FRAC TURES AND DISLOCATIONS OF THE CERVICAL SPINE

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All surgeons who treat injuries of the cervical spine would agree that their aim is to produce a stable, painless neck and to diminish any risk of continued or recurrent pressure on the spinal cord. There is, however, a wide difference of opinion about the best way to achieve this aim.

For dislocations, Böehler (1933) advised infiltration with local anaesthetic at the site of dislocation followed by manual traction. Crooks and Birkett (1944) believed that manipulation under general anaesthesia was the simplest method, whereas Crutchfield (1938) and others recommended the use of continuous traction by skull calipers. Evans (1961) advocated manual reduction under general anaesthesia with the muscle spasm eliminated by means of scoline, but Durbin (1957) stated: “Manipulation under anaesthesia may not only fail to reduce a dislocation of the neck, but may in fact increase the degree of paralysis.” Rogers (1942, 1957) advised the use of skull traction and advocated operative reduction in all cases in which the displacement was not reduced by this method. Durbin (1957) agreed with this. Ellis (1946), however, stated that nearly all dislocations could be reduced by manipulation or traction, open operation being very rarely indicated.

The one point upon which there is broad general agreement is that unstable dislocations of the cervical spine should be stabilised, but little advice is given on the early recognition of an unstable dislocation. The purpose of this paper is firstly to discuss the anatomical significance of the radiological appearances of fractures and dislocations of the cervical spine and secondly to try to correlate them with the stability of the spine, the incidence of neurological damage and the reduction of the displacement. The subject has been studied both experimentally and clinically.

EXPERIMENTAL WORK

Two experimental methods were employed. The aim of the first was to try to clarify the radiological interpretation of injuries of the cervical spine; the aim of the second was to examine some mechanical aspects of cervical dislocations.

Radiological studies—The cervical spine from the fresh cadaver of a young adult was dissected out leaving the interspinous ligaments, the capsules of the interfacetal joints and the intervertebral discs intact. Small pieces of Kirschner wire were inserted into the inferior articular facets of the fourth cervical vertebra and the superior facets of the fifth vertebra. Only one piece of wire was inserted into each facet on the left, whereas two pieces were put into each of the right facets. Radiographs were then taken after various manoeuvres and the following facts emerged. 1) It was impossible to produce a forward slip of the body of the fourth cervical vertebra on that of the fifth of more than half the antero-posterior depth of the body if the dislocation of the interfacetal joint was confined to one side. The forward slip was greater if the neck was held flexed and was considerably, but never completely, reduced if the neck was held extended (Fig. 1). 2) It was impossible to produce a forward slip of the body of the fourth cervical vertebra on the fifth of less than half the antero-posterior depth of the body if the interfacetal dislocation was bilateral. This deformity was again increased by flexion of the neck but never reduced to less than half the body depth by extension (Figs. 2 and 3). 3) In a unilateral dislocation it was impossible to determine on which side the facets were dislocated.
unless oblique views were taken. It is, however, essential to know exactly how the patient has been placed for the oblique projection in order to decide which side is dislocated.

*The significance of oblique projections*—Two different oblique views may be taken with the right side of the patient's neck nearest the film. For one view the patient lies on his right side and is semi-prone in relation to the film; in the other he is still on his right side but semi-supine in relation to the film (Figs. 4 and 6). According to radiographical convention, each of these films is labelled "right oblique view" because the patient remains on his right side. The practical importance is that in the former view, which should properly be labelled "right anterior oblique," the right intervertebral foramina and corresponding facets are shown whereas in the latter view (right posterior view), the left foramina and facets are shown. Even so, many people find it difficult to visualise which is the right anterior position and which is
the right posterior position. In the author’s opinion it would be less confusing if these two views were labelled “right oblique, semi-prone” and “right oblique, semi-supine” (Figs. 5 and 7).

Mechanical studies—These were performed on the same cadaver. The findings were as follows:—1) Any forward slip of the body which might occur in acute flexion of the neck was immediately and completely reduced on returning the neck to the neutral position so long as there was no dislocation of the facets. In this type of slip the superior facet rides up on the one below it (Cramer and McGowan 1944). It was termed “partial forward dislocation” by Rogers (1957). 2) An interfacetal joint could be dislocated unilaterally and locked in its dislocated position only if the corresponding interspinous ligament and the joint capsule of
the dislocated side were completely ruptured. This displacement could be produced with only minimal damage to the annulus and posterior longitudinal ligament in the region of the neuro-central joint of the dislocated side. If the annulus was more extensively damaged the body slip could be increased up to just short of a half the antero-posterior body depth (Fig. 8). It was difficult to reduce this dislocation by a straight pull in the longitudinal axis of the spine because of the integrity of the disc and of the capsule of the undislocated interfacetal joint. It was very easy to reduce if a slight amount of lateral flexion was introduced away from the dislocated side. 3) It was necessary to rupture the capsules of both interfacetal joints, the interspinous ligament, the annulus and the posterior longitudinal ligament in order to dislocate both facets, leaving a grossly unstable spine (Fig. 9).

CLINICAL MATERIAL

In the light of the experimental findings the case notes of fifty-nine patients with cervical spinal injuries who were treated at the Robert Jones and Agnes Hunt Orthopaedic Hospital, Oswestry, between 1945 and 1962 were reviewed. The following types of injury were excluded: 1) Injuries without radiological evidence of damage, such as hyperextension injuries as described by Taylor and Blackwood (1948); 2) injuries of the upper two cervical vertebrae, which form a unit different both structurally and functionally from the lower five; 3) minor fractures of the transverse or spinous processes and simple compression fractures without disturbance of alignment of the posterior borders of the vertebral bodies.

The injuries were divided into the following three groups, according to their appearance in the lateral radiograph: 1) “Bursting” fractures of the vertebral body with backward displacement of the postero-inferior margin of the body into the spinal canal (Fig. 10); 2) anterior dislocation of one vertebral body on that next below it by less than a half of the
TABLE I

Fifty-nine Patients with Cervical Spinal Injuries
Distribution of injuries according to appearances in lateral radiograph

<table>
<thead>
<tr>
<th>Type of injury</th>
<th>Number of patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bursting fracture (Group I)</td>
<td>16</td>
</tr>
<tr>
<td>Anterior dislocation, less than half body depth</td>
<td>23</td>
</tr>
<tr>
<td>Anterior dislocation, more than half body depth</td>
<td>20</td>
</tr>
</tbody>
</table>

Damage to the spinal cord—Thirty-five patients were tetraplegic on admission, but this does not indicate the incidence of damage to the cord because many patients were transferred for long-term treatment after initial treatment at other hospitals. A significant fact, however, is that two patients who at first had no symptoms of cord damage suddenly became tetraplegic twenty-four hours after admission and did not recover cord function. In both cases the injury was of Group III, in both there were other injuries, and in neither was the dislocation of the cervical spine recognised until the onset of the tetraplegia.

ILLUSTRATIVE CASE

A boy of nine was knocked down by a motor-car in July 1957. He was admitted to hospital conscious and with all limbs moving freely, but with retrograde amnesia of about twenty minutes. Radiographs of the skull showed no fracture; no radiograph was taken of the cervical spine.

In the morning of the next day he suddenly became tetraplegic. He was transferred the same day to the Robert Jones and Agnes Hunt Orthopaedic Hospital. Radiographs of the cervical spine
Fig. 13—Lateral radiograph taken shortly after the onset of tetraplegia. Group III dislocation of fifth cervical vertebra on sixth. Figure 14—Radiograph after twelve hours' traction with twelve pounds weight. Note the gross distraction. Figure 15—Radiograph after reduction of traction to three pounds.

(Fig. 13) showed a dislocation of the fifth cervical vertebra on the sixth with displacement of more than half the vertebral depth. The same evening skull traction with twelve pounds weight was applied. A radiograph taken twelve hours later showed that the affected vertebrae had been pulled too far apart (Fig. 14) so the traction was reduced to three pounds (Fig. 15). The boy made no recovery from the tetraplegia.

*Recovery from paralysis*—In Figure 16 the incidence of paralysis and the frequency of recovery are shown in relation to the type of vertebral injury. By “recovery” is implied either complete recovery or recovery sufficient to make the patient independent.

Many of the tetraplegic patients with Group I injuries had some sensory sparing, but had complete motor paralysis below the level of the lesion, whereas the tetraplegics with injuries of Groups II and III usually had complete sensory and motor loss. The average age of those who recovered was twenty-three. Four of the eight tetraplegic patients who recovered cord function began to show return of function after periods varying from three to forty days after injury. All these patients had Group I injuries; the other four who recovered all began to show signs of returning cord function within a few hours of injury.

Cord damage was a frequent complication of Group I and Group III injuries (85 per cent and 75 per cent respectively) but an infrequent complication of Group II injuries (less than 30 per cent). Tetraplegia did not complicate a Group II injury in any patient under the age of forty-two. The average age of the six paralysed patients in this group was fifty-five.

Paralysis complicating Group II injury had much the best prognosis, and that complicating Group I injury the next best. The outlook for recovery after tetraplegia with an injury of Group III is hopeless.
Reduction of dislocation—In forty-three cases (Groups II and III) there was a dislocation to be reduced. Three of these patients did not have head traction. In the first the dislocation was so gross that it was presumed that the cord had been completely transected, and this supposition was confirmed at necropsy (Figs. 17 and 18). Because of a misunderstanding the second patient did not attend for treatment for three months after his original attendance. With an injury of Group II he continued with his work with no neck support during the whole of that three months (Figs. 19 and 20). The clinical notes do not indicate why reduction was not attempted in the third case. The patient had an injury of Group III and her neck was merely immobilised in a Minerva plaster (Fig. 21). This course was presumably followed because she was not tetraplegic and because plaster immobilisation was thought to be safer than skull traction or attempted reduction. Six weeks later she was transferred to another hospital where cervical spinal fusion was done.

There thus remain twenty-two patients with Group II injuries and eighteen patients with Group III injuries in whom reduction was attempted. The methods included manipulation with anaesthetic (three cases), manipulation without anaesthetic (four cases), skull traction (twenty-four cases), halter traction (two cases) and operative reduction (seven cases).

Of the Group II injuries, eight were successfully reduced and fourteen were not reduced as judged radiologically by the congruity of alignment of the posterior margins of the vertebral bodies. Two of the latter group were later reduced by operation.

Of the Group III injuries, thirteen were successfully reduced and five were not reduced by closed methods. All these five were later reduced at operation.
In all, fourteen patients were subjected to operation (Table II). Operation was most commonly undertaken for reduction of dislocation, although the interval between injury and operation varied widely. Seven operations were performed in order to stabilise the spine. It is obvious that there were no standard criteria for assessing instability: the operations were done because the surgeons thought that the spines might be unstable and that it would be safer to fuse them. No patient with tetraplegia was improved by operation and two died within twelve hours of operation. Most of those who were free from symptoms after operation had no symptoms before it, but one patient with a spastic paraparesis was definitely improved by operation.

In only two cases did a dislocation definitely recur after reduction. Both patients had Group III injuries. In one, redislocation occurred on the day of reduction while skull traction with five pounds' weight was being maintained. The other dislocation recurred three months after reduction while the neck was immobilised in a Minerva plaster (Figs. 22 to 24).

DISCUSSION

Damage to the spinal cord may be caused by any sort of cervical injury. Therefore, the prime consideration in the treatment of injuries of the cervical spine should be the protection of the cord. In accident cases where there is any possibility of neck injury—including cases in which the patient is unable to remember the injury—a lateral radiograph of the neck will help to prevent a possible catastrophe. Rogers (1942) stated that the cord was "safe" when the patient was on skull traction and, with the exception...
of one redislocation during traction, the results in this series confirm his belief. If five pounds’ traction is inadequate to maintain reduction of an unstable fracture it seems most unwise to employ halter traction, since most patients cannot tolerate more than a few pounds’ pull applied in this way for more than a short period of time.

In his study of the mechanics of spinal injury Roaf (1960) pointed out the importance of rotational strain as a causative factor in spinal dislocations and it is clear that a rotational component must be present in the forces causing a unilateral dislocation of facets. It is equally logical to assume that lateral flexion of the neck away from the side of the dislocation followed by rotation of the neck towards the side of the lesion, as recommended by Böhler (1933) and by implication by Evans (1961), should be effective in reducing this dislocation. It is possible that in the fourteen cases with Group II injuries which were not reduced, a straight pull in the longitudinal axis of the spine was relied upon to reduce the dislocation, and no lateral flexion was applied. In fact, it is quite possible that a number of the unilateral dislocations were reduced as the skull calipers slipped out accidentally—a not infrequent

<table>
<thead>
<tr>
<th>Case number</th>
<th>Age (years)</th>
<th>Group</th>
<th>Interval between injury and operation</th>
<th>Reason for operation</th>
<th>Type of operation</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>47</td>
<td>III</td>
<td>5 months</td>
<td>No attempt had been made at reduction; it was thought safer to stabilise</td>
<td>Fusion</td>
<td>Free from symptoms</td>
</tr>
<tr>
<td>2</td>
<td>23</td>
<td>II</td>
<td>8 months</td>
<td>Persistence of root signs</td>
<td>Fusion</td>
<td>Free from symptoms</td>
</tr>
<tr>
<td>3</td>
<td>45</td>
<td>II</td>
<td>5 weeks</td>
<td>No obvious reason</td>
<td>Fusion</td>
<td>Free from symptoms</td>
</tr>
<tr>
<td>4</td>
<td>52</td>
<td>III</td>
<td>12 months</td>
<td>Spasticity and difficulty in walking after two previous injuries</td>
<td>Fusion</td>
<td>Free from symptoms</td>
</tr>
<tr>
<td>5</td>
<td>29</td>
<td>III</td>
<td>2 days</td>
<td>Tetraplegic. Failure of reduction</td>
<td>Reduction and wiring</td>
<td>Died from chest complication twelve hours after operation</td>
</tr>
<tr>
<td>6</td>
<td>47</td>
<td>III</td>
<td>5 weeks</td>
<td>Failure of reduction</td>
<td>Reduction, wiring and grafting</td>
<td>Free from symptoms</td>
</tr>
<tr>
<td>7</td>
<td>24</td>
<td>III</td>
<td>10 days</td>
<td>Tetraplegic. Failure of reduction</td>
<td>Reduction and wiring</td>
<td>Remained tetraplegic</td>
</tr>
<tr>
<td>8</td>
<td>47</td>
<td>II</td>
<td>7 weeks</td>
<td>Recurrence of slight vertebral shift in plaster</td>
<td>Fusion</td>
<td>Free from symptoms</td>
</tr>
<tr>
<td>9</td>
<td>30</td>
<td>III</td>
<td>1 day</td>
<td>Tetraplegic. Failure of reduction</td>
<td>Reduction and wiring</td>
<td>Remained tetraplegic. Died nine months later</td>
</tr>
<tr>
<td>10</td>
<td>21</td>
<td>III</td>
<td>1 day</td>
<td>Tetraplegic. Recurrence of dislocation after complete reduction</td>
<td>Reduction and wiring</td>
<td>Remained tetraplegic</td>
</tr>
<tr>
<td>11</td>
<td>45</td>
<td>III</td>
<td>4 weeks</td>
<td>Tetraplegic. No other reason given</td>
<td>Wiring and grafting</td>
<td>Remained tetraplegic</td>
</tr>
<tr>
<td>12</td>
<td>57</td>
<td>II</td>
<td>3 days</td>
<td>Tetraplegic. Failure of reduction</td>
<td>Reduction and wiring</td>
<td>Remained tetraplegic</td>
</tr>
<tr>
<td>13</td>
<td>50</td>
<td>III</td>
<td>1 day</td>
<td>Tetraplegic. Failure of reduction</td>
<td>Reduction and wiring</td>
<td>Died from chest complication twelve hours after operation</td>
</tr>
<tr>
<td>14</td>
<td>19</td>
<td>II</td>
<td>3 months</td>
<td>Failure of reduction. Stabilisation sought</td>
<td>Fusion</td>
<td>Free from symptoms</td>
</tr>
</tbody>
</table>
occurrence. Once it is realised that some lateral flexion is helpful in reducing these dislocations, it is clearly most important to be quite sure on which side the facets are dislocated. It is in this connection that the accurate labelling of oblique radiographs is stressed (Figs. 4 to 7).

The cause of the cord lesion in Group I injuries—Schneider and Kahn (1956) thought that the cord was held stretched over the projecting postero-inferior margin of the fractured vertebral body by the tautness of the denticulate ligaments. They recommended laminectomy and section of these ligaments in those cases with motor paralysis but with sparing of the posterior columns. It should be realised however that in these injuries the disc below the crushed vertebra has completely disintegrated and stability of the spine is maintained by the posterior supporting elements. Operations which disturb these elements could possibly lead to instability. Barnes (1961) thought that the patients described by Schneider and Kahn (1956) as having improved after operation would have improved in any case. He thought that the mechanism of cord injury might be acute retropulsion of the disc. The appearance of the cervical spine after such

an injury is shown in Figures 25 and 26. The wedge-shaped postero-inferior border of the fractured vertebra has sheared off a sliver of the posterior aspect of the vertebral body next below it and has displaced it into the cord. This sliver is quite invisible on the radiograph. It may be that such an occurrence is quite frequent in these injuries and it is possible that tomography might be helpful in revealing such spicules of bone.

Durbin (1957) and Rogers (1942) both agreed that irreducible dislocations should be reduced by open operation. Rogers (1957), however, stated that “one may arbitrarily accept as a satisfactory position one with less than three millimetres’ decrease in diameter of the lumen of the vertebral canal.” There seems no logical reason why the posterior surfaces of the vertebral bodies should not be congruously aligned if the dislocation has been reduced; the fact that they are not so aligned must mean that something is still preventing reduction. The lateral radiograph shown in Figure 27 was accepted as showing reduction, but the oblique radiograph taken on the same day shows that the facets on one side remain dislocated (Fig. 28).

The pedicles on each side form the upper borders of the intervertebral foramina below and the lower borders of the foramina above them. If in an oblique view the congruity of the
The value of the oblique projection in the detection of the cause of incomplete reduction. Figure 27—Lateral radiograph showing Group II dislocation of sixth cervical vertebra on seventh after "reduction." Figure 28—Oblique radiograph in the same case. There is obvious unilateral dislocation of facets.

FIGS. 25 AND 26
Damage to spinal cord in Group I injury. Figure 25—Radiograph showing "bursting" injury of the sixth cervical vertebra. Figure 26—Necropsy specimen of the same cervical spine in sagittal section. The upper pointer indicates the body of the sixth cervical vertebra. The postero-inferior part of the vertebra projects backward into the spinal canal but does not seem to be compressing the cord. The cord has been damaged by the sliver of bone (indicated by lower pointer) which has been driven backward from the posterior part of the body of the seventh cervical vertebra by the shearing action of the lower edge of the sixth.
intervertebral foramen is disturbed, then either the articular facet is dislocated on that side, or the pedicle is fractured. Fractures of the neural arch or of the articular facets are in the author's opinion extremely difficult to interpret in radiographs of the cervical spine, although Forsyth, Alexander, Davis and Underdal (1959) and Norton (1962) considered that there was a special type of fracture of the facet which allowed the vertebral body to shift forwards slightly. In their opinion this fracture was caused by an extension injury. A series of lateral and oblique films (Figs. 29 to 32) shows the alteration of the relation of the pedicle to the intervertebral foramen in a unilateral dislocation.

Group II dislocations—There were fourteen patients with unilateral facet dislocations which remained unreduced. In only one of these was fusion undertaken, for persistence of root signs eight months after injury (Case 2). The other thirteen patients are either free from symptoms or have so little in the way of symptoms that operative treatment is not warranted. It seems therefore that whereas such a dislocation should be reduced if possible in order to minimise painful root symptoms, nevertheless if it should prove irreducible there is no
indication to resort to operative reduction, or to fuse the spine at a later date except in a small proportion of cases. In no case in Group II did the displacement increase to produce a Group III dislocation.

Group III dislocations—When bilateral facet dislocations (Group III) are considered it is clear that they are much more dangerous for the following reasons. 1) None of these patients with tetraplegia recovered cord function. 2) The dislocation may be missed at first, and because the spine is unstable the injury may manifest itself as a suddenly occurring tetraplegia hours or days after the accident—presumably from some unguarded movement of the patient. 3) Because of the instability the dislocation is liable to recur and may even do so while the neck is in plaster. There were two cases of redislocation in this series. (Rogers (1957) reported redislocation in 12 per cent of cases, and study of the radiographs of other published reports (Cone and Turner 1937, McEwen and Bickerton 1945, Bailey 1961) shows that they also were radiographically Group III cases.) 4) Because of the rupture of all the ligamentous structures between the two vertebrae, great care and frequent checking with lateral radiographs are necessary during the reduction (Fig. 14).

Treatment of patients without cord injury—As a rule, these patients had an initial period of three weeks on skull traction and then were immobilised in a Minerva plaster which after ten weeks was replaced by some type of collar. This was worn for a further six months. Immobilisation of the cervical spine in a Minerva plaster is not absolute, but fixation of this degree does not seem necessary for injuries of Groups I or II either reduced or unreduced. It may well be that plaster fixation is used more for the peace of mind of the surgeon than for the benefit of the patient. James (1960) considers that absolute fixation of the cervical spine can be achieved by immobilisation in a "halo" splint and points out that fusion can be performed whilst this splint is being worn. Evans (1961) advises that after wiring and grafting of a cervical spine, a polythene collar is all that is required once the wound is healed.

CONCLUSIONS

1. It is possible to recognise an unstable dislocation of the cervical spine by study of the initial lateral radiograph.

2. When a patient with an injury to the head or neck is admitted to hospital a lateral radiograph of the neck must be taken. If this shows that one vertebral body has dislocated forward on that next below it by less than half the antero-posterior depth of the vertebral body, there is a unilateral facet dislocation. Right anterior and posterior oblique films must then be taken in order to determine on which side the facets are dislocated.

3. Such dislocations are essentially stable and do not displace further. They should be reduced by applying skull traction and, whilst the longitudinal pull is still acting, applying slight lateral flexion away from the dislocated side followed by slight rotation towards this side. Failure of closed reduction is not necessarily an indication for operative reduction. These patients may require fusion or foraminotomy at a later date if painful root symptoms persist.

4. Forward dislocation of a vertebral body on that next below it by more than half the antero-posterior depth of the body indicates dislocation of both facets, with extensive tearing of the annulus, of the longitudinal and interspinous ligaments and of the ligaments of the joints. Such a dislocation is, and will remain, unstable and liable to redislocation. Usually the dislocation can be easily reduced by a straight pull in the longitudinal axis of the spine by means of skull traction, followed by slight extension when the vertebrae are sufficiently distracted. Great care must be taken to have lateral radiographs at frequent intervals (five to fifteen-minute intervals) to avoid over-distraction. Ultimate stability is achieved more quickly and certainly by wiring and grafting the affected vertebras as soon after reduction as possible if the patient has escaped tetraplegia.

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5. Bursting fractures of the vertebral body, with backward protrusion of part of the body, give rise to tetraplegia in a very high percentage of cases, but over a third of these patients recover, the prognosis being better in the younger age groups. It is probably best to protect the cord for a few weeks by using skull traction, but no other manipulative treatment or immobilisation is necessary. The value of decompressing operations is unproven.

6. Operative treatment of a fracture-dislocation of the cervical spine is very rarely indicated if the patient is tetraplegic.

SUMMARY

1. Experimental radiological and mechanical studies on a cadaveric cervical spine are reported.

2. A series of fifty-nine dislocations and fracture-dislocations of the cervical spine is reviewed.

3. The methods of reduction and indications for operation are discussed.

I wish to thank the Director General of Medical Services of the Royal Air Force for giving permission to publish this paper. I am most grateful to Mr Robert Roaf, Director of Clinical Studies and Research at the Robert Jones and Agnes Hunt Orthopaedic Hospital, Oswestry, for his help and encouragement in the preparation of this paper, and to the Visiting Consultants at this hospital for permission to review their cases. I am also grateful to the following members of the staff for their help in various ways: Mrs M. Jackson, Senior Research Clerk, Mr J. B. M. S. Southern, Senior Clinical Photographer, and Mr W. G. Davies, Superintendent Radiographer. Miss U. Schwarzkopf did translations from the German.

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