PARAPLEGIA IN CERVICAL SPINE INJURIES

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The first recorded reference to paraplegia in cervical spine injuries is to be found in the Edwin Smith papyrus, written some four thousand years ago. The unknown author comments briefly upon the condition: "One having a crushed vertebra of his neck, he is unconscious of his two arms and two legs, and is speechless. An ailment not to be treated." Such pessimism was not without justification for in spite of notable contributions by Walton and Taylor, and more recently the introduction of caliper traction by Coleman, McKenzie, and Crutchfield, considerably more than half the patients with paraplegia die from the complications of spinal cord injury, and many survivors are left with varying degrees of paralysis.

One of the most puzzling features of injuries of the cervical spine is the lack of correlation between the degree of vertebral displacement and the severity of the spinal cord lesion. There are cases with no radiographic evidence of bone injury in which the cord is irretrievably damaged; others, with gross dislocation, may have no paraplegia. It is commonly believed that the spinal cord is damaged by the dislocated neural arches, and in the absence of radiographic evidence of bone injury it is assumed that spontaneous reduction of the dislocation has taken place. This view is not, however, in accord with experimental or post-mortem observations.

Radiographic study of specimens in which the dural sac has been filled with lipiodol shows quite clearly that the dislocated neural arches do not produce a degree of narrowing of the spinal canal which would compress the cord until there is locking of at least one articular process (Fig. 1). Once the articular processes are locked the dislocation is usually stable, and reduction cannot be secured without manipulation. Furthermore, examination of post-mortem material and observations at operation have convinced me that spinal cord injury can occur in the absence of any vertebral dislocation, and unless there is clear radiographic evidence of fracture of the articular processes which will permit spontaneous reduction of the dislocation we should look for an alternative explanation of the cord injury.

TYPES OF CERVICAL INJURY

Damage of the cervical cord may be caused by flexion injuries and hyperextension injuries. The number of cases of each type of cervical injury in a series of twenty-two patients with paraplegia is shown in Table I.

TABLE I

<i>Flexion injuries—</i>			
Dislocation	.	.	8 cases
Crush fracture of vertebral body	.	.	4 "
Acute retropulsion of intervertebral disc	.	.	3 "
Total	.	.	15 "
<i>Hyperextension injuries—</i>			
Dislocation	.	.	1 "
Injury to arthritic spine	.	.	6 "
Total	.	.	7 "

Three types of flexion injury may be recognised: 1) anterior dislocation; 2) crush fracture of a vertebral body; 3) acute retropulsion of an intervertebral disc. There are two types of hyperextension injury: 1) posterior dislocation; 2) injury to an arthritic spine.

FIG. 1

Experimental displacements of the cervical spine in which the dural sac has been filled with lipiodol. A shows the specimen in neutral position and C, D, E show degrees of flexion dislocation. B is a soft tissue radiograph of the spinal cord for comparison of size. In C there is subluxation of the articular processes. In D one articular process is locked. In E both articular processes are locked. The spinal cord is not compressed by the displaced neural arches until at least one articular process is locked.

It must be emphasised that these twenty-two cases were not an unselected group, for the reason that some were treated in a Spinal Injury Centre which tends to receive the more obscure types of injury. It is likely therefore that an unselected series would show a higher proportion of dislocations. The age incidence of the various groups is interesting (Fig. 6). All flexion injuries, and the one dislocation in extension, occurred in patients under fifty years of age; no hyperextension injuries in arthritic spines were encountered in patients under

fifty-seven years of age. The mortality rate in all types was high except in the group of three patients with disc injury, all of whom survived.

FLEXION INJURIES OF THE CERVICAL SPINE

Cervical dislocations—In dislocation of the cervical spine it is generally agreed that cord injury may be due to a combination of two factors: *a*) pressure on the dorsal surface of the cord by the dislocated neural arches; and *b*) often co-incident compression of the ventral surface of the cord by retropulsed disc material. Skeletal traction by means of a skull caliper is the treatment of choice. The dislocation can be reduced easily, without risk of further damage to the cord, and with better prospect of relieving the pressure of the disc than by other methods. The nine dislocations in this series presented no unusual features and it would be unprofitable to discuss them in further detail.

Acute retropulsion of disc—There were three cases of this type, all due to forcible flexion of the head on the trunk. In none was there radiographic evidence of bone injury but all the radiographs showed narrowing of one intervertebral disc.

Case 1. W. T., aged 34 years—Fell over the handlebars of his cycle on to the back of his head. He was examined within an hour of the accident and found to have incomplete paralysis and sensory loss in the lower limbs, trunk, and upper limbs. Radiographic examination showed lipping of the anterior margin of the third and fourth cervical vertebrae and narrowing of the intervertebral disc (Fig. 2). There was no bone injury. On the day after injury paralysis of the legs had increased and there was retention of urine. The Queckenstedt test showed complete spinal block, and myelography revealed an arrest of lipiodol opposite the damaged intervertebral disc (Fig. 3). By the third day there was complete paralysis of both legs. Laminectomy was performed, and a large protrusion of the disc was observed between the third and fourth vertebrae. The cord was compressed between the disc and the laminae, and pulsation did not return to the cord until the third, fourth, and fifth laminae had been removed. There was steady recovery of motor power and sensation after operation, and two months later the patient was able to walk without support.

Comment—Radiographic evidence indicated that the disc was degenerated before the accident, and this no doubt predisposed to "massive" protrusion of disc substance into the spinal canal as the result of flexion injury.

In the other two cases, considerable recovery of paralysis occurred without operative treatment (Table II), and there is therefore no proof that the cord injury was caused by acute disc protrusion. Nevertheless the mechanism of injury, the narrowed intervertebral disc, and the absence of radiographic evidence of bone injury, make the diagnosis reasonably certain.

Similar cases have been reported by Brooke (1944) and Brown and Little (1939). Although the Queckenstedt test in Brooke's patient gave normal readings, post-mortem examination revealed a large protrusion of the disc which was causing severe compression of the cord.

Treatment—We have now to consider the treatment most likely to relieve pressure on the cord in acute disc protrusions. Providing that the disc is not degenerated before injury, caliper traction will restore the normal disc height, and it is possible that some at least of the disc substance may find its way back into the intervertebral space. Even if this does not happen traction should straighten out the knuckle pressing on the cord (Jefferson 1940). If paraplegia is incomplete, and the Queckenstedt test gives normal readings of cerebro-spinal fluid pressure, the cord is probably not under severe compression and preliminary trial of skull traction is justified. If there is no recovery of paraplegia within a few days of the application of skull traction, laminectomy should be considered even when the Queckenstedt test is negative. Fleiss and Ingham (1943) and Brooke (1944) have reported cases of cord compression by a herniated disc with normal manometric readings.

FIG. 2

FIG. 3

Case 1. W. T., aged 34 years. Flexion injury of the cervical spine with incomplete paraplegia. Fig. 2 shows that the intervertebral disc between the third and fourth cervical vertebrae is narrowed but there is no bone injury. Myelography after injection of lipiodol into the lumbar theca (Fig. 3) shows complete block at the level of the herniated disc.

FIG. 4

FIG. 5

Case 4. A. G., aged 30 years. Fracture of cervical spine with residual paralysis of upper and lower limbs two years after injury. Fig. 4 shows crush fracture of sixth cervical vertebra. Fig. 5 shows the myelogram; there is a filling defect opposite the fractured vertebra.

TABLE II
POSTERIOR PROTRUSION OF INTERVERTEBRAL DISC

Case	Age	Nature of injury	Radiographic appearances	Type of paraplegia	Queckenstedt test	Operative treatment	Result
1 W. T.	34	Fell over handlebars of cycle on to back of head	Narrowing of disc between C.3 and 4 with arthritic lipping of adjacent vertebrae. No bone injury. Myelograph revealed complete block at the above level	Incomplete	Complete block	Laminectomy	Considerable recovery
2 W. S.	39	Fell from cycle and turned a somersault	Marked narrowing of disc between C.5 and 6 with arthritic lipping of adjacent vertebrae. No bone injury	Incomplete	No block	Nil	Almost complete recovery
3 B. R.	40	Fell headlong downstairs	Slight narrowing of disc between C.3 and 4. No other injury	Incomplete. Brown-Séquard syndrome	No block	Nil	Considerable recovery

TABLE III
COMPRESSION FRACTURES

Case	Age	Nature of injury	Radiographic appearances	Type of paraplegia	Treatment	Result
4 A. G.	30	Lorry collided with another vehicle. Thrown on to back of head	Compression fracture of C.6. Myelograph later showed persistent anterior filling defect at level of fracture	Incomplete	Plaster jacket, three and a half months	Incomplete recovery
5 J. T.	40	Fell twenty feet on to deck of ship	Comminuted fracture body of C.5	Complete	Nil	Death on the day of injury. Post - mortem — herniation of disc in addition to fracture; severe crush of cord
6 W. McA.	18	Performing hand spring; arms gave way and fell heavily on neck	Compression fracture of C.5.	Complete	Nil	Death second day. Post - mortem — no evidence of dislocation; severe crushing of cord at level of fracture
7 J. R.	18	Root of tree fell on to back of head	Compression fracture of C.4 and 5	Incomplete Queckenstedt—no block	Caliper traction ten weeks	Incomplete recovery

When there is strong presumptive evidence of disc protrusion, and spinal block is demonstrated by manometry, decompression of the cord is indicated urgently. In these circumstances laminectomy is likely to be more effective in relieving pressure on the cord than caliper traction.

Crush fracture of cervical vertebra—Four patients sustained crush fractures of the cervical column without radiographic evidence of dislocation of the articular processes. These cases are summarised in Table III. Post-mortem examination was made in the two fatal cases (Cases 5 and 6). In both, the spinal cord was severely crushed but there was no dislocation of articular processes. In Case 5 there was a large protrusion of the disc into the spinal canal. The two patients who survived had initially incomplete paraplegia, and yet there was poor recovery of function during a period of two years after injury.

Case 4. A. G., aged 30 years—Crush fracture of the sixth cervical vertebra, treated in a plaster jacket for three and a half months. He was admitted to the Spinal Injury Centre two years later with residual paralysis of both upper and lower limbs. Myelography showed a constant anterior filling defect which could hardly be explained by the residual spinal deformity, and was presumably due to disc protrusion (Figs. 4 and 5).

The evidence of this case strongly supports the view of Cramer and McGowan (1944) that cord injury in simple crush fractures is due not to pressure of the fractured vertebral body, or to dislocation with spontaneous reduction, but to compression of the ventral surface of the cord by retropulsed disc material. The treatment of compression fracture of a cervical vertebra complicated by paraplegia should therefore be on similar lines to that of compression of the spinal cord by a retropulsed intervertebral disc.

HYPEREXTENSION INJURIES IN ARTHRITIC SPINES

I have been unable to find any reference to injuries of arthritic spines except in the paper by Crooks and Birkett (1944). Nevertheless these injuries are by no means uncommon. In the present series there were six cases of this type and they were responsible for all spinal cord injuries in patients over fifty years of age (Fig. 6). All six patients had arthritic changes

FIG. 6

in the cervical spine of moderate or severe degree, and there was strikingly little radiographic evidence of recent vertebral injury. The injury proved fatal in five of the six patients although only one had complete paraplegia. Two cases serve to illustrate the features:

Case 12. T. B., aged 63 years—Fell a distance of ten feet on to his forehead, forcibly hyperextending the neck. There was complete motor paralysis and sensory loss below the fifth cervical cord segment. Radiographs showed marked osteoarthritic changes in the cervical spine with ossification of the anterior common ligament between the fourth, fifth, and sixth vertebrae (Fig. 7). An osteophyte was avulsed from the lower anterior margin of the third cervical vertebrae; there was no other bone injury. Five hours after injury he was able to move the left leg, and tactile sensation had returned to both lower limbs. Four days after injury the patient was able to move both legs and urine was passed voluntarily. The Queckenstedt test showed no spinal block. From the eighth day his condition deteriorated steadily and he died on the eleventh day after injury.

FIG. 7

FIG. 8

Case 12. T. B., aged 63 years. Hyperextension injury of osteoarthritic spine with incomplete paraplegia. Fig. 7 shows an osteophyte avulsed from lower margin of C.3. The anterior common ligament is ossified between C.4, 5, and 6. Fig. 8 shows the autopsy specimen; the anterior common ligament and intervertebral disc between C.3 and 4 are ruptured.

Post-mortem examination revealed rupture of the anterior common ligament between the third and fourth cervical vertebrae. The rupture extended through the intervertebral disc to the posterior common ligament which was intact (Fig. 8). Abnormal hyperextension of the spine was possible at the level of injury but there was no dislocation of the articular processes. The spinal cord had a normal appearance apart from slight constriction at the level of injury.

Comment—The post-mortem findings prove beyond doubt that this was a hyperextension injury. Ossification of the anterior common ligament in the lower cervical spine accounted for localisation of violence to the upper vertebrae, and the anterior common ligament ruptured immediately above the ossified region. The cord injury was not severe, and a younger patient might have recovered.

Case 9. T. N., aged 58 years—Fell from a glass roof on to his head. There was complete motor paralysis; pain and temperature sensation were impaired below the fourth cervical cord segment; other forms of sensation were normal. Radiographs showed moderate arthritic changes in the cervical spine but no evidence of recent injury. There was no change in the neurological findings until he died eighteen hours after injury.

Post-mortem examination showed rupture of the anterior common ligament between the sixth and seventh cervical vertebrae (Fig. 9). The intervertebral disc was avulsed from the body of the upper vertebra but the posterior common ligament was intact. Abnormal hyperextension of the spine was possible at the level of injury; the upper vertebra hinged on the lower, with the articular processes acting as the fulcrum. The joint capsule of the articular processes was intact on both sides. The spinal cord had normal appearances apart from slight constriction opposite the sixth cervical vertebra; no intramedullary haemorrhage was observed on section of the cord (Fig. 10).

Comment—The post-mortem findings were very similar to those in Case 12, and proved beyond doubt that the injury was due to hyperextension violence. Neurological examination indicated that the level of spinal cord injury was three to four segments higher than that of vertebral injury, and it is therefore unlikely that the paraplegia was due to direct contusion of the cord. It is possible, however, that the cord was subjected to traction at the moment

FIG. 9

FIG. 10

Case 9. T. N., aged 58 years. Hyperextension injury with incomplete paraplegia (Fig. 9). The anterior common ligament between C.6 and 7 is ruptured and the disc is avulsed from the upper vertebra. Fig. 10 shows slight constriction of the spinal cord at the level of vertebral injury.

of extreme hyperextension, and in these circumstances the upper level of the cord lesion might well be several segments higher than the vertebral injury.

No post-mortem examination was made in the other three fatal cases but the nature of accident, and the radiographic appearances, leave little room for doubt that they too were hyperextension injuries. A summary of the clinical and radiographic features of the six cases is given in Table IV.

TABLE IV
HYPEREXTENSION INJURIES IN ARTHRITIC SPINES

Case	Age	Nature of injury	Radiographic appearances	Type of paraplegia	Result
8 J. S.	57	Fell downstairs on to face	Moderate osteoarthritis. Osteophyte avulsed from lower margin of C.6. No displacement	Incomplete	Recovery apart from residual weakness in hands
9 T. N.	58	Fell through glass roof	Moderate osteoarthritis. No fracture or dislocation	Incomplete	Death second day
10 M. C.	77	Knocked down by motor car	Advanced spondylitis. Vertebrae ankylosed below C.4. Fracture lower margin of C.3. Backward displacement of C.3 on 4 by .5 cm.	Incomplete	Death fourth day
11 J. McQ.	67	Knocked down by car	Gross osteoarthritis. No fracture or dislocation	Complete	Death one week after injury
12 T. B.	63	Fell from ladder distance of ten feet on to head	Gross osteoarthritis. Fracture of osteophyte on lower anterior margin of C.3. No dislocation	Incomplete	Death tenth day
13 G. B.	61	Fell seven feet from scaffolding on to forehead	Gross osteoarthritis. No fracture. Widening of intervertebral space between C.4 and 5 anteriorly	Incomplete	Death second day

Mechanism of injury—Elderly patients are predisposed to hyperextension injury by two factors. With advancing years there is a tendency to kyphosis of the thoracic spine which

FIG. 11

Mechanism of hyperextension injury of cervical spine. The anterior common ligament is torn or avulsed with a bone fragment. There is no dislocation of articular processes.

common ligament or the zygapophyseal joint capsules. Immediately the striking force is removed normal alignment of the vertebrae is restored by spasm of the neck muscles and for this reason the radiographic appearances may be deceptive. (Case 9.)

Nature of the spinal cord injury—I have been unable to find a completely satisfactory explanation of the spinal cord lesion in these hyperextension injuries. Unlike flexion injuries there is neither gross dislocation of the vertebrae, nor retropulsion of the intervertebral disc. The cord damage is not usually severe, for the paraplegia was incomplete in five of the six patients. Two possible explanations of the spinal cord injury have been considered: 1) that it may be caused by "spinal concussion" as the result of minor displacement of a vertebral body; or 2) that it may be due to traction injury at the moment of extreme hyperextension.

is usually compensated by cervical lordosis (extension deformity of the neck—Fig. 12). This is a relatively fixed position, and any increase in the degree of extension is liable to cause strain or injury (Brown and Kuhns 1942). The risk of injury by hyperextension violence is greater when mobility of the spine is impaired by arthritic changes in joints and ligaments. In the event of a fall, the neck cannot be flexed in the normal defensive manner, so that when the head strikes the ground powerful angulation strain in extension is applied to the cervical region. The brunt of this violence falls on the anterior common ligament: it may rupture; or a small flake of bone may be avulsed from the lower anterior margin of the upper vertebra (Fig. 11). The tear extends backwards through the intervertebral disc, or the disc itself may be torn from the vertebra above. There is no tendency for the disc to herniate into the spinal canal as in the case of flexion injuries. Once the disc has ruptured there is little resistance to further hyperextension, and considerable separation of the vertebral bodies can occur without rupture of the lax posterior

FIG. 12

Tracing of radiograph of extension deformity of cervical spine compensatory to severe thoracic kyphosis. The angle between pedicles and body is more acute than in a normal spine and the spinal canal is therefore narrowed.

When there is extension deformity of the neck compensating for thoracic kyphosis the angle between the vertebral bodies and the pedicles is decreased (Fig. 12), and consequently the spinal canal is narrowed. Moreover, in hypertrophic arthritis, osteophytes may project from the posterior margins of the vertebral bodies into the spinal canal and still further reduce the margin of safety. In these circumstances it is possible that minor displacements of the vertebrae may be sufficient to concuss the spinal cord.

We have also observed that when the disc is ruptured considerable separation of vertebral bodies is possible and it is tempting to postulate that there may be traction injury of the cord. The fact that in some patients the neurological level of cord injury was several segments higher than the vertebral injury gave support to this view.

FIG. 13

FIG. 14

Steel markers have been placed in the spinal cord through the intervertebral disc between the third and fourth, and fifth and sixth vertebrae (Fig. 13). The anterior common ligament and intervertebral disc between the fourth and fifth vertebrae have been divided and the neck hyperextended (Fig. 14). There is no increase in the distance between the markers and therefore no evidence that traction force has been applied to the spinal cord.

Experiments were performed on cadavers to test the accuracy of this hypothesis. Hollow needles were inserted through the intervertebral discs immediately above and below the one which was to be divided, and were pushed on into the spinal cord. After checking the position of the needles by radiography a steel marker was introduced through the lumen of each needle into the spinal cord and the needles were removed. Further X-ray films were taken and the distance between the markers measured. The anterior common ligament and intervertebral disc between the two markers was divided. With wedges placed between the spinous processes above and below the level of section, in order to simulate the rigidity of an arthritic spine, the neck was forcibly hyperextended until there was a considerable gap between the vertebrae. Further radiographs were taken in this position and the distance between the markers again measured. Finally the spinal cord was removed and the position of the markers rechecked by radiography. These tests failed to demonstrate any separation of the markers, and the theory that paraplegia may be due to traction injury of the cord is unsupported. It must be admitted, however, that the experiments were crude, and certainly did not reproduce accurately the conditions of the living subject, so that it would be unwise to dismiss finally the possibility of mild traction lesions which stop short of neural disruption.

Treatment—There is no indication for the use of caliper traction in hyperextension injury of an arthritic cervical spine. The intervertebral disc is not displaced backwards into the spinal canal, and any vertebral displacement that there may be is corrected easily by moderate flexion of the neck. It is not necessary to use external splintage for it cannot assist restoration of cord function, and elderly patients are so intolerant of plaster jackets or collars that their application often hastens the fatal termination.

Since becoming aware of the true nature of these injuries I have been content to do no more than use a small pillow to keep the neck slightly flexed, and to arrange the usual nursing care of a paraplegic patient. It cannot be claimed that the results are any improvement on more ambitious methods, but at least it has the merit of making more comfortable the few remaining hours or days of the patient's life.

SUMMARY

Twenty-two cases of paraplegia complicating injury of the cervical column have been reviewed. The vertebral injury may be due to flexion or hyperextension violence. *Flexion injury*—There are three types of flexion injury: 1) dislocation; 2) compression fracture of a vertebral body; 3) acute retropulsion of an intervertebral disc. Evidence is presented in support of the view that disc protrusion is the cause of the cord lesion when there is no radiographic evidence of bone injury, and in some cases at least when there is a compression fracture. Treatment is discussed and the indications for caliper traction and laminectomy are presented.

Hyperextension injury—There are two types of hyperextension injury: 1) dislocation; 2) injury to arthritic spines. Hyperextension injury of an arthritic spine is the usual cause of paraplegia in patients over fifty years of age. The mechanism of hyperextension injury is described. The possible causes of spinal cord injury, and its treatment, are discussed.

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