and postoperative neurological status for patients with spinal cord injuries is shown in Table 1. On the basis of gas myelography, the spinal cord injuries had been separated into those of the spinal cord and of the conus medullaris. However,
TABLE 2

Results of surgery in 18 patients with cauda equina injury

<table>
<thead>
<tr>
<th>Functional Category</th>
<th>Interval Between Injury and Surgery</th>
<th>Pre Post</th>
<th>Pre Post</th>
<th>Pre Post</th>
<th>Pre Post</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt; 1 Week</td>
<td>1-4 Weeks</td>
<td>&gt; 4 Weeks</td>
<td>Total</td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>1</td>
<td>8</td>
<td>9</td>
<td></td>
<td></td>
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<td>B</td>
<td>1</td>
<td>3</td>
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<td>D</td>
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<td>E</td>
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<td>1</td>
<td>8</td>
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<tr>
<td>F</td>
<td>2</td>
<td>5</td>
<td>G</td>
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The only difference between the two groups was that none of the patients in Category G had a conus injury. Since the distribution of severity of injury and degree of postoperative improvement was otherwise much the same in both groups, they are considered together. Of the patients in postoperative Category A, 16 are functionally normal. The data on patients with cauda equina injury are summarized in Table 2. Four of the patients in postoperative Category A are functionally normal. The relationships between initial and final condition for the patients in each category prior to surgery were similar for both spinal cord and cauda equina injuries, and are shown together in Table 3.

Of the entire group, three patients had normal bladder control and were able to walk without assistance before surgery. Although each had some neurological deficit that improved after operation, disabling pain was the major indication for surgery. Radicular pain was a prominent symptom in 28 patients and was satisfactorily relieved by surgery in all but two.

**Previous Laminectomy**

A laminectomy had been performed previously in 16 patients. After laminectomy four had recovered partially and one had become worse. A progressive flexion deformity with associated back pain developed at the level of fracture in five of 11 patients in whom a spinal fusion had not been done at the time of laminectomy.

The interval between laminectomy and anterior resection varied between 7 weeks and 17 years. The neurological status had either stabilized or deteriorated during this interval. After anterior resection, 12 patients improved, 11 significantly. Four became able to walk, three without assistance. Three patients who were walking with assistance before operation were afterward able to walk unaided. Of 14 patients who were unable to void prior to anterior resection, nine regained control of micturition.

**Spine Fusion**

Spine fusions were performed in 26 patients; 12 thoracic and 14 lumbar. Twenty-one were anterior interbody fusions using rib or iliac crest grafts, two were done posteriorly with Harrington rods, and three were both anterior and posterior. Initially, the patients were kept in bed until radiographic evidence of fusion was obtained. In most patients this required 2 to 3 months. This prolonged period of immobilization proved to be unnecessary. More recently, the patients have been allowed out of bed in a cast or brace as soon as they can tolerate the appliance.

All but two of the fusions were done at the time of anterior resection. One of these patients was admitted with a flaccid paraparesis and a burst fracture of L-3. The first operation was done several hours after admission without a preliminary myelogram. Initially there was a moderate improvement in neurological function followed after several weeks by regression despite continued immobilization. A gas myelogram demonstrated residual bone and disc tissue in the spinal canal. At the time of reoperation a spinal fusion was performed. Subsequent improvement was steady and 1 year later the neurological examination was normal.
The second patient was admitted with severe radicular pain and a profound para-paresis secondary to an L-2 fracture dislocation. A laminectomy had been performed 7 weeks previously. After anterior resection the pain was relieved and voluntary control of the bladder regained. Lower limb muscle strength improved, but was insufficient for walking. During the next 2 years the neurological condition remained stable but aseptic necrosis of L-2 and progressive angulation developed. To protect residual neurological function, an anterior fusion was done from L3-T12 using iliac bone. After radiographic evidence of fusion was obtained, the patient was allowed to sit up in a chair. The graft fractured, and a repeat fusion with tibial and iliac bone was required.

Associated Injuries

Associated injuries were frequent. Of the 36 patients with vertebral fractures admitted to our hospitals on the day of injury, 19 also had other fractures. Each of the patients with a gunshot wound required prompt laparotomy or thoracotomy because of visceral injury. Of the patients with closed fracture, laparotomy was necessary in four because of visceral injuries, and thoracotomy in one for repair of a traumatic aortic aneurysm. Two patients had a tension pneumothorax, and another was comatose and hemidecerebrate.

Evoked Potentials

Satisfactory somatosensory evoked potentials secondary to transcutaneous stimulation of the peroneal nerves were recorded before and after surgery in 28 patients. Polyphasic evoked potentials with latency of less than 35 msec were considered normal, and were recorded before operation in six patients, each of whom had normal perception of joint rotation in the lower limbs. In contrast, of the 22 patients with abnormal recordings, only two had what appeared to be normal perception of joint rotation. Changes in perception of touch, pain, and temperature could not be correlated with abnormal evoked potentials. Two types of abnormal recordings were obtained before surgery, a flat record, and a monophasic response of slightly to moderately increased latency (Fig. 3).

Flat tracings were recorded bilaterally before surgery in nine patients. The records remained flat after surgery in five, one of whom improved clinically. In one case, the flat record changed to a monophasic wave.
form of long latency. In three patients the neurological examination and the evoked potentials became normal, the latter following a sequence of flat to monophasic to normal.

The responses were monophasic with minimally increased latency in eight patients before surgery and became normal afterward in six. Perception of joint rotation and of overall neurological function improved correspondingly. The wave forms were unchanged in two patients, one of whom recovered clinically.

In the five patients whose responses were not bilaterally symmetrical, all monophasic responses returned to normal, while only one of three flat records showed recovery.

Deaths and Complications

One patient died of aspiration pneumonia 12 days after operation. Two patients had a superficial wound infection, two had pneumonia, and two suffered a postsurgical respiratory distress syndrome. Five patients required further surgery, three of whom have already been mentioned. The fourth patient was operated on for replacement of a bone graft displaced as a result of a fall from bed, and the fifth for reinsertion of dislocated Harrington rods.

Discussion

In a study of CNS biomechanics, Brieg showed that the spinal canal becomes longer in flexion and shorter in extension with a corresponding change in length and therefore in cross-sectional area of the spinal cord. At full spinal flexion the cord is maximally stretched, and with additional stretch the axial tension sharply increases and becomes pathological. He points out that a compressive force exerted on the cord is greatest at the point of contact, decreasing rapidly with distance from this point until it is zero at the opposite surface. Conversely, this force induces an axial tension that increases with vertical distance from the point of application. Consequently, the axial tension is greatest on the opposite side of the spinal cord. Therefore, if a force is exerted by herniated disc or a posteriorly displaced vertebral body upon the anterior surface of the spinal cord, a laminectomy would be without benefit unless the posterior surface of the cord had been pushed against the lamina. Even then, barring the possible effects of denticulate ligament section, only the posterior compression will be relieved. However, removal of the displaced tissue and reconstruction of the spinal canal contour toward normal will relieve the
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anterior compression, the posterior compression, and the pathological axial tension.

These theoretical considerations are supported by clinical observations. The results of laminectomy in our patients had been unsatisfactory, although better than others have reported. Despite a considerable interval between laminectomy and anterior resection in these patients, however, the results with anterior resection were surprisingly good. Although removal of abnormally placed tissue anterior to the spinal cord can be accomplished with a wide laminectomy, the necessary manipulation introduces an increased risk. Furthermore, the high incidence of progressive flexion deformity of the spine following laminectomy in patients with vertebral body fracture suggests that in many of these patients a fusion should have been performed. An interbody fusion is more sound mechanically than a posterior fusion and can be done conveniently by the lateral approach. Even without laminectomy a fusion is indicated if there is evidence of instability or if the fracture is extensively comminuted. The latter type of fracture can be adequately treated by closed methods in patients without a neurological deficit. However, if the neurological condition requires operation, then the necessary removal of both normal and abnormal bone may lead to progressive deformity and possibly recurrent neurological deficit unless a fusion is performed. While an anterior resection and fusion can be done using a transperitoneal or transpleural approach, the risks and morbidity associated with thoracotomy and laparotomy are imposed.

In most of the patients the neurological deficit was at its worst immediately after injury. The neurological deterioration that developed in five patients a week or more following injury appeared to be related to mechanical factors. Therefore, spinal cord edema or release of catecholamines do not seem to be significant factors in patients with incomplete myelopathy. Improvement without specific treatment is not uncommon in patients with an incomplete neurological deficit but is unusual when traumatic myelopathy has been immediate and complete. This difference in clinical course suggests a fundamental difference in pathology. The development of severe edema and of significantly increased levels of catecholamines within the cord may be a result rather than a cause of devastating spinal cord injury with neuronal disruption. Consequently, administration of steroids to patients with incomplete lesions is probably unnecessary and may be hazardous if the level of spinal cord injury is sufficiently high to produce an effective sympathectomy and resultant increase in gastric acid secretion.

Since the neurological condition remained stable as long as the patients were immobilized, immediate operation does not seem to be required. The results indicate that patients operated on more than 1 week after injury did as well as those operated on earlier. Many of these patients had visceral injuries requiring urgent laparotomy. Because immediate spinal surgery did not appear to provide additional benefits, it seems preferable to allow the patient's general physiological condition to stabilize, meningeal lacerations to seal, and the local reaction to injury to subside. Signs of delayed abdominal bleeding from a ruptured viscus can then be recognized and not be obscured by events associated with early spinal surgery. Time should be taken to adequately assess the extent and location of the pathological process, and in this connection gas myelography was very useful. In addition to demonstrating the extent and character of the biomechanical abnormality (Fig. 4), it was also possible to differentiate precisely between involvement of the spinal cord and of the cauda equina. This distinction is an important factor in determining the vigor with which methods for control of bleeding are applied. Blood loss from torn epidural veins can be substantial and is the major disadvantage to the lateral approach for anterior resection.

Evoked potential recordings appear to have a prognostic value and also provide an objective supplement to the clinical examination. Spinal cord angiography prior to anterior resection has been advocated to identify the artery of Adamkiewicz so that it can be avoided at surgery; however, our observations and those of others suggest that the hazards of interrupting the artery of Adamkiewicz may be more apparent than real. Since most of our operations were done from the left side and required exposure of vertebral bodies between T-5 and L-2 with unilateral division of the segmental vessels at these levels, it is probable that the artery of...
Adamkiewicz was divided in at least some instances. Only one of our patients was worse following operation and this procedure was done at L5–S1. The low incidence of neurological disability after the bilateral and often extensive division of segmental arteries associated with resection of thoracic and abdominal aortic aneurysms indicates that the collateral circulation is adequate if the blood pressure is maintained at normal levels. The risks of angiography must also be considered. While selective vertebral angiography has been reported to be safe,7 the technique does not appear to have been extensively applied in patients with posttraumatic myelopathy.

The results of surgical treatment in our patients suggest that while the outlook is poor for patients with sensory perception only, the presence of some motor function indicates the possibility of substantial functional recovery. Furthermore, if deformity of the cord or roots can be demonstrated, the length of time elapsed since injury should not preclude surgical treatment.11

The controversy over surgical versus nonsurgical management of spinal injuries has not been settled. Frankel, et al.,8 have reported considerable recovery of neurological function in patients with thoracic and lumbar fractures following improved vertebral alignment achieved by postural techniques. While their criteria for evaluating neurological recovery differs from ours, and all their patients were admitted within 14 days of injury, it is nevertheless possible to make some comparisons. Their Categories C (Motor Useless) and D (Motor Useful) correspond to our Categories B through F, and their Category E (Recovery) to our Category A. In their series, 78 patients were in groups C and D (our B through F). Of these, 31 did not improve, 20 improved partially, and 27 (35%) recovered. Of 49 of our patients in Categories B through F before surgery, seven did not improve, 13 improved partially, and 29 (60%) reached Category A. It is possible our patients might have improved without surgery, but the relatively long interval between injury and operation compared with the prompt postoperative improvement observed in many of them (Fig. 2) indicates a cause-and-effect relationship. Although reduction can be achieved by postural techniques it is difficult to see how bone and disc displaced into the spinal canal can be extracted by extension of the spine. Furthermore, if the interspinous ligament is ruptured in a flexion injury with compression fracture (Fig. 4), progressive flexion deformity with increasing neurological deficit can be anticipated if fusion is not performed.9 Surgical reconstruction of the spinal canal can be expected to achieve a satisfactory biomechanical situation for the spinal cord and nerve roots more rapidly and efficiently than is possible by closed methods. Since the spine can be fused at the same time, the patient need not remain in bed for an extended period of time.

Although a number of factors may be implicated in the pathogenesis of an incomplete myelopathy, the major factor appears to be distortion of neural tissue. Therefore, the primary object of treatment in these patients should be the restoration, and when necessary the maintenance by spinal fusion, of a normal anatomical relationship between the spinal cord and the spinal canal.

References
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