FRACTURES OF THE DORSO-LUMBAR SPINE

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This paper is based on a study of 166 fractures or fracture-dislocations of the dorso-lumbar spine occurring in 152 miners during the six-year period ended in 1945. One of the objects of the analysis was to investigate the relationship between anatomical and functional results—in other words to examine the validity of the assumption that a good anatomical result is indispensable to a good functional result. This assumption was the basis of the teaching of Bohler (1935) which influenced the practice of most continental clinics; it was reiterated in recent American writings by Key and Conwell (1946); and it has been supported in Great Britain by so great an authority as Watson-Jones (1943) in the words: "perfect recovery is possible only if perfect reduction is insisted upon; even slight degrees of wedging of the vertebrae may cause persistent aching pain. . ." Nevertheless an assumption it remains, and an assumption that has the most vital repercussions on treatment. The fact that it is held so widely and authoritatively is yet another reason for submitting it to careful and critical examination.

The assessment of deformity is a matter of precision, involving measurable criteria. The assessment of function, however, is based on criteria that are subject to individual judgment rather than precise measurement. Because of the importance of the hypothesis to be examined it seemed necessary to impose an exacting standard for the estimation of function, and certain safeguards were therefore observed: 1) no case was assessed in less than two years, and the average follow-up was five years—long enough to include both late improvement and late complications; 2) the measurement of such physical properties as mobility and muscle power is straightforward but the assessment of pain, which is the most important limiting factor in function, is much more difficult. However, the fact that all these patients were miners provided a satisfactory solution, namely, their ability to withstand the conditions of stress that arise in working at the coal-face in cramped positions. No patient was classified as having gained a perfect functional result unless he could work under these conditions without discomfort and had, in fact, done so for a number of years.

MECHANISM OF INJURY

All the injuries were due to direct violence, usually severe enough to cause contusion and tenderness of the erector spinae muscles, a factor that is of significance in relation to treatment and residual pain. The usual mechanism was hyperflexion which is always associated with a forward shearing stress. The patient was "buried" by a fall of roof or coal with his head between his knees. If the main force falls on the shoulders, the dorso-lumbar region receives the greatest strain; but if the force is applied lower down, the lumbar or lumbo-sacral regions are involved. If the knees are extended at the time, the pelvis is fixed by the tight hamstring muscles and there is much greater stress at the lumbo-sacral region. This was noted in two cases of traumatic spondylolisthesis at this level. In some cases, forward flexion was combined with twisting to one side and this was associated particularly with fractures of the laminae and with the variety of fracture to be described later as "lateral wedge fracture." There were no examples of extension fracture which must be very rare indeed in the dorso-lumbar region, though not so rare in the neck.

Level of injury—Table I shows the distribution of fractures at different levels. Cervical injuries and isolated fractures of the sacrum were not included.
The distribution does not differ materially from that which has been recorded by other writers. The important point to note is that 66 per cent. of the injuries were confined to three vertebrae—the twelfth dorsal, first lumbar and second lumbar.

### TABLE I
**Level of Injury in 166 Fractures occurring in 152 Patients**

<table>
<thead>
<tr>
<th>Level of fracture</th>
<th>Number of cases</th>
<th>Percentage of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dorsal 10 and above</td>
<td>7</td>
<td>4.2</td>
</tr>
<tr>
<td>Dorsal 11</td>
<td>12</td>
<td>7.2</td>
</tr>
<tr>
<td>Dorsal 12</td>
<td>34</td>
<td>20.5</td>
</tr>
<tr>
<td>Lumbar 1</td>
<td>49</td>
<td>29.6</td>
</tr>
<tr>
<td>Lumbar 2</td>
<td>27</td>
<td>16.3</td>
</tr>
<tr>
<td>Lumbar 3</td>
<td>17</td>
<td>10.2</td>
</tr>
<tr>
<td>Lumbar 4</td>
<td>12</td>
<td>7.2</td>
</tr>
<tr>
<td>Lumbar 5</td>
<td>8</td>
<td>4.8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>166</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

Number of cases with multiple fractures=14 (9%)  

**Type of fracture**—The fractures were classified on an anatomical basis into four main types: anterior wedge fracture, lateral wedge fracture, fracture-dislocation, and isolated fracture of the neural arch (Table II). This differs from the classification adopted by Watson-Jones (1943) who did not differentiate lateral wedge fractures or isolated fractures of the neural arch, and believed that comminuted wedge fractures were relatively common (15 per cent.).

### TABLE II
**Types of Fracture**

<table>
<thead>
<tr>
<th>Type of Fracture</th>
<th>Number of cases</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior wedge fracture</td>
<td>88</td>
<td>58</td>
</tr>
<tr>
<td>Lateral wedge fracture</td>
<td>21</td>
<td>14</td>
</tr>
<tr>
<td>Fracture-dislocation</td>
<td>29</td>
<td>19</td>
</tr>
<tr>
<td>Isolated fractures of the neural arch</td>
<td>14</td>
<td>9</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>152</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

**Anterior wedge fracture**—The extent of wedging varies, but in half the cases it is minimal. It cannot, in fact, be severe without involving the posterior interspinous ligament since the fulcrum of movement is at the nucleus pulposus of the intervertebral disc (Figs. 10 and 11). If this fulcrum remains intact, and wedging is severe, rupture of the ligament with subluxation of the posterior intervertebral joints is inevitable. This can often be demonstrated in good radiographs, or it can be inferred from the undue separation of spinous processes. Many so-called wedge fractures with severe wedging are, in fact, fracture-subluxations in which the inferior facets of one vertebra are displaced upwards or even "perched" on the superior facets of the other (Fig. 15). The importance of recognising this lies in the fact that it is an unstable position which is easily converted into a fracture-dislocation with forward displacement of the vertebral body and possible damage to the cord; whereas cases with minimal or moderate wedging and an intact posterior interspinous ligament are quite free from this danger.

There is a special type of anterior wedge fracture in which the whole of the vertebral body is more evenly compressed. This "concertina" type of compression occurs in older people and there is little or no angulatory deformity. As a rule it is associated with
degenerative changes in the nucleus which fails to act as a fulcrum. The interspinous ligament remains intact and vertical compression occurs.

Wedge fracture with comminution—These cases are stated by Watson-Jones to constitute 15 per cent. of all spinal fractures and to be associated especially with the type of direct violence that occurs in mining accidents. Since this was the mechanism responsible for all cases in the present series it would have been reasonable to expect a higher incidence, even up to 30 per cent.; but in fact only eight cases were seen in simple wedge fractures (Figs. 1 and 2). Comminution is much more often seen in fracture-dislocations. Its importance in association with wedge fractures lies in the fact that it has been put forward as an explanation of late redisplacement which will be discussed later.

![Fig. 1](image1.png)  ![Fig. 2](image2.png)

Vertical compression fracture showing comminution of the vertebral body and slight retropulsion. There is also an anterior wedge fracture of L1 without comminution (Fig. 1). The compression was reduced and after six months' immobilisation in plaster the comminuted body healed well. There was no collapse but the disc spaces above and below are narrowed, and spontaneous fusion is occurring (Fig. 2). This is often the case when there is comminution.

Lateral wedge fracture—This is a type of vertebral fracture that has not been described in previous classifications. It constitutes 14 per cent. of the present series and has certain anatomical and clinical characteristics that appear to justify its differentiation. It is a flexion-rotation injury, the usual history being that the patient's head is forced forwards and to one side. The unilateral wedging, the associated fractures of transverse processes on the convex side, and the damage to the posterior intervertebral joint on the concave side, should be noted (Figs. 3 and 4).

Certain clinical features are specially associated with this fracture. 1) The prognosis is not good; in this series only 21 per cent. gained complete functional recovery as against 40 per cent. in anterior wedge fractures. 2) Residual pain, if present, is commonly at the site of fracture (93 per cent.) whereas in anterior wedge fractures pain is usually at the fifth lumbar level regardless of the site of fracture (72 per cent.). The pain in lateral wedge fractures is related either to the displaced intervertebral joint which may also involve the nerve root, or to tearing of the iliopsoas muscle as indicated by associated fractures of the transverse processes which usually show wide separation, indicating severe damage to the soft tissues. Retroperitoneal haemorrhage is not uncommon and may present all the signs and symptoms of an acute abdominal catastrophe. Two patients in this series with lateral wedge fractures...
were submitted to laparotomy, with negative findings (Fig. 3), before the spinal condition was diagnosed. 3) These fractures are difficult to reduce. In fact, reduction was achieved only three times in twenty-one patients; in two of the three there was redisplacement, and the only good anatomical result was secured by grafting. 4) Damage to the cord may occur in lateral wedge fractures whereas there was no such damage in any anterior wedge fracture in this series. There were two paraplegias in twenty-one cases of lateral wedge fracture and both failed to recover. The probable explanation is that the cord and cauda equina are tethered laterally by the nerve roots and dentate ligament, so that lateral flexion is more liable to tear the cord than simple forward flexion. This is supported by the fact that in the two cases mentioned above, paralysis was greater on the side opposite the wedging.

Fracture-dislocation—The essential difference between a fracture-dislocation and a simple wedge fracture lies in the fact that in fracture-dislocation there is rupture of the posterior interspinous ligament. Several degrees of displacement may be distinguished such as simple upward subluxation of the facets, "perching" of the facets, forward dislocation with fracture of the facets or neural arch, and forward dislocation with locking of the facets. All these can be reduced by manipulation except the last, in which manipulation is dangerous. It is important, therefore, to distinguish between them before attempting manipulation and this calls for radiographs of the very best quality. A test reduction may be carried out by turning the patient carefully into the prone position and repeating the lateral view. If there is no reduction in the amount of forward displacement it may be inferred that the facets are locked. Damage to the cord or cauda equina is very frequent in fracture-dislocations (62 per cent. in the present series). There were twenty cases of paraplegia, eighteen associated with fracture-dislocations, and two with lateral wedge fractures.
Irauamatie

spondylohisthesis. Closed reduction
failed and the patient refused operation. Plaster bed six months. After two years there was
spontaneous arrest but the patient still had referred
pain in both lower limbs.

Fig. 5

Fracture of the lamina of the second lumbar vertebra. After three years, although there is
only fibrous union, forward sliding is minimal.
There is no disability and the patient works
at the coal-face.

Fig. 6

Fracture of lamina of third lumbar vertebra. This patient was not seen until six weeks after injury and during
that time he had been walking about. Note that there has been no forward sliding (Fig. 7). Three years later
there is still no forward sliding and union has occurred (Fig. 8). The patient is now working at the coal-face.

Fig. 7

Fig. 8

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Neural arch fractures—These are rotation injuries, as shown by the fact that half of them are associated with fractures of the transverse processes. They are often described wrongly as fracture of the pedicles—an extremely rare injury which probably never occurs except as part of a severe fracture-dislocation. The site of fracture is at the interarticular part of the lamina so that when there is displacement, as in the bilateral variety, the superior facet slides forwards and the inferior facet remains behind, as in the classical type of spondylolisthesis (Fig. 5).

In bilateral laminar fractures the level of injury is important. If it occurs above the fourth lumbar vertebra the tendency to slide forwards is minimal (Fig. 6). The patient illustrated in Figure 7 was not seen until six weeks after injury, during which time he had been walking about. He was then treated by simple recumbency after which union occurred readily with no further displacement.

At the level of the fourth or fifth lumbar vertebrae the story is quite different, for it is here that body-weight exerts a forward shearing stress. If a bilateral laminar fracture is overlooked at this level (and it is quite easy to do this) forward sliding is bound to result, with consequent spondylolisthesis. The most perfect X-ray films are needed and suspicion should always be aroused if there is a fractured transverse process at this level.

![Image](image-url)

**Fig. 9**

Chance's fracture, through the spinous process, laminae and vertebral body.

A special type of laminar fracture has been described recently by G. O. Chance (1948). In this, the fracture line is horizontal and is continued anteriorly into the body and posteriorly into the spinous process (Fig. 9). There may be slight wedging but since the fracture line passes through bone all the way, and there is no subluxation of the facets, or rupture of the posterior ligament, reduction is followed by bony union which is stable. As Chance points out, failure to recognise these cases may lead to unnecessary grafting operations.

**REDISPLACEMENT AFTER REDUCTION**

Redisplacement after reduction and prolonged immobilisation is more common than is generally supposed. Stanger (1947), reviewing a series of fracture-dislocations of the spine several years after injury, found that deformity had recurred in a high proportion of cases. The same is true of simple wedge fractures and, in the present series, it was the exception rather than the rule for a good anatomical result to be maintained in any case in which initially there had been more than minimal deformity. In the earlier years of the period covered by this review great pains were taken to maintain complete reduction in plaster, sometimes for six months, only to see deformity recur, very often within a month of removing the plaster. The questions that arise are whether the factors responsible for such
redisplacement can be recognised at the outset, and whether a perfect anatomical result is in fact an indispensible objective in treatment.

**Mechanism of flexion-extension movement in the normal spine**—It is necessary first to consider the mechanism of flexion and extension in a normal spine. The fulcrum of this movement is not at the interarticular joints but at the nucleus pulposus of the intervertebral disc. (Calví and Galland 1930.) Normally, the posterior part of the disc space actually narrows in hyperextension, proving that this point is behind and not in front of the fulcrum (Fig. 11). If the fulcrum remains intact, any degree of hyperflexion capable of producing even minimal wedging of the vertebral body exerts great leverage on the interspinous ligament. If hyperflexion proceeds still further, rupture of the ligament is inevitable; there may be an avulsion fracture of the spinous process, and a varying degree of subluxation of the facets, depending upon the degree of separation of the spinous processes. This is the sequence of events if the fulcrum remains intact; but in many cases the interspinous ligament is the stronger of the two and the disc itself is crushed.

![Fig. 10 and Fig. 11](image)

*Fig. 10 and Fig. 11*

The normal mechanism of spinal movement. Fig. 10 shows the intervertebral joint in full flexion and Fig. 11 in full extension. The fulcrum is at the nucleus pulposus.

Thus, four structures are involved—the vertebral body, the disc, the intervertebral joints and the interspinous ligament. Each of these should be considered separately whenever the radiographs of an injured spine are examined. Furthermore, the erector spinae muscles may be overstretched or partly ruptured.

**Factors concerned in redisplacement after the reduction of vertebral fractures**—The three most important factors concerned in redisplacement can now be considered. They are: comminution of the vertebral body; crushing of the intervertebral disc; and rupture of the interspinous ligament.

*Commination of the vertebral body*—Commination is comparatively rare in simple wedge fractures. When it occurs, consolidation is delayed, as pointed out by Watson-Jones (1943). However, the vertebral body has a good blood supply (evidence of avascular necrosis was observed only twice in the present series) and in about half the patients consolidation of bone in the fully reduced position can be achieved; but the price to be paid is six months in plaster (Fig. 2). Commination, however, is almost invariably associated with damage to the disc, the interspinous ligament, or both, in which case some collapse is inevitable whatever happens to the vertebral body.

*Crushing of the intervertebral disc*—This is much more common than is often supposed. It can be recognised in the original radiograph by narrowing of the disc space (Fig. 12) though, after reduction, the space may appear to be normal (Fig. 13). Sometimes the disc can be seen
Vertebral fracture with almost complete disappearance of the disc space indicating that it has been damaged irretrievably (Fig. 12). The disc has no blood supply and is incapable of repair so that deformity is inevitable. Perfect anatomical reduction was maintained for six months (Fig. 13). Nevertheless recurrence of deformity was inevitable—and the inevitable happened three months after removal of the plaster; the disc space collapsed again (Fig. 14).

Often wrongly diagnosed as a wedge fracture with severe deformity (Fig. 15). It is in fact a fracture-subluxation with perching of the facets and rupture of the interspinous ligament. This is an unstable type and should have been grafted. It was fully reduced and immobilised in plaster (Fig. 16). But deformity will recur however long this position is maintained because the interspinous ligament is ruptured. Two years later (Fig. 17) deformity has recurred.

to have prolapsed into the vertebral body and to have remained there after reduction. Lastly, damage to the intervertebral disc may be recognisable only many months later by thinning of the disc space or spontaneous anterior fusion. When the disc is damaged, redisplacement is inevitable, for the disc has no blood supply and it is incapable of repair. Some residual deformity must therefore be accepted and it is not only futile to immobilise damaged soft tissues in an extreme position for long periods in the hope of achieving what is, in fact, impossible, but it is actually harmful to do so. Occasionally, crushing of the disc into the body of the vertebra may cause retropulsion of the posterior part of the vertebral body into the spinal canal (Fig. 1).
Rupture of the interspinous ligament—This ligament may be overstretched, partly torn, or completely ruptured, with or without avulsion-fracture of the spinous process. The significance of these findings is exactly the same as in the case of injuries of the medial collateral ligament of the knee joint. Overstretching and incomplete rupture are compatible with sound healing and restoration of stability; but a completely ruptured ligament seldom heals unless it is sutured. In the case of the spine, it is easier to fuse the spinous processes than to suture the ligament. The degree of damage can be estimated by the amount of separation of the spinous processes in lateral radiographs. In the case illustrated in Figure 15 complete reduction was maintained for six months but nevertheless subluxation recurred within one month of removing the plaster, though not to the original extent.

ANALYSIS OF END-RESULT DISABILITY

1) Pain—In this series all the patients were miners and their capacity for work, involving considerable physical stresses and the adoption of cramped positions, was a searching test of function. The miners of Great Britain have special rehabilitation centres, situated in every coalfield, staffed by experienced orthopaedic surgeons and providing a high standard of medical and social service. Spinal injuries are thirty-five times more common in miners than in the rest of the community and as consulting surgeon to this service I have had the opportunity of observing the work of all my colleagues throughout the mining areas.

It has been a universal experience that even the most exacting and prolonged tests in a rehabilitation centre are not equivalent to the functional test of work at the coal-face. Many patients discharged from a rehabilitation centre in the highest grade of recovery fail to stand up to the demands of full work. The reason is always the same—pain returns under the particular conditions of stress and posture that are involved in actual work at the coal-face. Other factors such as mobility, muscle power and muscle endurance are important, but pain under stress is the crucial factor, and as an end-result symptom it calls for detailed analysis. It should perhaps be repeated that no cure was accepted as complete unless the patient had done full work for two years without disability—so that the conclusions may be accepted with some assurance.

<table>
<thead>
<tr>
<th>Type of fracture</th>
<th>Number of cases</th>
<th>Pain at site of fracture</th>
<th>Low back pain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior wedge fracture</td>
<td>58</td>
<td>28%</td>
<td>72%</td>
</tr>
<tr>
<td>Lateral wedge fracture</td>
<td>15</td>
<td>33%</td>
<td>7%</td>
</tr>
<tr>
<td>Fracture dislocation</td>
<td>7</td>
<td>43%</td>
<td>57%</td>
</tr>
<tr>
<td>Fractures of the neural arch</td>
<td>9</td>
<td>33%</td>
<td>67%</td>
</tr>
<tr>
<td>Total</td>
<td>89</td>
<td>40%</td>
<td>60%</td>
</tr>
</tbody>
</table>

Pain is of two types: 1) at the site of fracture; 2) in the low back, independent of the site of fracture. Pain at the site of fracture nearly always occurred in patients with lateral wedge fractures. Of patients who sustained such fractures and had residual pain the localisation was to the site of fracture in 93 per cent. (usually towards the side of wedging), whereas in patients with residual pain after anterior wedge fractures it was localised to the site of fracture in only 28 per cent.

In patients with residual pain after anterior wedge fractures, low back pain is the rule. It occurred independently of the site of fracture in 72 per cent. of these cases. The characteristic features were that it was eased by complete rest, brought on by prolonged sitting or standing, eased by moderate exercise, and brought on again by severe exercise or prolonged forward
stooping. These findings suggest a soft tissue pathology rather than a bone or joint pathology. They are, in fact, identical with those found in cases of low back pain resulting from sprains and contusions and it is probable that they are due to fibrosis and adhesions occurring in damaged muscles and ligaments immobilised in their shortened position. As evidence of this, it was much commoner in patients with anterior wedge fractures treated by hyper-extension plasters (80 per cent.) than in those treated by other methods (37 per cent.). Every surgeon who has operated on these cases in the early stages is familiar with the extensive haemorrhage that is to be found in the erector spinae muscles. This extends to the pelvic attachment, even in high lumbar fractures, because haemorrhage in muscle always tends to gravitate to the most dependent part. It is understandable that pain due to subsequent fibrosis should be felt so commonly at the lower attachment of the muscle.

2) Mobility—Reference must be made to loss of mobility as an end-result symptom if only because it has been overstressed in the past. Localised stiffness in the lumbo-dorsal spine causes no appreciable disability, and the test of making the patient bend forwards and put his hands flat on the floor, which is illustrated in many text-books as proof of spinal mobility, is quite fallacious. The radiographs reproduced in Figure 19 are of the patient shown in Figure 18; the greater part of the movement is obviously occurring at the hip joints. Because

of their occupational conditions most miners retain the long hamstring muscles characteristic of infancy and can perform this test even with a “poker” back. In short, localised fusion of damaged vertebrae, whether the cause be disease or trauma, is the best possible thing that could happen and it causes no significant limitation of movement. If there is gross restriction of movement it is usually due to muscle spasm resulting from pain, and abolition of the pain will restore mobility.

3) Power and endurance—Whereas mobility is unimportant, muscle power in the erector spinae group is very important. The miner depends on the strength and endurance of these muscles for his livelihood. These two properties of muscle—power and endurance—must not be confused: they are quite distinct; they have a different physiological basis; and they call for a different technique of treatment in rehabilitation (Nicoll 1948). Pain, however, may inhibit the full use of muscles and prevent their full redevelopment. These functions of muscle can be measured fairly accurately but in doing so it is important to know whether deficiency is due to actual loss of muscle power, or simply to painful inhibition restricting
full output. In the miner, these muscles have to be capable of working at a high level of efficiency for eight hours without respite under conditions that are particularly trying.

RELATIONSHIP BETWEEN DEFORMITY AND DISABILITY

We may now consider the hypothesis, on which present-day orthodox treatment is based, that a good anatomical result is indispensable to a good functional result. The hypothesis will be examined from two aspects: 1) records of individual cases; 2) statistical analysis of the whole series. It is hoped to show that there are no grounds whatever for the above assumption.

Early in 1940, a miner was admitted to hospital suffering from a supraspinatus cuff injury. In the ordinary course of examination it was impossible not to notice that he had a deformed back, and radiographs showed gross deformity (Fig. 20). This fracture-dislocation of the spine had been sustained thirty years previously; it had never been diagnosed or treated and it had united in the position of deformity; the miner has been completely free from symptoms and has worked at the coal-face ever since. This case not only proves that gross deformity is compatible with complete functional recovery, but that there may be no late complications.

![Fig. 20](image)
Thirty years ago this man was injured in a pit accident. Treatment was "three months in a feather bed." Every other day his back was rubbed with honey—an ancient remedy mentioned in the Edwin Smith papyrus. It proved so effective that within a year he was at the coal-face and has worked there ever since.

![Fig. 21](image)
Vertebral fracture resulting in spontaneous fusion in a position of deformity. The surgeon was mortified at this terrible result but the patient himself was quite pleased with it because he has no pain and no other symptoms and he has been working at the coal-face without interruption for the last five years.

Shortly after this patient was seen, another miner was admitted, suffering from the fracture-dislocation shown in Figure 21. He developed pneumonia soon after admission and his general condition was so serious that, for six weeks, any treatment by which to reduce the deformity was out of the question. At the end of that time reduction was impossible and the deformity shown in the radiograph had to be accepted as the final anatomical result. The spinous process was so prominent that he developed an adventitious bursa over it and could not lie on his back in comfort. This prevented him from carrying out certain exercises, and his treatment at the Rehabilitation Centre had to be interrupted in order to excise the bursa and the underlying bony prominence. He made a perfect functional recovery and has worked ever since as an underground ripper—very heavy work, equivalent in almost every way to work at the coal-face.
Fracture-dislocation of the spine with severe deformity and incomplete paraplegia. The vertebral body has split vertically and the spinal cord escaped complete section only by slipping between the fragments. Closure of the gap would have been dangerous and overzealous efforts at reduction might have ended in disaster.

Same case as shown in Fig. 22, three years later. Spontaneous fusion with marked deformity. The paraplegia recovered and the patient went on to achieve a perfect functional result. He is now working as an underground ripper.
The patient whose radiographs are illustrated in Figure 22 had incomplete paraplegia. There was so much comminution and displacement that complete reduction was impossible. Moreover, enthusiastic attempts at reduction might easily have inflicted further damage on the cord which obviously had escaped total section only by a miracle; it was lying between the two halves of the vertebral body. The patient was simply turned into the prone position and a plaster bed was made in which he was nursed for five months. The final anatomical result is shown in Figure 23. He recovered completely from the paraplegia and resumed full work as an underground ripper. He has no pain in the back and mobility is not restricted significantly.

Lastly, the case illustrated in Figure 24 shows a fracture-dislocation with locking of the facets. There was no damage to the cord. This patient was seen many years ago, before the locked-facet syndrome was well known or the method of dealing with it understood. Naturally, attempts at reduction failed. This man also made a perfect functional recovery and went back to full work at the coal-face. He continued to do this for four years without symptoms until a further accident necessitated arthrodesis of the ankle joint.

These examples, which could be multiplied, show that marked deformity is compatible with perfect function. In fact, there were twenty-four patients in the present series who achieved perfect function despite residual deformity. However, any attempt to refute a general hypothesis by quoting individual examples is unscientific. It is always possible that such examples may represent the exception rather than the rule, in which case all that has been proved is that the rule has exceptions. A more scientific method is to examine a series of consecutive and comparable cases. The results in fifty patients in whom recovery, as judged by the very high standard already noted, was classified as complete are analysed in Table IV.
From Table IV it is clear that the anatomical result is not a significant factor. This is also borne out when the group of anterior wedge fractures is analysed separately. Of eighty-eight patients in this group, fifty-four showed good anatomical results; of these, twenty (37 per cent.) gained perfect functional results. Thirty-four patients had residual deformity and, of these, thirteen (38 per cent.) gained perfect functional results. Table V is an analysis of end-results in relation to treatment, and here a significant factor may be noted.

**TABLE V**

**ANALYSIS OF TREATMENT IN RELATION TO END-RESULTS IN 152 PATIENTS WITH FRACTURES AND FRACTURE-DISLOCATIONS OF THE DORSO-LUMBAR SPINE (excluding seventeen patients who died or had irrecoverable paraplegia)**

<table>
<thead>
<tr>
<th>End-result (working capacity)</th>
<th>Fixation in plaster</th>
<th>”Functional” treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal-face</td>
<td>23 (27%)</td>
<td>27 (55%)</td>
</tr>
<tr>
<td>Light work underground</td>
<td>9 (10%)</td>
<td>13 (27%)</td>
</tr>
<tr>
<td>Light work on surface</td>
<td>54 (63%)</td>
<td>9 (18%)</td>
</tr>
<tr>
<td>Total</td>
<td>86 (100%)</td>
<td>49 (100%)</td>
</tr>
</tbody>
</table>

Of all patients with dorso-lumbar fractures treated in plaster, 27 per cent. were subsequently classified as having gained perfect functional results, whereas, of patients treated by what may be called "functional" methods, 55 per cent. achieved a similarly good end-result. However, analysis of this kind is not really scientific because it might so happen that cases selected for functional treatment had a type of fracture with an inherently better prognosis. The same analysis was therefore made in relation to individual types of fracture (Table VI).

**TABLE VI**

**ANALYSIS OF TREATMENT IN RELATION TO END-RESULTS IN 88 ANTERIOR WEDGE FRACTURES**

<table>
<thead>
<tr>
<th>End-result (working capacity)</th>
<th>Fixation in plaster</th>
<th>”Functional” treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal-face</td>
<td>10 (20%)</td>
<td>24 (63%)</td>
</tr>
<tr>
<td>Light work underground</td>
<td>5 (10%)</td>
<td>8 (21%)</td>
</tr>
<tr>
<td>Light work on surface</td>
<td>35 (70%)</td>
<td>6 (16%)</td>
</tr>
<tr>
<td>Total</td>
<td>50 (100%)</td>
<td>38 (100%)</td>
</tr>
</tbody>
</table>

It is seen that in the group of anterior wedge fractures 20 per cent. of patients treated in plaster were classified as having gained perfect results; whereas 63 per cent. of patients treated by "functional" methods gained perfect results. In the other groups, the number of
patients treated functionally was too small to justify conclusions, but there was some evidence in the case of fracture-dislocations that plaster applied in the physiological position gave better results than hyperextension plasters. Magnus (1931), working in the Ruhr Coalfield, came to similar conclusions. He found that in patients treated without fixation in plaster the average duration of incapacity was seventeen weeks and the disability compensation 45 per cent., this comparing with twenty-eight weeks and 64 per cent. respectively for patients treated in plaster.

It is submitted that these findings lead to four conclusions: 1) a good functional result is not dependent on a good anatomical result; 2) consolidation is rapid even in the absence of fixation; 3) the important factor in determining function is stability between the damaged segments and not the position in which it is achieved; 4) prolonged fixation of damaged soft tissues, especially in their shortened position, is in itself a cause of disability.

TREATMENT OF DORSO-LUMBAR FRACTURES

Stable and unstable fractures—When there is no special problem of spinal cord injury the best classification, for purposes of treatment, is into stable and unstable varieties. Stable fractures include anterior and lateral wedge fractures and all laminar fractures above the fourth lumbar level. Unstable fractures include all fracture-subluxations with rupture of the interspinous ligament, all fracture-dislocations, and all laminar fractures at the level of the fourth and fifth lumbar vertebrae. In the stable group there is no danger of the deformity increasing and thereby threatening the cord. They should, therefore, be treated “functionally” and not by immobilisation in plaster. In these patients the degree of deformity is never great, it causes no functional disability, and it can be disregarded from the cosmetic point of view. All such patients treated without plaster fixation were examined radiographically on admission, on discharge, and several years later, and in no instance was there significant increase in the deformity. It must be stressed again, however, that nearly all so-called “simple wedge fractures” in which there is severe wedging are, in fact, fracture-subluxations with rupture of the posterior interspinous ligament and are, therefore, unstable.

In the unstable group, deformity is likely to increase and it may even endanger the cord. The high incidence of paraplegia in fracture-dislocations (62 per cent. in the present series) suggests that the cord is always vulnerable in this type of injury. Unstable injuries should therefore be protected against increasing displacement until consolidation is well advanced.

“Functional” treatment of stable fractures—When functional treatment is adopted no attempt is made either to reduce or immobilise the fracture, but the patient is kept in bed for three or four weeks in order to rest the damaged soft tissues and relieve pain. During this period he carries out only extension exercises and receives heat and massage to the back every day to assist the absorption and dispersal of exudates in the muscles and fascial planes. After four weeks he gets up, starts a scheme of full exercises, and is transferred to a Rehabilitation Centre. At the end of eight weeks he has progressed to the highest exercise grade in the Centre and begins a period of hardening which aims at reproducing the stresses and postural difficulties of underground mining. At the end of twelve weeks he should be fit to start work, but often requires another two months on progressively heavy underground work before returning to the coal-face. Some patients beat even this timetable, whereas orthodoxy would demand that every fracture should be reduced and immobilised in hyper-extension for at least four months (Fig. 25).

Treatment of unstable fractures—In this series the best results in unstable fractures were gained by applying a “protective” plaster in the neutral or physiological position. The
associated disc or ligament injury makes some degree of residual deformity inevitable. The vertebral bodies are, therefore, allowed to approximate in the plaster so that anterior fusion can occur. In practice, spontaneous anterior fusion with deformity gives a better functional result than surgical fusion. Of ten fracture-dislocations treated on these lines, seven returned to full work at the coal-face; all had spontaneous anterior fusion with deformity and they represent the best results of any group in the present series. No patient whose fractured spine has been treated by surgical fusion has ever returned to coal-face work. The advantages of spontaneous anterior fusion are that it is both stronger and more localised. Posterior fusion is mechanically less sound because the graft is under tension instead of compression. Moreover, undamaged vertebrae are usually included in surgical fusion so that four instead of two become fixed.

The "double clothes-peg" graft described by Bosworth (1942) has removed some of the above objections, and it is now being used to supplement anterior fusion, care being taken not to extend the spine beyond the point at which anterior fusion would be prejudiced by distracting the bodies. It is believed that unless there is firm anterior support any posterior graft will eventually give way. A recent series of fifteen unstable fractures treated by the Bosworth graft is being followed-up and will be studied with the object of determining whether or not the long-term functional results are better than those gained by spontaneous anterior fusion.

**Treatment of dorso-lumbar fractures with paraplegia**—The primary surgical treatment of traumatic paraplegia is still a matter of controversy. In Great Britain a conservative attitude is generally adopted, whereas in the American continent open reduction and grafting is favoured by Rogers, Munro, Botterill, Cone and others. Even among those who favour early operation there is a difference of view regarding the indications. Some would explore almost every case while others, such as Penfield, would operate only on patients with incomplete paraplegia showing a spinal block. On the other hand, Naffziger shares the views of Jefferson, Guttmann, Böhler and others, that paraplegia which is clinically complete from the time of injury and remains so for forty-eight hours indicates that there is complete section of the cord or at least an irrecoverable lesion. Guttmann contends that in these circumstances, paraplegia having been accepted as a permanent disability, the spinal injury should be ignored and all efforts be concentrated on the prevention of pressure sores while stabilisation of the spine in the displaced position is achieved. Böhler points out that this occurs rapidly and that stability can be gained even sooner than would be the case if reduction and grafting had been carried out. However, the premise on which these views are based is not universally accepted and the surgeon who discounts all possibility of recovery within forty-eight hours of injury without the most incontrovertible proof accepts a heavy responsibility.

Many surgeons believe that recovery may occur even after lesions which remain complete for several days. This writer has seen several examples of late recovery in lesions at the cauda equina level, and at least one in which the cord itself was involved, and if this possibility is accepted the lumen of the neural canal should be restored and the spine stabilised in that position in accordance with the dictum of Rogers of Boston. It is generally agreed, however, that any form of plaster fixation, either by means of a plaster cast or plaster bed, is certain to lead to pressure sores so that the maintenance of the reduced position, whether obtained by manipulative methods or by open operation, is difficult. In the absence of plaster fixation, reduction can be maintained only by some form of graft or internal fixation which is self-stabilising, the patient thereafter being nursed on a Stryker frame. If the spinous processes and neural arches are intact, a self-locking letter-box graft can be used. This was adopted recently in two patients who were given no external support and were turned regularly for
Fracture-dislocation with paraplegia (inset) treated by self-locking letter-box graft of the spinous processes. No external fixation was used and the patient was turned regularly for nursing care. Ten months later reduction has been maintained and fusion has occurred. Recovery from the paraplegia, in this case, was complete.

![Fig. 26]

Traumatic spondylolisthesis (Fig. 27) treated by open reduction and grafting (Fig. 28). This is the only way of reducing such cases but it must be done early. Manipulative reduction should not be attempted because it is: a) impossible, b) dangerous.
nursing care; reduction was maintained until fusion occurred and pressure sores were avoided (Fig. 26). All such methods of self-locking graft depend, however, on the integrity of the posterior neural arches and facets. In three recent cases (one seen by the courtesy of Mr Gordon Irwin of Newcastle) there was such disruption of the neural arches that neither manipulative nor operative reduction could have succeeded in restoring the lumen of the spinal canal and decompression by laminectomy appeared to be justified, especially when there was evidence of spinal block. The primary treatment of traumatic paraplegia is obviously a subject about which there is still much to be learned, and in the present state of our knowledge any dogmatic recommendation is unjustified.

**Treatment of isolated fractures of the neural arch**—The treatment of fractured laminae depends upon the level of injury and the stage at which the case is first seen. Many of these fractures are overlooked because they demand a very high standard of radiography, especially in the lumbo-sacral region. It has already been stated that above the level of the fourth lumbar vertebra there is no danger of forward sliding beyond minimal limits so that these cases can safely be treated by functional methods. In the present series there were six such cases and four were classified as complete cures. If the lesion is at the fourth or fifth lumbar level, treatment depends upon whether or not there is spondylolisthesis. If not, union will probably occur with four months' immobilisation on a plaster bed; but if forward sliding has already begun, union is unlikely to occur because the conditions resemble those of a gap fracture. Open reduction and fusion is then the best treatment. The method of closed reduction advocated by Watson-Jones (1943) was tried twice but there was no improvement in the position and in one case a temporary foot-drop resulted.

In the present series, there were eight patients with fractures of the laminae at the low lumbar level and of these, six had already begun to slide when first seen. Progressive displacement was prevented in all of them by grafting but none was able to resume strenuous underground work because of low back pain under stress, though all were able to do lighter forms of underground or surface work. The best result was in one whose fracture of the laminae was not displaced but failed to unite after immobilisation in a plaster bed. Operation was then undertaken and fusion occurred in a good anatomical position. From the total of fourteen cases at all levels, there were only five perfect results and all these were good anatomical results. It does seem, therefore, that in this particular type of fracture a good anatomical result is essential. Recently, a case of traumatic spondylolisthesis with considerable immediate displacement was seen and operated on within a few days. It was possible to secure complete reduction and this has been maintained (Figs. 27 and 28). It is now considered that this is the only way of obtaining reduction in these cases; but it must be done early.

**Treatment of lateral wedge fractures**—Lateral wedge fractures present a difficult problem in treatment. Of the twenty-one examples in the present series two were complicated by permanent paraplegia and are, therefore, excluded from the results. Of the remaining nineteen, five were treated functionally with one perfect result. Twelve were treated by immobilisation in plaster, with three perfect results, all of which had residual deformity and one of which showed spontaneous fusion (Fig. 4). Two were treated by immediate surgical fusion; one gained a perfect anatomical result; but neither was able to return to coal-face work because of pain. This experience has been repeated in two other patients who have not yet been observed long enough to qualify for inclusion in the present series. Although the total number of cases is small, it seems justifiable to conclude that since these are stable fractures, since orthodox treatment in plaster does not correct the deformity, and since a good anatomical result secured by grafting does not lead to a perfect result, functional treatment should be the method of choice. Any conclusions based on such a small number of cases, however, must be regarded as tentative, and the final answer to this problem must await the result of further experience.
CONCLUSIONS

Certain types of dorso-lumbar fracture are stable and the deformity will not increase if there is reasonable protection in the early stages. In some of these (e.g., dorsal fractures and lateral wedge fractures) the deformity cannot be corrected in any case, whilst in others it will inevitably recur if it is corrected. The final anatomical result can be assessed accurately at the outset and, if this is within limits known from experience to be compatible with perfect function, there is no case for immobilising damaged soft tissues in an extreme position for many months—a procedure which in itself is likely to produce disability.

In unstable fractures, deformity may increase beyond functionally insignificant limits and may jeopardise the cord in so doing. More rigid protection is then necessary, but the aim should be to produce spontaneous anterior fusion in the best anatomical position compatible with that objective, and this is hindered rather than assisted by extreme hyperextension maintained for long periods. Sometimes it may be necessary to reinforce anterior by posterior fusion, but it is doubtful whether posterior fusion alone will ever stabilise a spine that lacks anterior support.

SUMMARY

1. A series of 166 fractures and fracture-dislocations of the dorso-lumbar spine has been reviewed.
2. A new method of classifying these injuries is suggested.
3. A type of fracture with lateral wedging, previously unidentified, which has certain distinctive clinical and anatomical features is described.
4. The factors responsible for redisplacement are discussed and it is considered that in most cases this is predictable from the outset.
5. At the present time orthodox treatment is based on the assumption that a perfect anatomical result is indispensable to a perfect functional result. Analysis of the results in the series now reported shows that there are no grounds for this assumption.
6. Treatment is discussed in the light of the foregoing conclusions. This is based on a division of cases into stable and unstable types, the recognition of which is of crucial importance.

REFERENCES

Guttman, L. (1948): Personal communication.
Schmieden (1931): Hefte zur Unfallheilkunde, 9, 4, 59.