4

Intervertebral Disc Calcification

4.1. Introduction

Although calcification of the nucleus pulposus is not a common pathological finding in intervertebral discs, it warrants discussion for a number of reasons.

4.2. Complications

First of all, it is one of the few causes of *acute excruciating spinal pain,* the most common being pathological fractures, acute inflammatory lesions, some tumours and the vascular catastrophe of dissecting aortic aneurysm.

Secondly, paraplegia of sudden onset may complicate prolapse of calcified nuclear material into the thoracic spinal canal. This cause of paraplegia may go unrecognized if the calcified nuclear material is dispersed into the spinal canal where it may be difficult to see on plain X-rays. An erroneous diagnosis, such as acute ascending polyneuritis or vascular accident to the cord may then be made.

Thirdly, while Kohler and Zimmer (1968) have stated that it is relatively common in adults, the belief is widespread that it is of little clinical significance. Indeed, Nachemson (1976) included intervertebral disc calcification in a list of radiological findings in the lumbar spine which, in his view, have no significance as causes of low back pain.

Surgeons in consultant practice should beware of generalizations about disease processes which may lead them to think that certain pathological changes cannot be related to a patient's symptoms.

While it is clear that nucleus pulposus calcification may be associated with localized spinal pain of moderate severity and that the pain usually responds to simple conservative methods of treatment, it is equally clear that this disc disorder may have serious consequences for individual patients and that surgical operations may be required in the course of treatment.

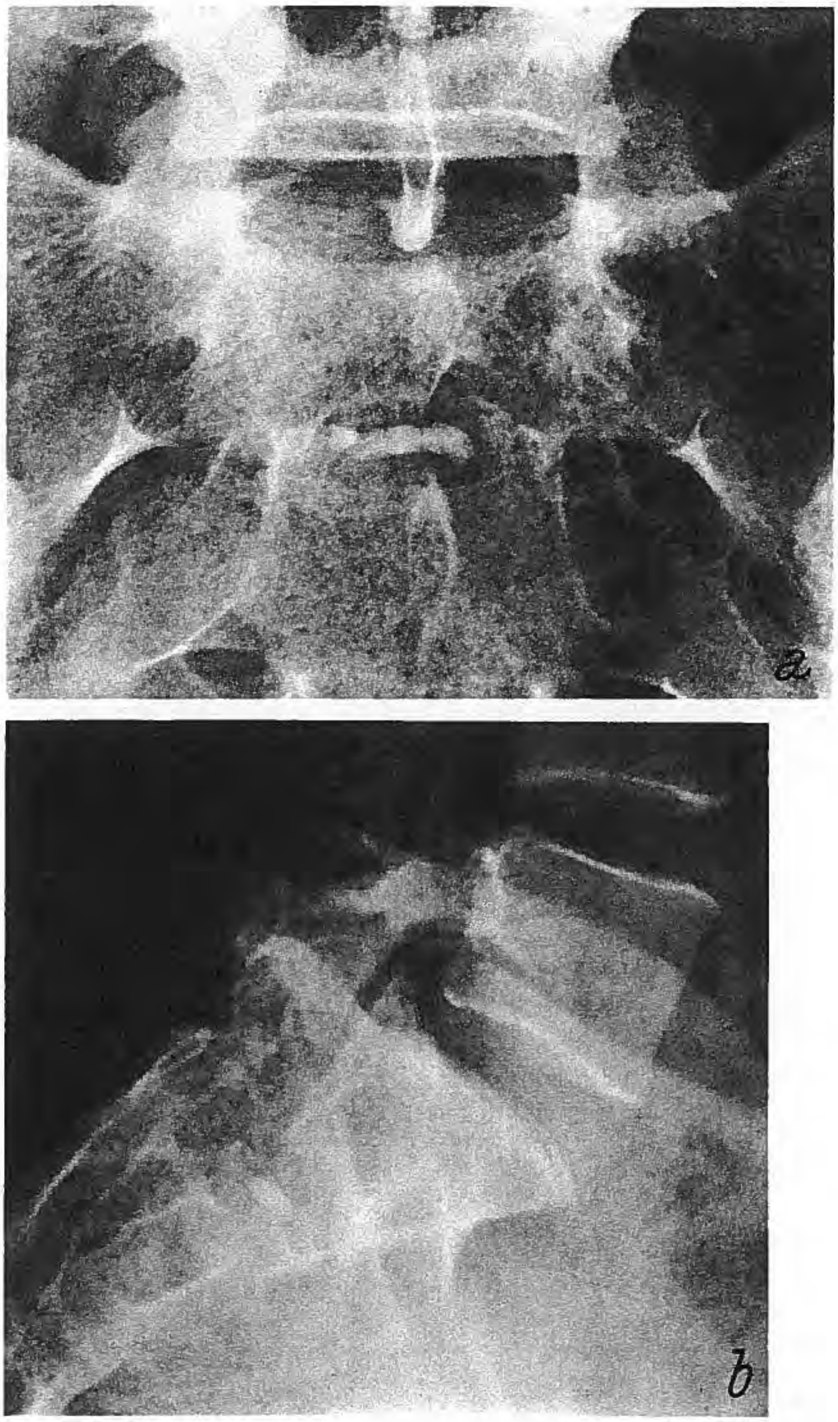
4.3. Patterns in Children

Clinical syndromes associated with nucleus pulposus calcification in children are well recognized, though rare. Bouts of acute painful wry neck or severe spinal pain of sudden onset, with fever, moderate elevation of the erythrocyte sedimentation rate and occasional increase in white cell counts, subside rapidly with rest. Typically, widespread calcification of variable density outlines the area of one or more of the

Figure 4.1. A lateral X-ray of the thoraco-lumbar spine in a child aged 11, showing nucleus pulposus calcification at multiple levels. Note the straight lumbar spine due to muscle spasm

Table 4.1

Age	Sex	Site
54	F	L3/4
46	M	T10/11
42	F	T11/12
46	F	L3/4
45	F	L5/S1
51	F	T9/10, T10/11
33	F	T12/L1
38	F	L1/2
57	F	L4/5, L5/S1
47	F	L1/2
56	M	L1/2
60	F	T8/9



Figures 4.2. Antero-posterior (**a**) and lateral views (**b**) of the sacrum in a female aged 36, showing nucleus pulposus calcification in a rudimentary sacral intervertebral disc

nuclei pulposi. This calcification usually disappears within a few weeks of its first recognition on the X-ray examination of the spine (Fig. 4.1).

The natural history of symptomatic paediatric intervertebral disc calcification has been defined recently by Sonnabend *et al.* (1982), following a review of 35 papers on the subject. Most of these cases occur in the cervical discs. Trauma seems to play a part, at least as a precipitating factor. In children, the disorder is usually asymptomatic in the thoracic spine.

In this review of 89 children with symptoms attributed to the lesion, the sex ratio boys:girls was 1.5:1, but in 19 children who were asymptomatic, it was 0.5:1.

Crock (1982) reported twelve cases of intervertebral disc calcification in adults, ten of whom required surgical treatment for the relief of severe intractable pain, not responsive to conservative measures of treatment. Only two of these patients were males.

The sites of disc calcification also differed markedly from that seen in children (Table 4.1).

In dogs with disc calcification, involvement of the sacral *intervertebral* discs occurs in about 4 or 5%. Apparently not previously reported in man, I have observed a female patient with the condition in the first sacral intervertebral disc, where it has caused troublesome sacral pain for a number of years (Figs. 4.2a, b).

4.4. Patterns in Adults

The radiological appearances of calcific deposits in this series of twelve cases were classified into four groups.

1. Small discrete irregularly opaque shadows within the nucleus pulposus lying nearer the posterior than the anterior boundary (Figs. 4.3a, b, 4.4).
2. Widespread calcification of variable density giving the nucleus pulposus a fluffy outline (Figs. 4.5, 4.6).
3. Small discretely outlined zones of calcification lying adjacent to one vertebral end-plate but peripherally located in the nucleus pulposus (Figs. 4.7a, b).
4. Discrete aggregates of densely calcified material confined to the area of the nucleus pulposus (Figs. 4.8a, b, 4.9, 4.10).

Computerised tomography may provide valuable information on the spatial distribution of calcified disc tissue with particular reference to its relation to the spinal canal and its neural contents (Fig. 4.11).

a) Clinical Features

Examples of type 1 nucleus pulposus calcification are illustrated in Figs. 4.3a, b, 4.4. These patients, one female (Figs. 4.3a, b) and the other male (Fig. 4.4), presented

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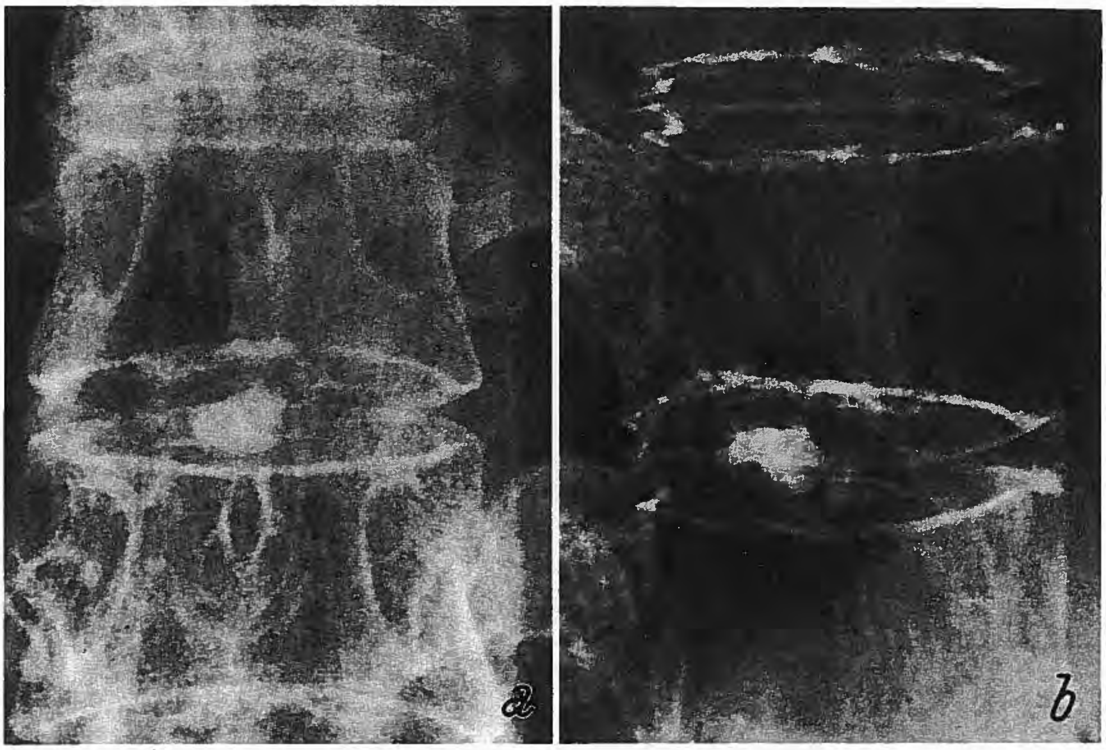
Figures 4.3 a and **b.** Antero-posterior and lateral X-rays of the mid-dorsal spine in a female patient aged 60 showing *type 1* nucleus pulposus calcification

Figure 4.4. Lateral X-ray of the thoraco-lumbar junction in a male aged 56 years showing *type 1* nucleus pulposus calcification. This X-ray appearance remained unchanged in eight years

Figure 4.5. Lateral X-ray of the thoracic spine showing *type 2* nucleus pulposus calcification at the T11/12 intervertebral disc space in a female patient aged 42

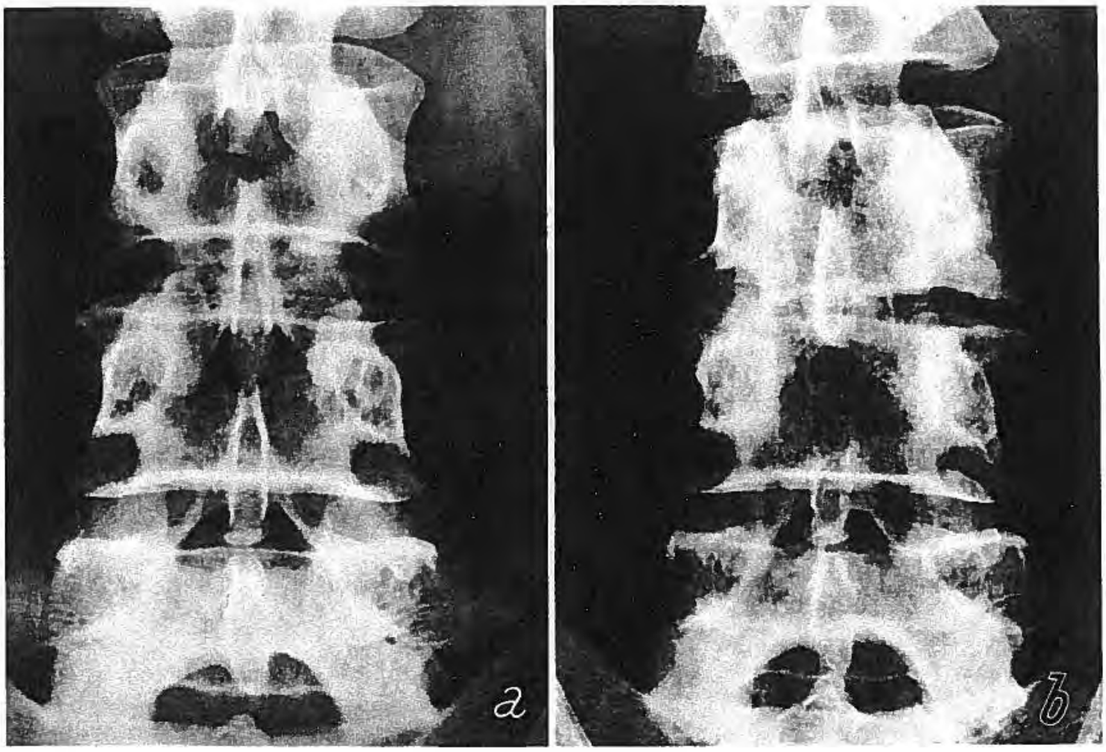


Figures 4.3

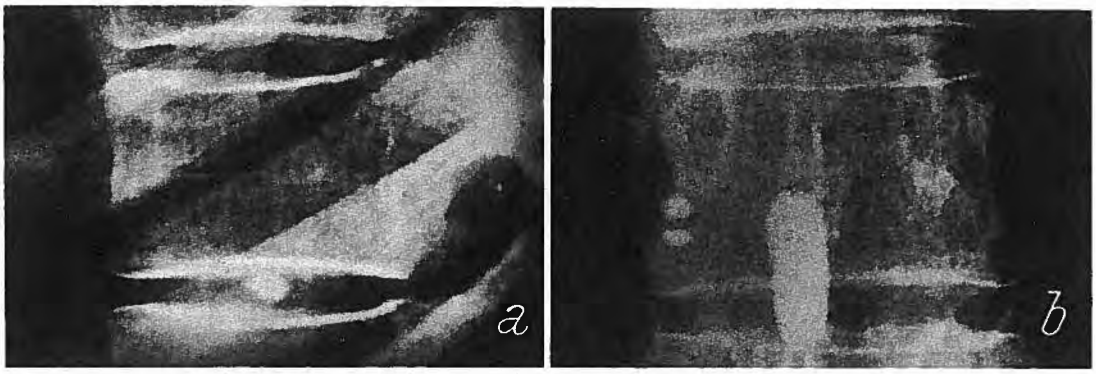
Figure 4.4

Figure 4.5

Figure 4.6



Figures 4.7



Figures 4.8 a and **b.** Lateral and antero-posterior radiographs of the thoracic spine in a female patient aged 47 years showing *type 4* nucleus pulposus calcification at the T8/9 intervertebral disc level. The middle lobe of the right lung was adherent to this disc in the paravertebral gutter, the remainder of the pleural cavity being free of adhesions

Figure 4.9

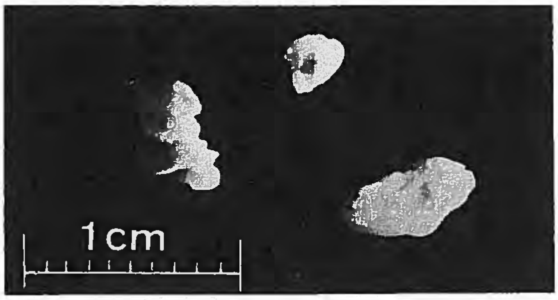


Figure 4.10

Figure 4.9. A lateral radiograph of the thoracic spine showing *type 4* nucleus pulposus calcification at the T10/11 intervertebral disc space in a male patient aged 46

Figure 4.10. A photograph of the calcium calculi removed at operation from the disc shown in Fig. 4.9

Figure 4.6. Lateral tomogram of the L4/5 and L5/S1 area of the spine in a female patient aged 45 years showing *type 2* nucleus pulposus calcification at L5/S1

Figures 4.7. a Antero-posterior view of the lumbar spine in a female patient aged 54 years showing *type 3* nucleus pulposus calcification at the L3/4 level on the right side of the photograph. **b** Antero-posterior photograph of the lumbar spine showing spontaneous interbody fusion at the L3/4 level six years after partial disc excision

Table 4.2. Protocols

	Case 1	Case 2	Case 3
Sex	Female	Male	Female
Age	54	46	42
Occupation	Home duties	Workman	Home duties and nurse
X-ray	L3/4	T10/11	T11/12
Type of lesion	3	4	2
Date of presentation	May, 1970	February, 1971	October, 1973
Date of operation	October, 1970	1976	September, 1974
Trauma	None	Heavy blow to trunk	Heavy lifting
Major symptoms	Excruciating lumbar back pain with referred leg pain	Lower thoracic pain, weakness of legs	Severe low thoracic spinal pain, radiating around lower ribs
Intra-disc hydro-cortisone injection	Not administered	Not administered	Not administered
Previous surgery	None	Lumbar spine fusion–8 years earlier for tuberculous disease, T11 to L1	Nil
Type of operation	Trans-lumbar canal partial disc excision	Interbody fusion	Interbody fusion
Result	Improved. Spontaneous interbody fusion observed in X-rays several years after operation	Improved	Improved

	Case 4	Case 5	Case 6
Sex	Female	Female	Female
Age	46	45	51
Occupation	Home duties and factory worker	Home duties	Home duties and telephonist
X-ray	L3/4	L5/S1	T9/10, T10/11
Type of lesion	3	2	3
Date of presentation	August, 1975	1976	1977
Date of operation	September, 1975	1976	1977
Trauma	Lifting	None	None
Major symptoms	Excruciating mid-lumbar pain, (R) hip flexed	Severe low back pain–marked lumbar spasm	Severe thoraco-lumbar junction pain
Intra-disc hydro-cortisone injection	No help	No help	No help
Previous surgery	None	Lumbar spinal fusion–20 years earlier L4/5 for degenerative disc disease	Multiple operations including lumbar fusion for lumbar spondylosis and degenerative spondylolisthesis at L4/5 level
Type of operation	Trans-lumbar canal partial disc excision	Interbody fusion	Extra pleural partial disc excisions
Result	Improved	Fair	Fair

	Case 7	Case 8	Case 9
Sex	Female	Female	Female
Age	33	38	57
Occupation	Home duties and nurse	Home duties and nurse	Home duties
X-ray	T12/L1	L1/2	L4/5, L5/S1
Type of lesion	3	3	2
Date of presentation	December, 1976	1973	1978
Date of operation	March, 1978	1978	March, 1979
Trauma	None	Heavy lifting	Back pain persisted following motor vehicle accident
Major Symptoms	Severe mid- to upper lumbar pain, occasional (L) thigh pain	Severe upper lumbar back pain	Severe lumbar back pain, buttock pain. Marked muscle spasm
Intra-disc hydro-cortisone injection	No help	No help	No help
Previous surgery	Cervical fusion	Intercostal neurectomy	Lumbar laminectomy
Type of operation	Extra-pleural interbody fusion	Extra-peritoneal disc excision	Extra-peritoneal partial disc excisions
Result	Fair	Improved	Improved

	Case 10	Case 11	Case 12
Sex	Female	Male	Female
Age	47	56	60
Occupation	Home duties and factory worker	School teacher	Home duties
X-ray	T8/9	L1/2	T8/9
Type of lesion	4	1	1
Date of presentation	July, 1979	February, 1972	1976
Date of operation	October, 1979	No operation	No operation
Trauma	Lifting and twisting	Digging	None
Major symptoms	Severe thoracic pain, aggravated by deep breathing, radiating around chest wall	Upper lumbar back pain	Mid-thoracic back pain
Intra-disc hydro-cortisone injection	Not administered	Not administered	Not administered
Previous surgery	Lumbar laminectomy	None	None
Type of operation	Trans-pleural disc excision	No operation	No operation
Result	Improved	Improved with brace and analgesics	Improved with brace and analgesics

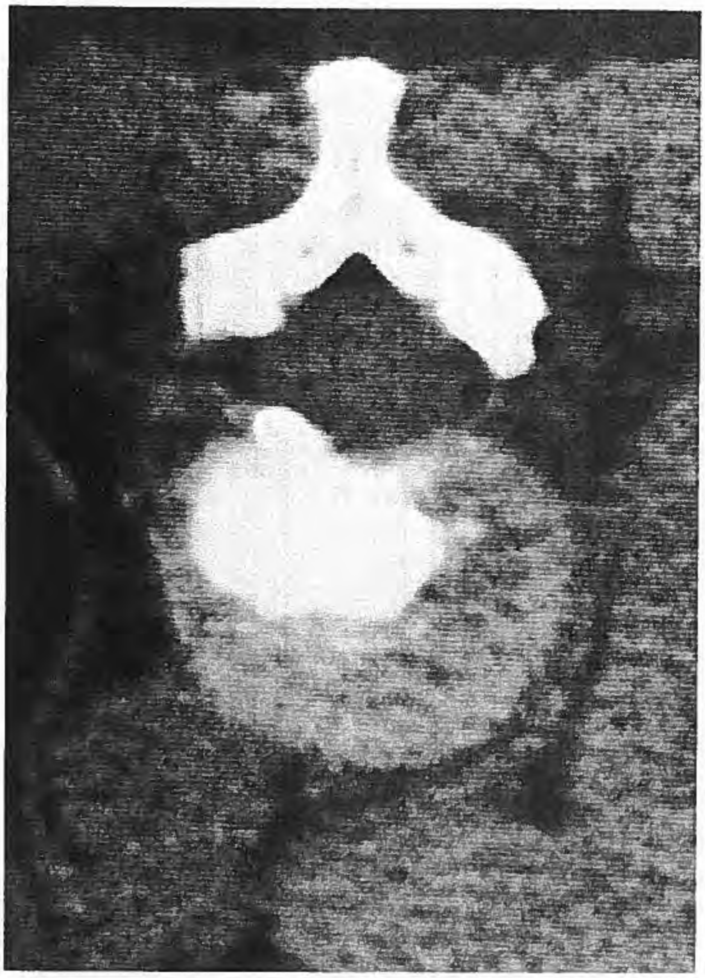


Figure 4.11. A computerised tomograph showing the pattern of calcification of disc tissues at the disc between the vertebrae T11/12, in a female, aged 49 years. The calcification (type 2) is shown extending postero-laterally into the spinal canal where it is related to the antero-lateral aspect of the spinal cord on the left side

with spinal pain of sudden onset, localized respectively to the mid-thoracic spine and to the upper lumbar zone. In both, symptoms were controlled promptly with simple measures including the use of spinal supports for some months. The radiological appearance of the calcification shown in Fig. 4.4 remained unchanged in X-rays taken at follow-up eight years later. There were no outstanding clinical features characterizing these cases.

By contrast, more serious problems were seen in the ten patients whose details are shown in Table 4.2. Eventually all were treated surgically.

In four of the patients in the surgical group, nucleus pulposus calcification was found in the mid- and low lumbar discs. These patients presented with severe low back pain and paraspinal muscle spasm. One had a unilateral psoas muscle spasm preventing hip extension. The severity of the pain was such that family members complained bitterly that conservative treatment was ineffective, and they insisted that their relative should be admitted to hospital.

Table 4.3. Patterns of nucleus pulposus calcification

	Female	Male
Type 1	1	1
Type 2	3	–
Type 3	5	–
Type 4	1	1

In the other six patients in the surgical group, nucleus pulposus calcifications were localized in the upper lumbar and lower thoracic discs. Again, *the pain of which they complained was intense in character,* localized in the upper lumbar and upper abdominal regions, and in the thoracic spine and radiating to one or both sides of the thoracic cage. Deep breathing, coughing and sneezing aggravated the pain. Paraspinal muscle spasm was also marked. One patient, the only male in the series, presented with low thoracic pain and weakness of his legs. There were no specific abnormal neurological findings in any of these patients.

b) Pathological Findings

There were two striking observations made at operation. One concerned the local inflammatory response apparently induced by the nucleus pulposus calcification in the region of affected discs. The other related to the appearance and texture of the calcified material removed.

Within the spinal canal, in the retro-peritoneal space and between the parietal and visceral pleura, adhesions were found related to the affected discs. The most remarkable evidence of this pathology was seen in the right hemi-thorax (case 10) where well-formed filmy adhesions had to be divided between the visceral pleura of the middle lobe of the lung in the paravertebral gutter and the antero-lateral surface of the disc between T8 and T9, immediately adjacent to the nucleus pulposus calcification (Figs. 4.8a, b) on the right side of the disc space.

The calcified material removed from the intervertebral discs at operation was either white in appearance, with the consistency of soft paste, or in the shape of irregular calculi, slightly yellowish in colour.

Histological examination was carried out on tissue removed in five cases. In each case degenerative fibro-cartilage was found associated with calcification. Chemical analysis confirmed the presence of calcium in the tissues. No abnormal cartilaginous proliferation was found in any case, nor was there any evidence of specific inflammation.

c) Surgical Treatment

The types of operation carried out in the ten patients reported by Crock (1982), are set out in Table 4.2.

Summary

While calcification of the nucleus pulposus is a rare disorder of thoracic and lumbar discs in adults, it seems reasonable to draw attention to a number of observations made in this series of ten patients who underwent surgical operations for this problem.

Nine out of ten of the patients were female and in eight out of the ten there was some history of trauma.

Six of the patients had had some form of spinal surgery performed prior to the onset of their nucleus pulposus calcification.

While the pathological changes induced within the disc itself include some features of non-specific inflammation, it is interesting to note the capacity of this lesion to induce non-specific inflammatory changes at the surface of an affected disc.

Observations of retro-peritoneal fibrosis, perineural fibrosis in the spinal canal and localized pleural reactions have been reported in this series.

The pain in certain cases of nucleus pulposus calcification is acute in onset, intense in character and frequently unrelieved by conservative measures. In particular, intra-disc injections of hydrocortisone appear to be ineffective, whereas in cases of acute supraspinatus tendonitis they often relieve patients of pain.

Analysis of the findings in the ten patients presented in this chapter suggests that acute nucleus pulposus calcification deserves more serious consideration in clinical practice than is normally accorded to it.

5

Spondylolisthesis

5.1. Planning of Treatment

Spondylolisthesis is a condition in which one vertebral body slips forward on the one below it. Associated with the forward displacement of the vertebral body there is either a laminal defect or degenerative arthritis of the inferior laminal facet joints.

The most common type of spondylolisthesis requiring surgical treatment is that seen with pseudarthroses in the lamina, so-called *spondylolytic spondylolisthesis.* Pseudarthroses occur in the pars interarticularis on each side. These take the form of asymmetrical false joints with false capsules and synovial linings in which osseous loose bodies may be found.

In *degenerative spondylolisthesis* the slip of the vertebral body is associated with degenerative arthritis of the inferior facet joints of the lamina; this condition is seen most commonly in women after the menopause.

Spondylolisthesis usually occurs at one level in the lumbar region, though rarely two or more adjacent levels may be involved (Fig. 5.1). Spondylolisthesis is one of the academic subjects that has appealed to orthopaedic surgeons for many years. It has been classified in various ways, five clinical groups being widely recognized: congenital, isthmic, degenerative, traumatic, and pathological.

In this chapter, conservative treatment will not be discussed, beyond pointing out that many patients with this condition who present for the first time with symptoms will respond to a variety of conservative measures.

Likewise, the academic aspects of this subject will not be dealt with in depth. Readers may refer to the published work of Newman, Wiltse, McNab, and Louis, listed in the short bibliography which is found at the end of this book.

a) History

Patients may develop a wide range of symptoms and signs, including: back pain, referred leg pain, a combination of back and leg pain, or in severe cases, evidence of lower cauda equina dysfunction with impairment of bladder function and impotence. In the extreme example of vertebral body slip, described as *spondyloptosis,* the pelvic

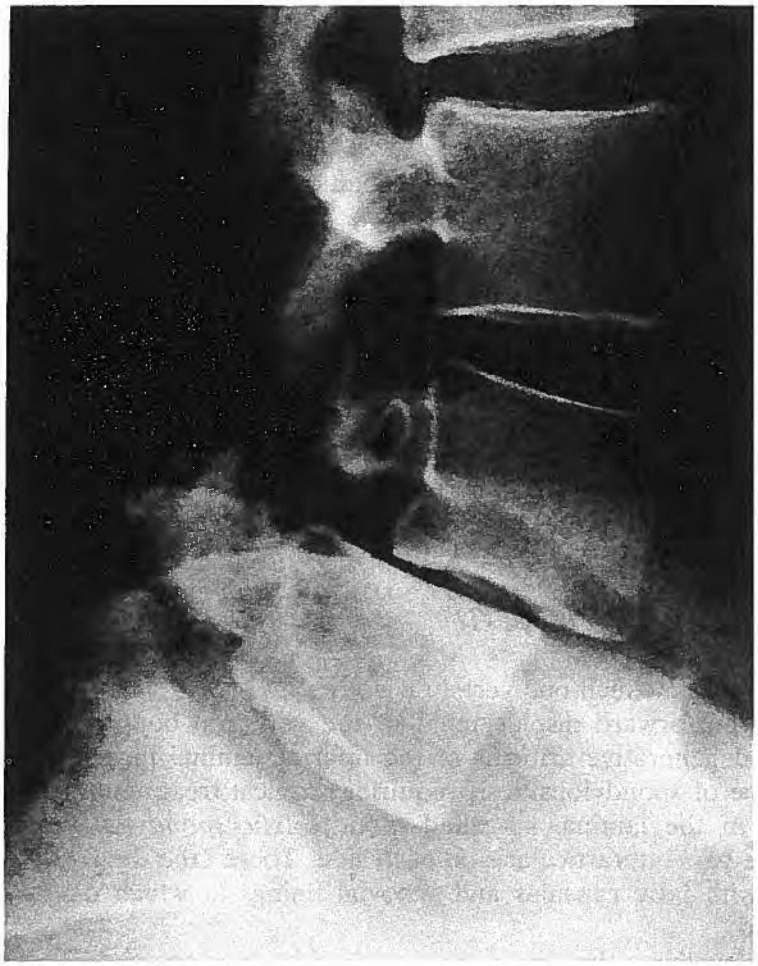


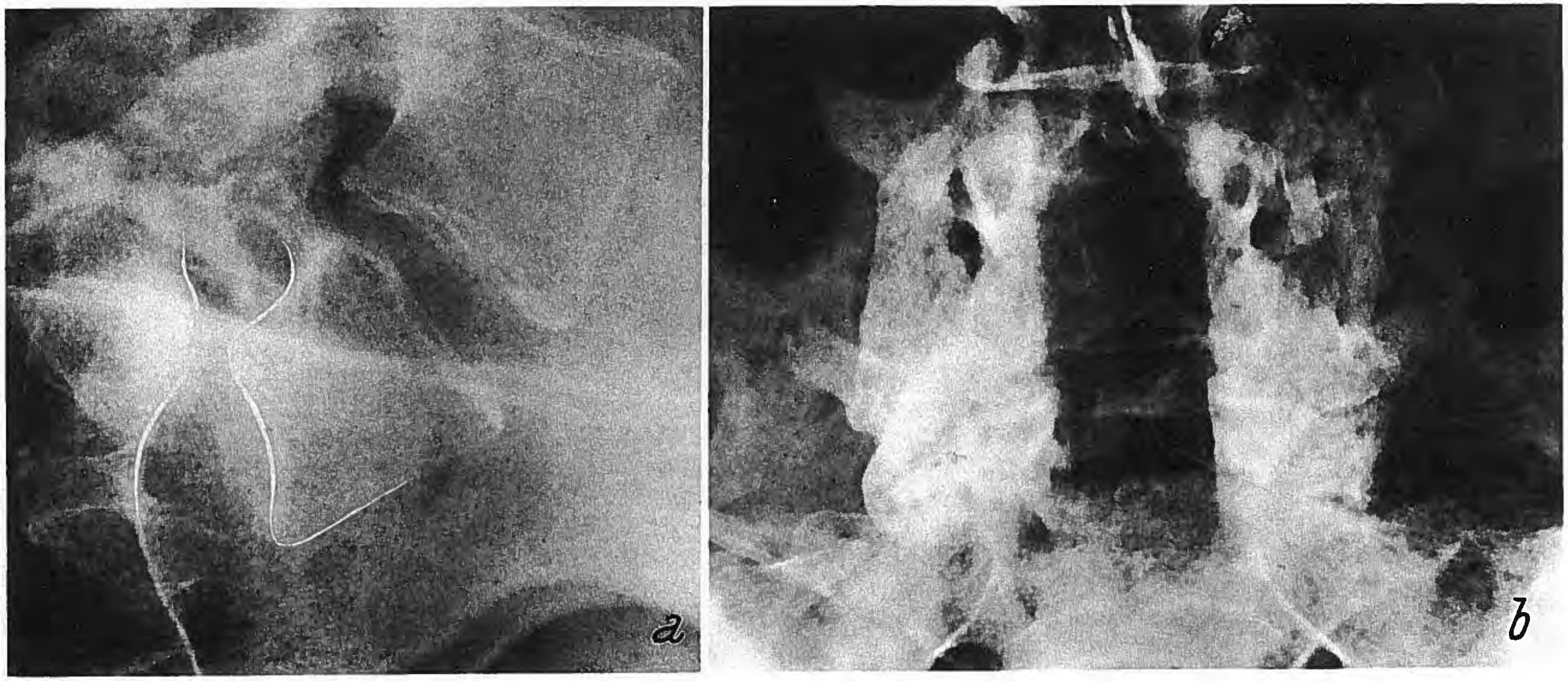
Figure 5.1. A lateral radiograph of the lumbar spine of a woman aged 45 years showing spondylolytic spondylolisthesis, Grade 1, at L5/S1 with a normal intervertebral disc, and Grade 2 at L4/5 with disc resorption at that level. *This patient only required conservative treatment* for low back pain

outlet may become obstructed during labour, rendering Caesarean section essential (Fig. 5.2).

In practice, no single operation will necessarily produce a cure in patients with spondylolisthesis. Hence it is necessary to make a careful analysis of each case, attempting to introduce some rationale to the planning of treatment.

In assessing individual patients with a view to selecting a particular type of operation for use in treatment, one must first take account of the outstanding features in the clinical history. Careful analysis of individual symptom patterns may indicate, for example, that decompression of the spinal canal alone may be the operation of choice. This will be the case where the patient's dominant symptoms are bilateral buttock and leg pain.

Where the symptom pattern combines the complaints of back and leg pain, then both decompression of the spinal canal and combined spinal fusion may be indicated. For the treatment of back pain alone, spinal fusion may be indicated.



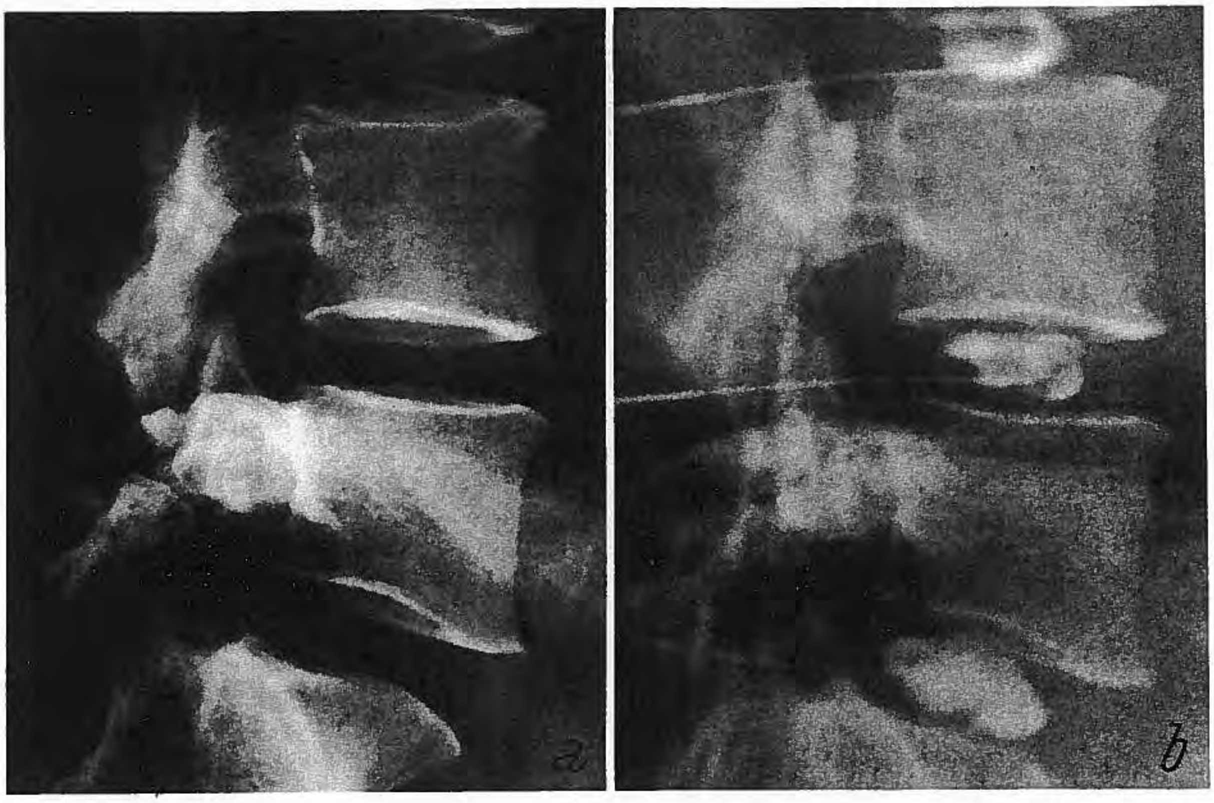
Figures 5.2. **a** A lateral radiograph of the lower lumbar spine showing spondyloptosis of L5, with the vertebral body slipped forward and rotated, lying anterior to the 2nd sacral vertebra. **b** An antero-posterior view showing multi-level intertransverse fusion with spinal canal decompression

b) Physical Parameters

Having considered the history, four physical parameters should be analyzed in each case before the definitive decision can be taken on the type of surgical procedure required.

i) Role of Laminal Pseudarthroses in Symptom Production

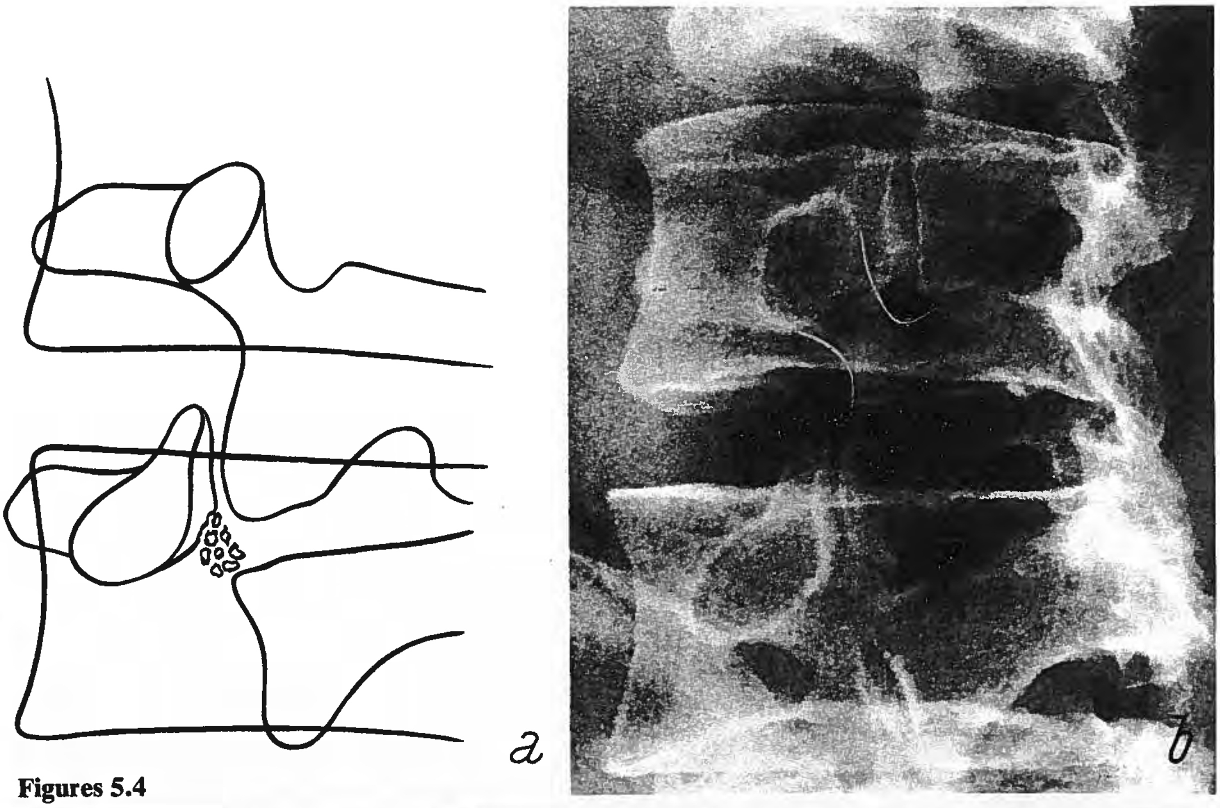
The first of these is the role of the laminal pseudarthroses in symptom production. The structure of the pseudarthroses varies considerably. Defects in the pars inter-



Figures 5.3. **a** A lateral radiograph of the lower lumbar spine showing a spondylolytic defect in the lamina of L5. **b** Normal discograms at L3/4, L4/5 and L5/S1 in this case

Figures 5.4. **a** A drawing to illustrate a spondylolytic defect in the lower of two laminae which are viewed obliquely. **b** An oblique radiograph of the lower lumbar spine showing a normal lamina with the pars interarticularis outlined in the middle of the photograph and the spondylolytic defect involving the lowest lamina shown on the film. Loose bodies in the pseudarthrosis are clearly visible

Figures 5.5 a–d. Photographs of loose laminae ("rattlers") removed at operations from patients with spondylolytic spondylolisthesis. The specimens have been photographed from above except for **b**, which is a lateral photograph. In **a**, note the complex nature of the pseudarthroses with the loose body on the right side of the photograph. In **b**, the large pseudarthrosis is visible in profile and the inferior facet of the lamina is visible on the bottom right of the photograph. The views of the specimens in **c** and **d** show the asymmetric nature of the pseudarthroses on either side of the lamina



Figures 5.4

Figures 5.5

articularis are usually bilateral, though rarely symmetrical. They are often associated with bulky false joints from which recognizable synovial tissue may be extracted and in which a number of loose bodies may be found. These pseudarthroses are immediate posterior relations of the emerging nerve roots at the intervertebral foramina on both sides. Their obtrusions into the intervertebral foramina and nerve root canals may be the sole cause of referred leg pain in patients with spondylolytic spondylolisthesis, or in rare cases of spondylolysis (Figs. 5.3a, b). In the usual case with bilateral laminal defects, the spinous process, lamina and the inferior articular processes remain as a single unit which is loose in the vertebral column. When the spinous process is grasped with an instrument during operation, this whole unit can be moved freely. It has been described as the "rattler". Removal of the "rattler" is said to relieve nerve root pressure. However, if only the "rattler" is removed, the proximal portions of the pseudarthroses which remain attached to the pars interarticularis on each side, leading up to the superior articular facets, remain in the spine. The related nerve roots cannot be seen throughout their courses unless these proximal segments of the pseudarthroses are also removed, thereby completing the nerve root decompressions. *Simple removal of the "rattler", therefore, is always inadequate* (Figs. 5.4a, b, 5.5a–d, 5.6).

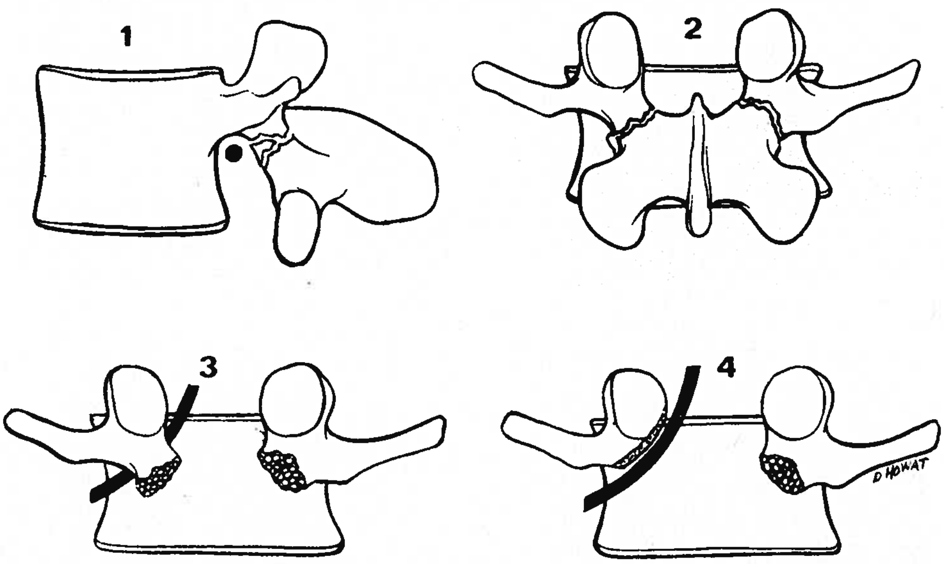
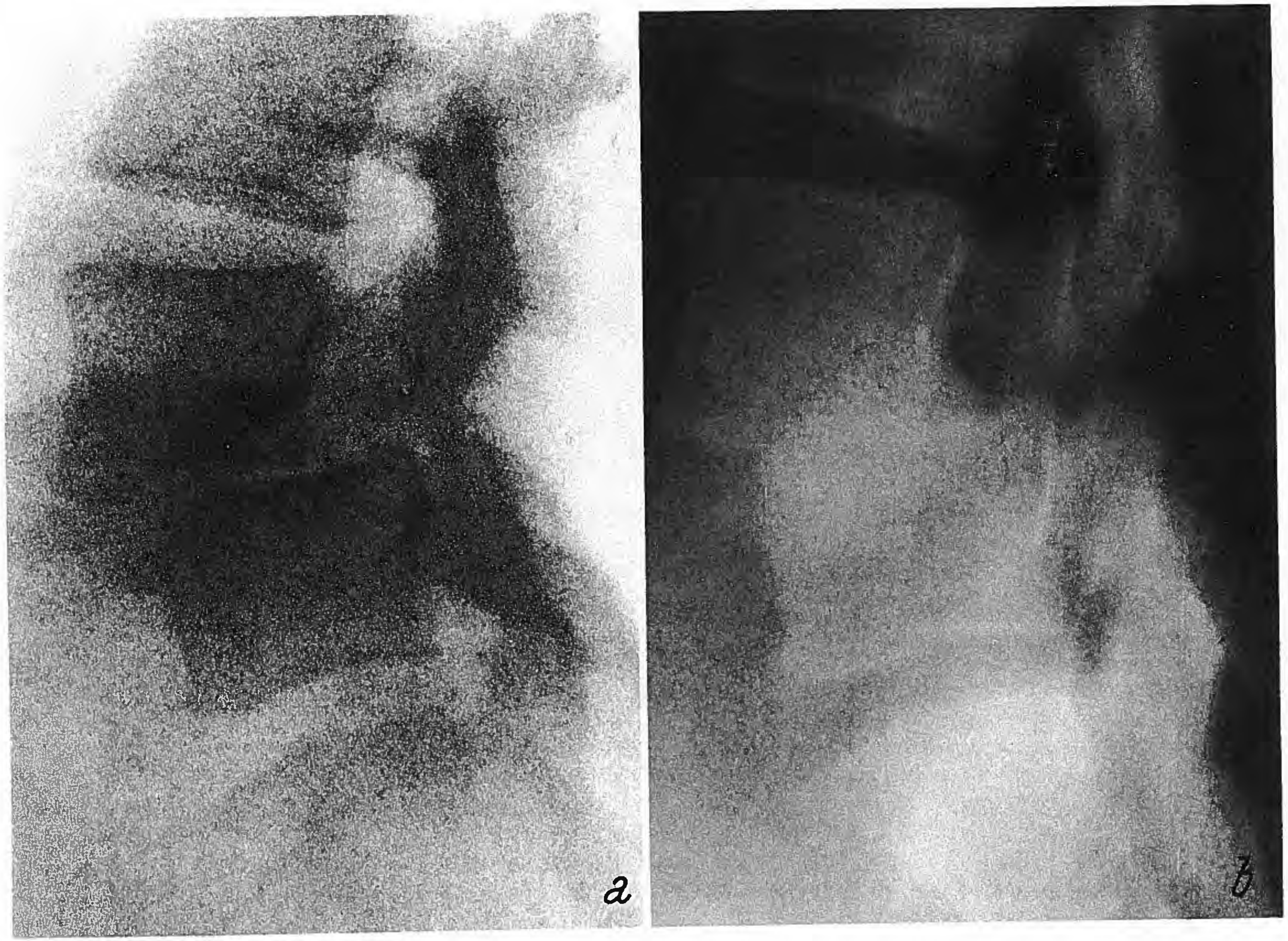


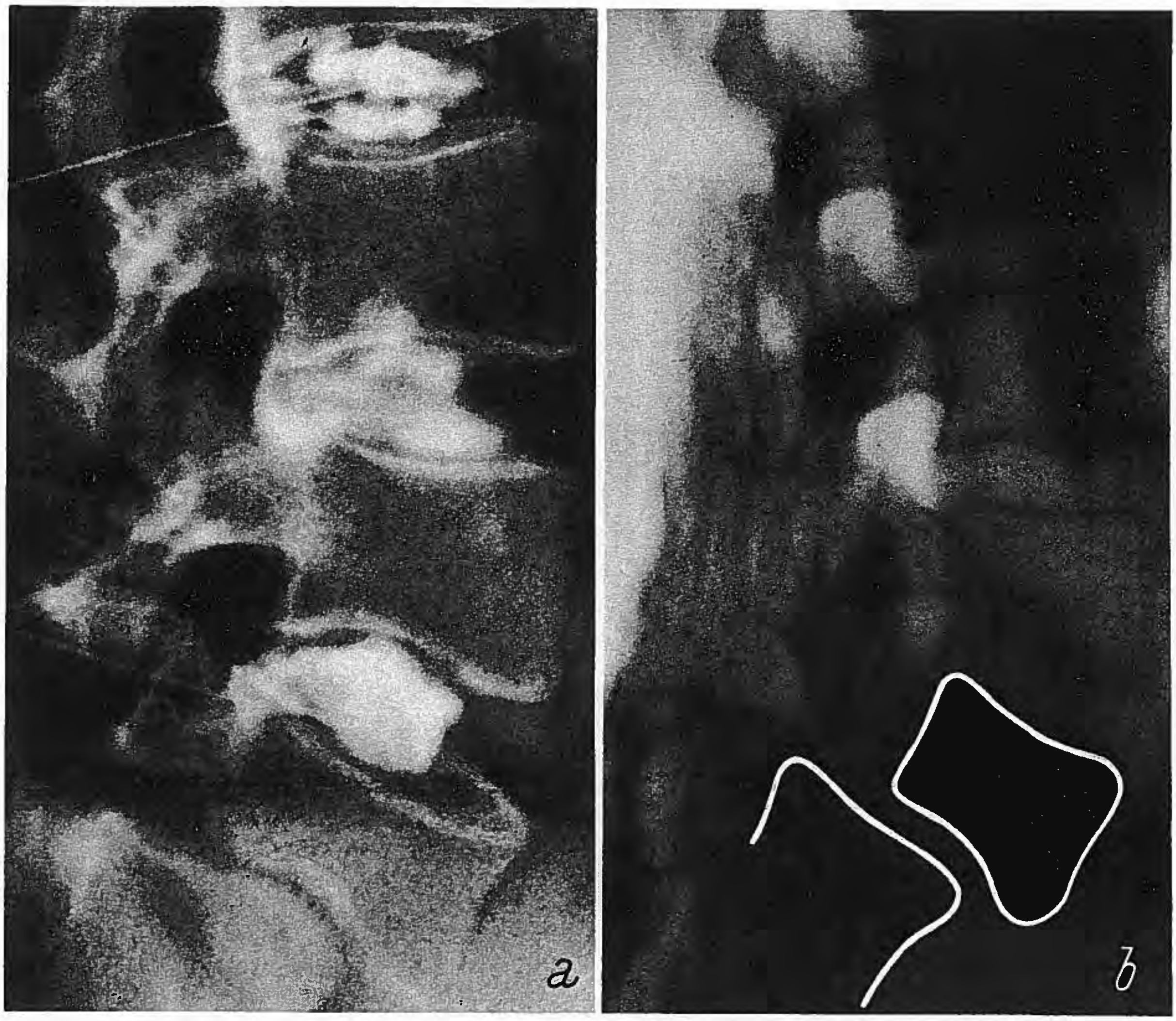
Figure 5.6. **1** and **2** show the relationship of the laminal pseudarthroses to the spinal nerves. The soft tissues such as ligamentum flavum, false capsule and synovium are not depicted. **3** and **4** show the nerve root relations after removal of the "rattler" of spondylolysis, and the correct method of decompression **(4)** of the root canal and intervertebral foramen on the left side of the drawing

ii) State of Discs Adjacent to Slip

The second parameter to be considered concerns the state of discs adjacent to the vertebral slip, both above and below it. *Discography* may be an essential special investigation where the symptom pattern is characterized by a mixture of back and leg pain. For example, in the case of spondylolisthesis at L4/5, if the discograms at L3/4 and L5/S1 are normal, then operative treatment should be restricted to the L4/5 segment alone (Figs. 5.7a, b). In other circumstances, the presence of



Figures 5.7. **a** A lateral radiograph of the lumbar spine in a 45 year-old man showing Grade 2 spondylolisthesis at L4/5. **b** Interbody grafts have been inserted transversely. The tomogram shows the appearance one year after operation



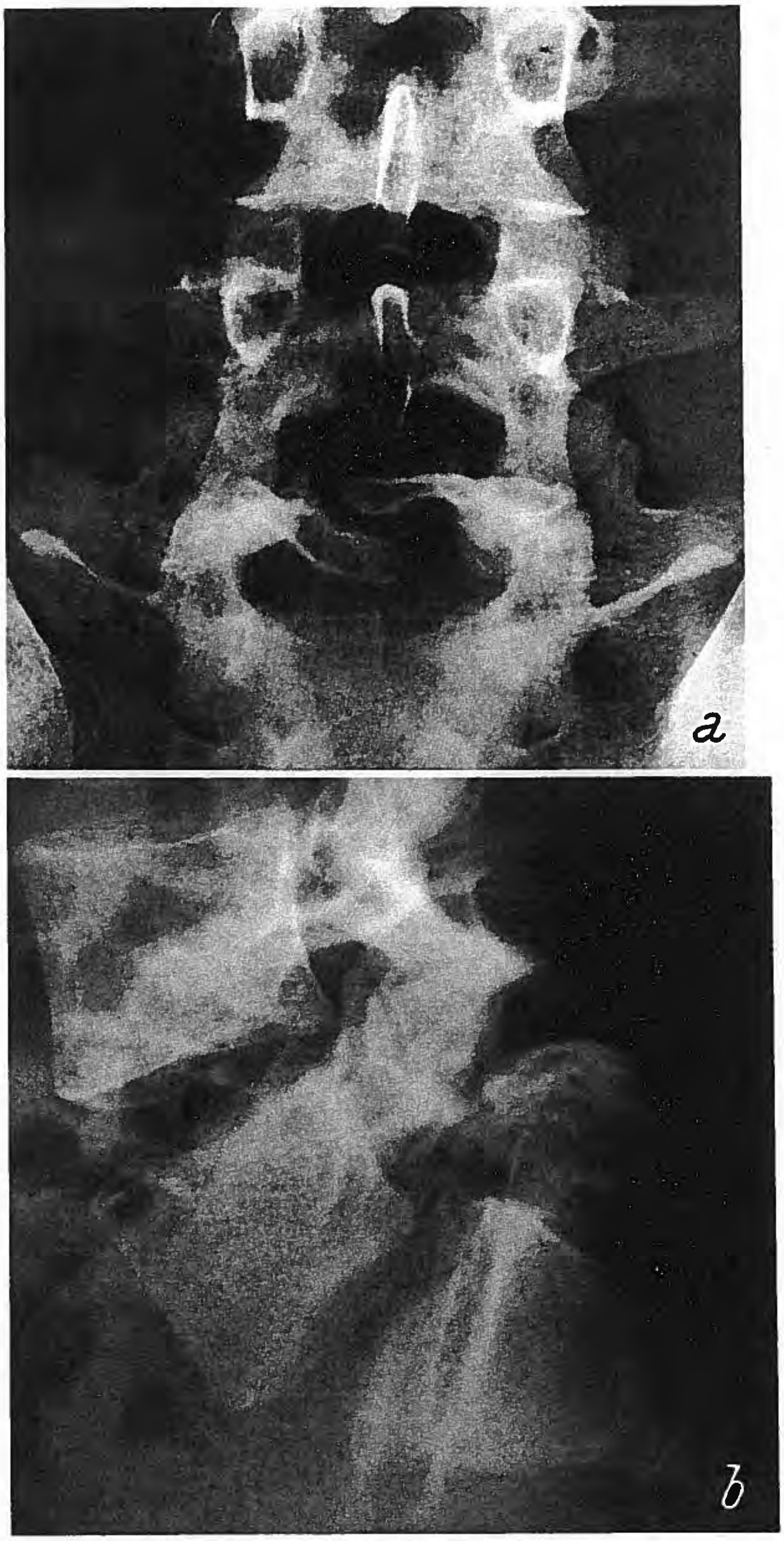
Figures 5.8. **a** A lateral radiograph of the lumbar spine of a man aged 45, showing Grade 2 spondylolisthesis at L5/S1, with discograms at L2/3, L3/4 and L4/5. Post-traumatic disc disruptions are shown at each level, causing severe back pain. The patient had fallen from a height of 25 feet (8 metres). **b** A lateral tomogram of the same patient's spine taken 9 months after an extensive multi-level posterior spinal fusion, which was planned after the discography shown in Fig. 5.8a

disruptive disc lesions demonstrated by discography above the level of the spondylolisthesis may help in planning the extent of a spinal fusion procedure (Figs. 5.8a, b).

Finally, in assessing the state of the discs in cases of spondylolisthesis where unilateral sciatica is a problem, *lumbar myelography* is essential to exclude the diagnosis of disc prolapse, either at the level of the vertebral slip, or at some adjacent disc space.

iii) Shape of Spinal Canal

The third parameter to be considered is the shape of the spinal canal. When a patient with spondylolisthesis is found to have laminal abnormalities, then again,

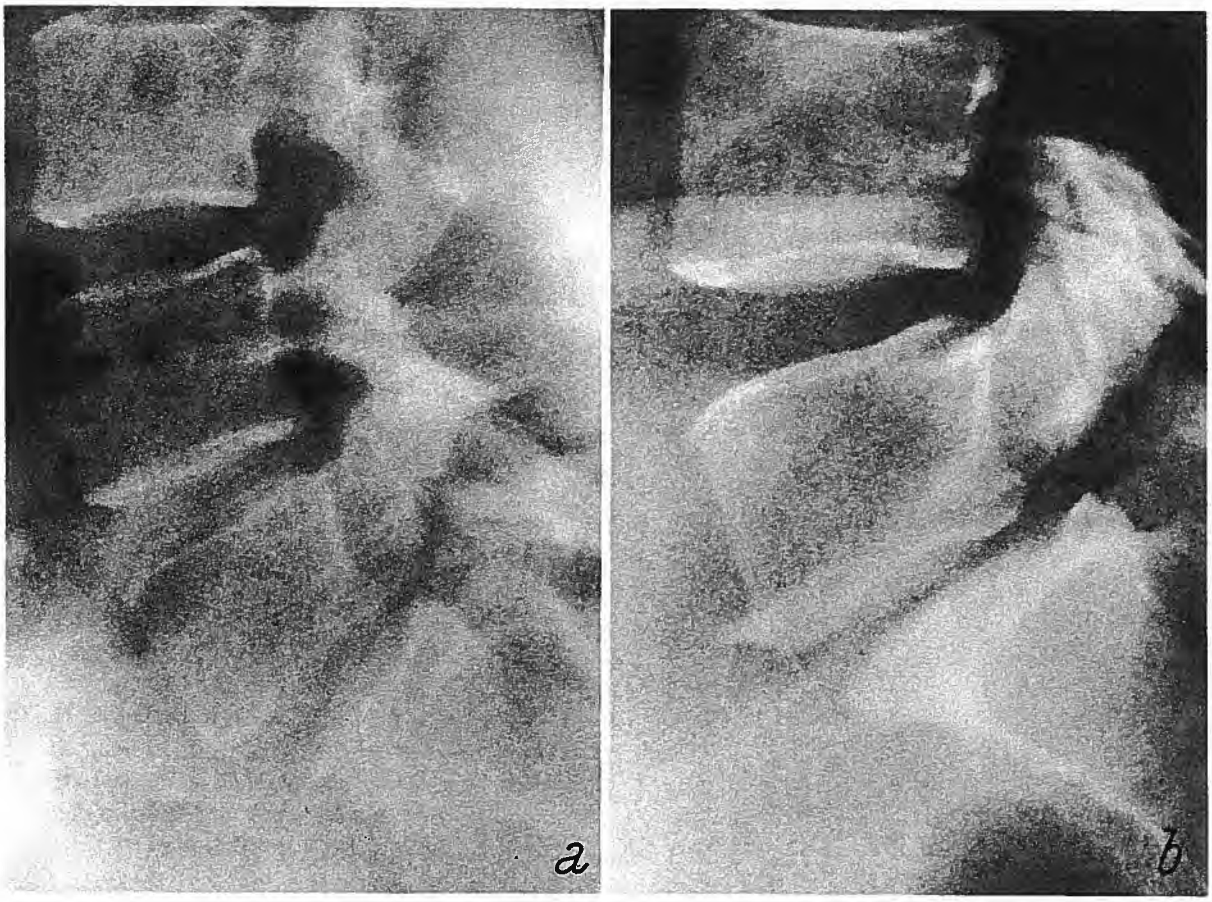


Figures 5.9 a and **b.** Antero-posterior and lateral radiographs of the lower lumbar spine in a 21 year-old male with Grade 1 spondylolisthesis. Spondylolytic defects are visible at L5/S1 but the lamina is grossly abnormal with spina bifida occulta. In such patients, if surgery is contemplated, myelography is essential

myelography is essential if the symptoms include referred leg pain (Figs. 5.9a, b). In such cases, associated spinal canal stenosis may be found. Spinal fusion alone may then be contraindicated, concomitant decompression of the spinal canal being necessary.

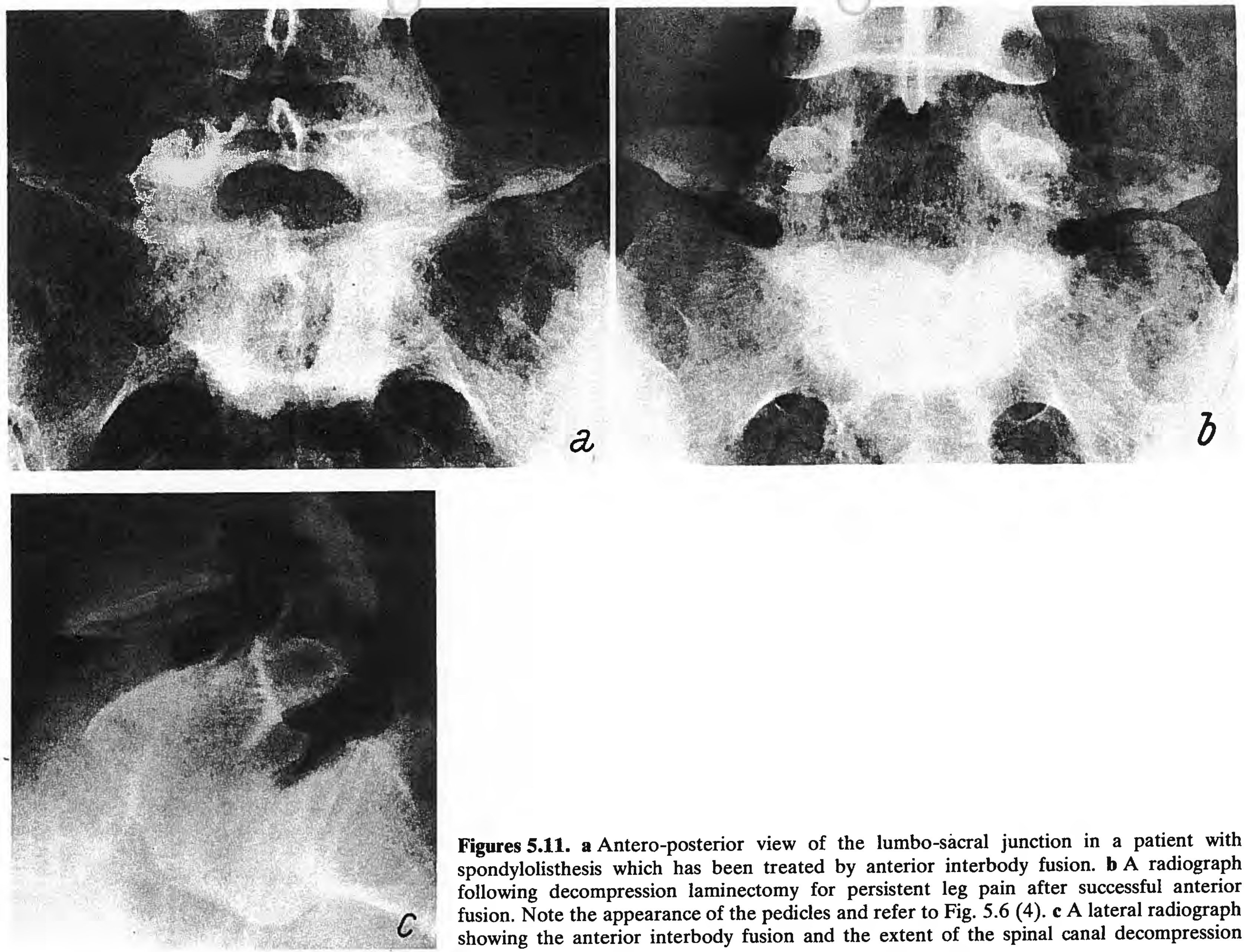
iv) Degree of Vertebral Slip

The fourth parameter for consideration is the degree of vertebral slip. Increase in the degree of slip usually occurs gradually over a number of years, often in association with progressive narrowing of the related intervertebral disc (Figs. 5.10a, b). In the



Figures 5.10a and **b.** Lateral radiographs of the lumbar spine in an adult showing in **(a)** spondylolytic spondylolisthesis Grade 1 at L5/S1 with a normal intervertebral disc. The same spine five years later **(b)** showing disc resorption and increase in slip to Grade 2

presence of grade one or grade two spondylolisthesis, anterior interbody fusion may be satisfactory. However, this method should be reserved for thin patients who have had neither previous abdominal surgery, nor antecedent history of venous thrombosis. For cases with higher grades of slip, in which spinal fusion is being considered, standard methods of posterior fusion or inter-transverse-alar fusion may be considered. Freebody (1971) has described a method for anterior lumbar interbody fusion applicable even in advanced grades of spondylolisthesis. This



Figures 5.11. **a** Antero-posterior view of the lumbo-sacral junction in a patient with spondylolisthesis which has been treated by anterior interbody fusion. **b** A radiograph following decompression laminectomy for persistent leg pain after successful anterior fusion. Note the appearance of the pedicles and refer to Fig. 5.6 (4). **c** A lateral radiograph showing the anterior interbody fusion and the extent of the spinal canal decompression

method calls for special training and even then its success rests on the surgeon having above-average skill.

In recent years, attempts have been made to reduce higher grades of slip, either by manipulation under anaesthesia or by the use of femoral traction. Once reduced, anterior interbody fusion may be used, supplemented by one of a variety of devices now available for fixation, such as the plate and screws designed by Professor Louis of Marseilles, France. These manoeuvres are mentioned for the sake of completing the record of surgical measures in current use. If they are to be used at all, then *the considerable attendant risk of these heroic efforts must be thoroughly appreciated,* with particular reference to cauda equina injuries.

By contrast Bohlman and Cook (1982) have reported success by combining spinal canal decompression and in-situ posterior interbody fusion, using fibular grafts in two cases of spondyloptosis.

In children, symptomatic spondylolisthesis may require surgical treatment and this should be undertaken early if there is any fear of increase in the degree of vertebral slip. Bilateral inter-transverse-alar fusion is usually effective.

The operation for the removal of the "rattler" and decompression of the nerve root canals recommended by Gill and White (1965) can be recommended for use in adults whose symptoms are predominantly those of referred leg pain, which is usually bilateral. Following the Gill and White operation, some increase in vertebral slip may occur in a few patients. However, if back pain persists as a major problem, then spinal fusion may be required. The choice of method, be it inter-transverse-alar or anterior interbody fusion, will depend on the particular skills and preferences of the surgeon, bearing in mind that either method applied to this particular problem requires special training.

While theoretically it may be desirable to perform spinal fusion and spinal canal and foraminal decompression operations simultaneously, this is not always possible. Furthermore, if the cases have been selected for surgical procedures according to the recommendations set out above, the results are usually good and the combined operations are then unnecessary.

There will be a few patients who may continue to complain of referred leg pain after successful spinal fusion and, conversely, a few who will complain of back pain after relief of their leg pain (following spinal canal and foraminal decompression). These patients will require relevant secondary operations (Figs. 5.11a–c).

The choice of treatment in patients with symptomatic degenerative spondylolisthesis follows the same general lines outlined above. However, in this condition, spinal fusion alone is usually the operation of choice.

5.2. Technique of Postero-Lateral Inter-Transverse-Alar Spinal Fusion

a) Indications

This operation has virtually replaced the older methods of posterior spinal fusion introduced by Hibbs and Albee earlier this century, along with many variants such as "H" grafts and screw fixation with facet grafts.

When the transverse processes are sturdy this method of spinal fusion can be recommended for the treatment of:

1. spondylolisthesis, especially in children;
2. lumbar spondylosis causing back pain;
3. failed anterior interbody fusions.

b) Preliminary Preparation

Blood loss is often considerable so that transfusion facilities with three or four litres of blood must be available.

The patient's spinal X-rays must be displayed in the operating room.

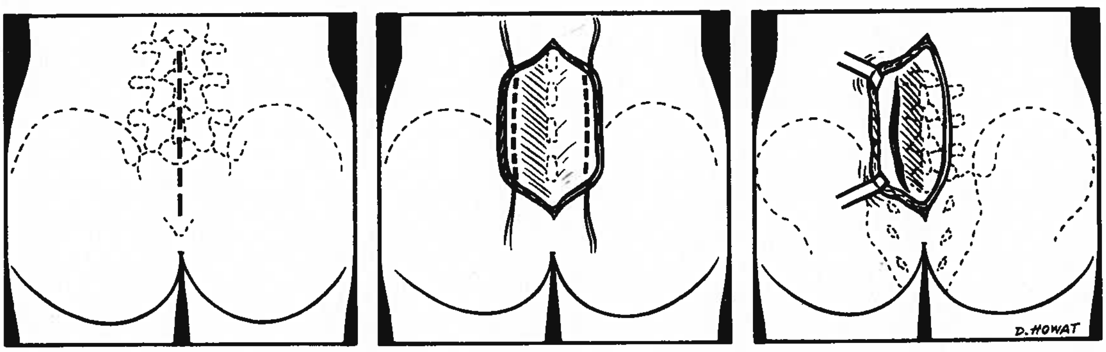
c) Positioning

Patients should be placed prone on a suitable frame to avoid compression of the abdominal cavity (see pp. 106–107).

d) Incisions

In children a long mid-line incision is recommended, extending from L2 to the lower sacrum.

In adults, the laterally placed, parallel vertical incisions advocated by Wiltse (1978) are recommended (Figs. 5.12a–c).



a b c

Figures 5.12a–c. Drawings to illustrate the mid-line skin incision and the laterally placed incisions in the lumbo-dorsal fascia for the paraspinal sacro-spinalis splitting approach recommended by Wiltse

e) Exposure of the Graft Bed

If the mid-line incision is used, the paraspinal muscles are separated as described on pp. 110–113. Their dissection is carried laterally beyond the facet joints until the posterior surfaces of the transverse processes and the alae of the sacrum on both sides can be palpated. The bulky paraspinal muscle mass is then retracted backwards and laterally to the level of the tips of the transverse processes. Blood loss is

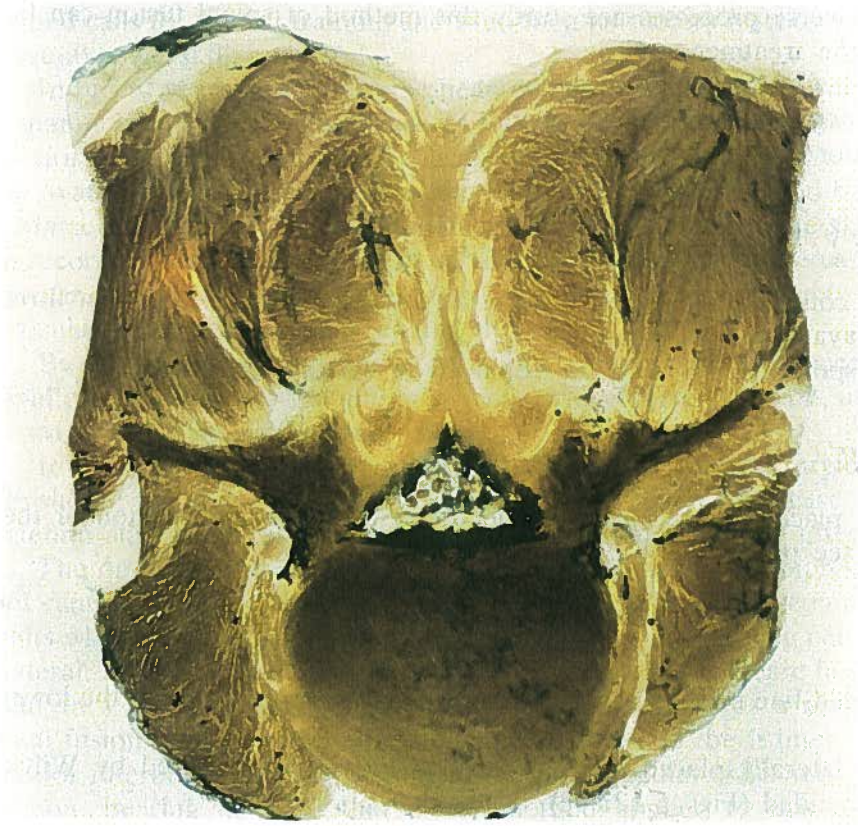
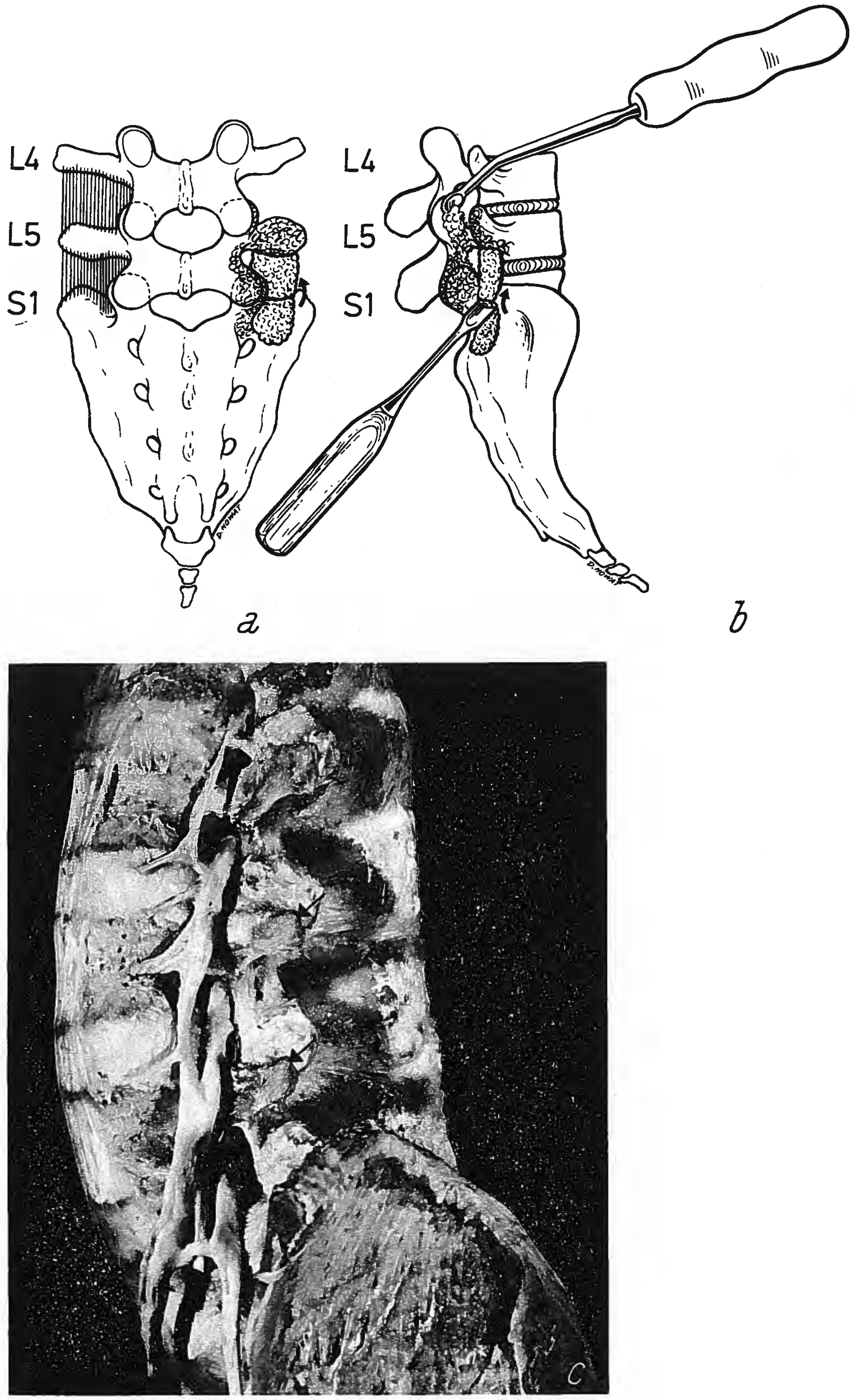


Figure 5.13. A photograph of a transverse section of a mid-lumbar vertebra, with the paraspinal muscles intact. The specimen has been cleared by the Spalteholz technique. Note the arrangements of the paraspinal muscles posteriorly, with a plane of cleavage clearly visible between the muscle bundles related to the posterior aspects of the transverse processes at their junctions with the superior articular facets. This is the plane of cleavage recommended for use in inter-transverse-alar fusions by Dr. L. Wiltse of Long Beach, California

considerable during this stage of the operation and it is often difficult to see the transverse processes of L5 in the depth of the wound unless the paraspinal muscles have been separated from as high as the lamina of L2.

Using the lateral paraspinal muscle splitting incision of Wiltse (1978), less extensive longitudinal dissection of these muscles is required to gain good exposure of the bony structures to be "fused". Modified Gelpi retractors inserted between the separated muscle fibres aid in obtaining a clear view (Fig. 5.13).

Figures 5.14. **a** A drawing of the lower lumbar spine seen from behind to show the intertransverse ligaments between L4, L5 and S1. On the right side note the preparation of the graft bed for an inter-transverse-alar fusion. The arrow indicates an upturned segment of bone cut from the ala of the sacrum and turned up towards the transverse process of L5. **b** A drawing to depict the preparation of the graft bed for an inter-transverse-alar fusion. Note the use of a curette to roughen the surface of the outer aspect of the superior facet of L5, leaving intact the capsule of the joint at that level. A chisel is shown turning up the flap of cortico-cancellous bone from the ala of the sacrum towards the transverse process of L5. **c** A photograph of a dissection of the lumbar spine viewed from the side, to show the siting of intertransverse grafts in relation to the spine as a whole (see arrows)



Figures 5.14

Preparation of the bed for the graft requires meticulous attention to detail. The intertransverse ligaments and muscles should be preserved. *For fusions at L5/S1 level* the capsules of the lumbo-sacral facet joints should be excised allowing access to the joint surfaces for excision of their articular cartilages and sub-chondral bone plates. The facet joint capsules between the superior facets of L5 and the inferior facets of L4 should be preserved intact. All remnants of soft tissues must be removed from the sacral alae, from the inferior facets of L5, from the lateral aspects of the partes interarticulares on both sides cephalad to the outer aspects of the superior facets of L5, from the outer aspects of the pedicles of L5 and the posterior surfaces of the transverse processes of L5.

The exposed surfaces of the transverse processes of L5 should then be decorticated carefully, using a gouge and hammer or Leksell type rongeur. Then, with a stout curved curette the cortical bone on the outer sides of the L5 pedicles and superior facets of L5 should be broached to expose bleeding cancellous bone. The lateral aspect of the pars interarticularis of L5 lamina on both sides should also be roughened (Figs. 5.14a–c).

Cortico-cancellous flaps cut from the postero-superior surface of the alae of the sacrum on both sides should be turned upwards to lie on the intertransverse ligaments, adjacent to the transverse processes of L5.

f) Preparation of Graft Bone

Autogenous grafts should be cut from the postero-lateral aspect of the iliac crest, access to this being obtained usually by undercutting the tissues between the lumbo-dorsal fascia and the iliac crest on one side.

Thin strips of cortico-cancellous bone, with other slivers of cancellous bone can be obtained usually in sufficient bulk from one side of the pelvis.

g) Placement of the Grafts

Thin strips of cancellous graft should be packed into the facet joints of L5/S1–then other strips should be placed *accurately* along the length of the spine extending from the upper edges of the decorticated transverse processes, but below the level of the intertransverse ligaments, at the space immediately above the level to be "fused".

Cortico-cancellous strips–with the cortical surfaces directed outwards to lie facing the paraspinal muscles–should be packed in carefully at the conclusion of this stage of the operation (Figs. 5.15, 5.16).

After placing the graft chips with equal care on both sides of the spine, the wounds should be closed with suction drainage. Where multi-level fusions have been performed, some surgeons have used screw fixation of the facet joints to aid in stability until fusion has occurred (Fig. 5.17).

Figure 5.15. A drawing depicting the inter-transverse-alar graft mass on the left side

Figure 5.16. An antero-posterior tomogram showing satisfactory intertransverse grafts at L4/5 in a patient with sacralization of the last lumbar vertebra. (Mr. Chris Haw's case)

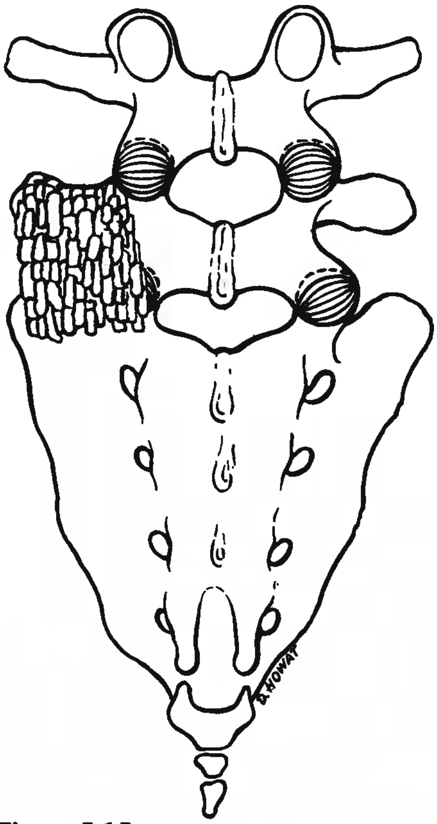


Figure 5.15

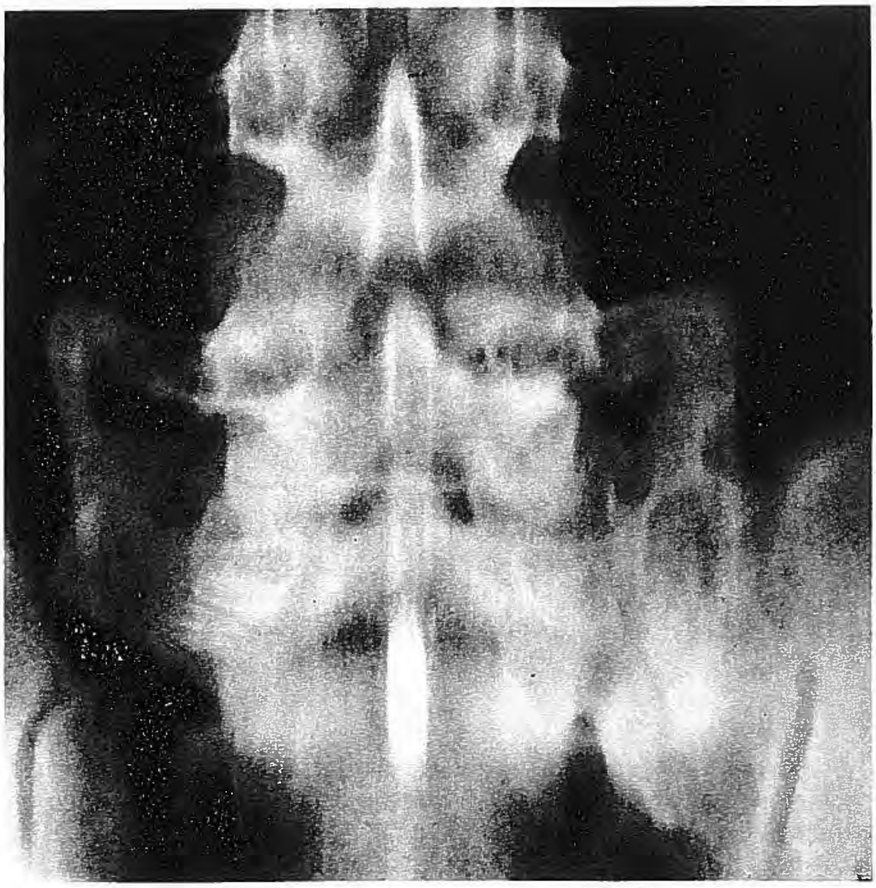


Figure 5.16

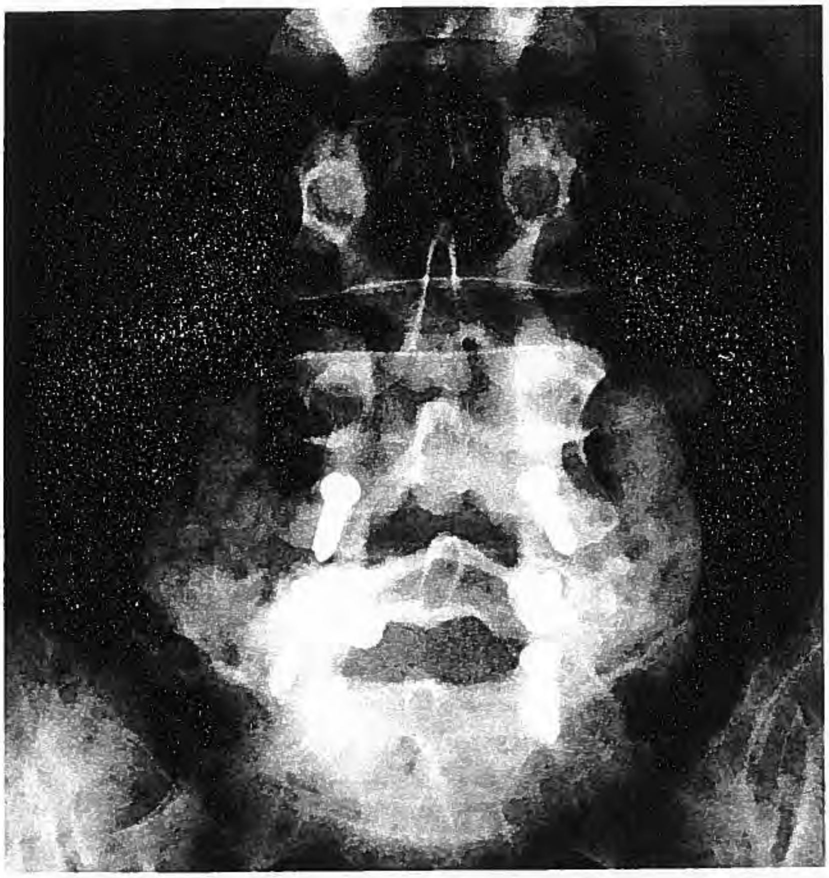
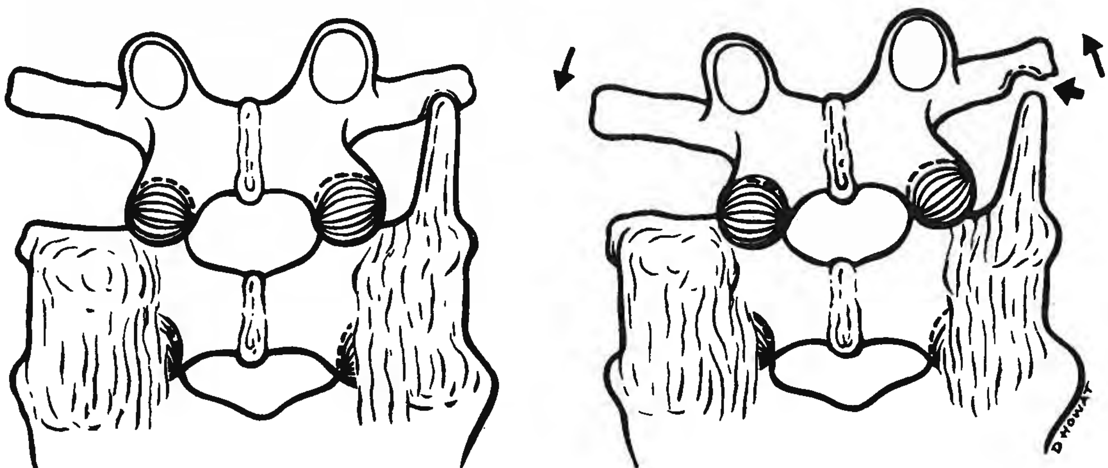
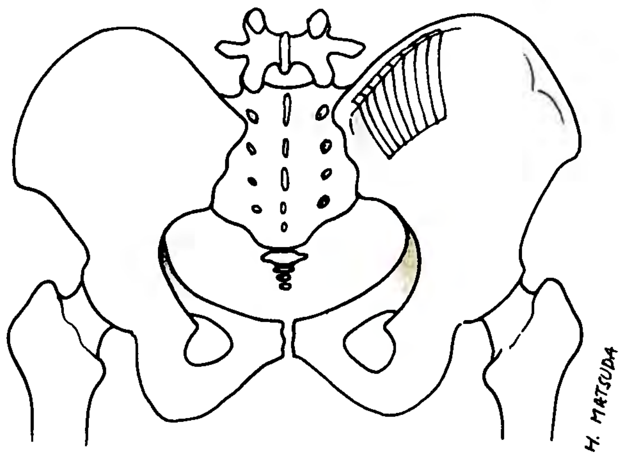


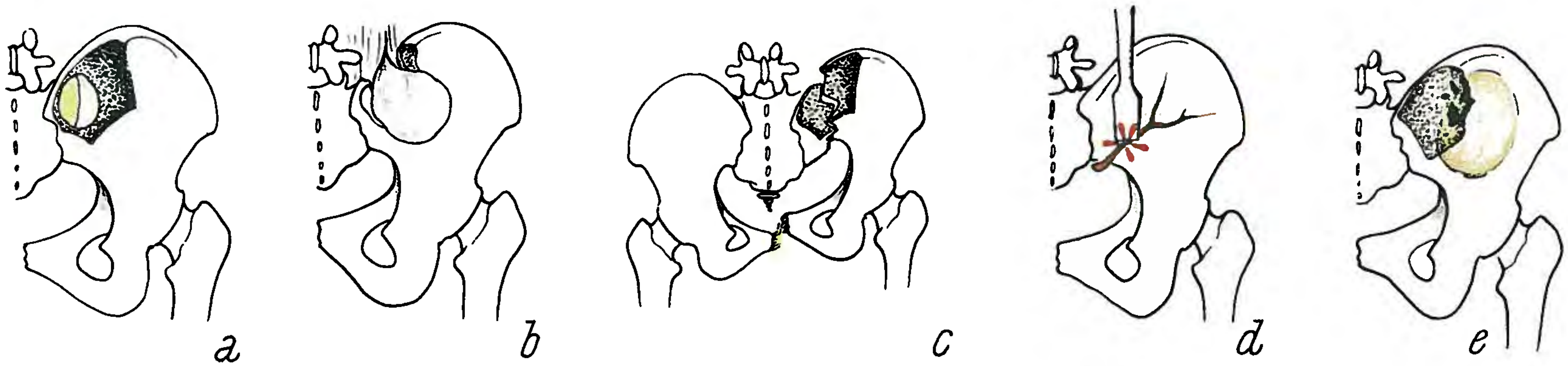
Figure 5.17. An antero-posterior radiograph of the lower lumbar spine showing a multi-level inter-transverse-alar fusion with supplementary screw fixation of the facets in the fused area. (Mr. John Cloke's case)



a b

Figures 5.18 a and **b.** A drawing showing inter-transverse-alar grafts with an "unwanted segment" of graft extending up on the right side producing a pseudarthrosis between the tip of the grafted bone and the transverse process, visible when the patient flexes to the side. This is a cause of local chronic back pain easily relieved by excision of the "unwanted segment" of graft





Figures 5.19 a–e. Drawings depicting the potential hazards at the donor site after removing cortico-cancellous grafts from the posterior third of the iliac crest. **a** Shows penetration of the sacro-iliac joint. **b** Lumbar hernia. **c** Dislocation of the sacro-iliac joint and symphysis pubis. **d** Potential for haemorrhage from the superior gluteal artery. **e** Gross local sepsis

h) Post-Operative Care

Retention of urine is common and it should be managed as recommended on p. 82. The use of catheters is best avoided.

Following multi-level spinal fusions, wearing of surgical corsets or braces is recommended. Patients are encouraged to get out of bed early and to walk short distances within a few days of their operation.

i) Complications

Unless this operation is performed with the attention to detail outlined above, failure rates from non-union will be high. In cases of failure, when examining X-rays taken months after operation, it is often difficult to identify any grafted bone on one or other side of the spine. Conversely, in some cases, segments of "unwanted graft" may impinge on adjacent mobile segments of the posterior elements of the spine–often far removed from the site of the primary pathology, causing chronic back pain (Figs. 5.18a, b).

If grafted bone breaches the intertransverse muscles and ligaments, it may hypertrophy, producing nerve root irritation and foraminal stenosis. This problem has been recognized by Kirkaldy-Willis (1980) in C.T. Scans of the lumbar spine taken after inter-transverse-alar fusion operations.

j) Infections

See pp. 240, 241.

k) Graft Site Problems

Wiltse (1978) has warned of the risk of damaging cuneal nerves as they cross the posterior iliac crest, leading to chronic pain at the donor site.

Major complications may occur during or after the removal of large quantities of bone from the region of the posterior ilium. Attention should be focussed on the potential problems of severe haemorrhage during graft removal, sacro-iliac joint injury, lumbar hernia formation, pelvic dislocation and deep-seated infection of the pelvic bones (Figs. 5.19a–e).

5.3. Spinal Canal and Nerve Root Canal Decompression With Foraminal Enlargement

After the initial exposure of the affected area of the spine (pp. 110–113), the interspinous ligaments should be excised from the superior and inferior aspects of the spinous process of the "rattler"–that hyper-mobile segment of the roof of the spinal canal found in spondylolysis and spondylolytic spondylolisthesis which consists of the spinous process, the inferior articular facets and the lamina, split across its pars interarticularis on both sides and carrying the two distal surfaces of the pseud-arthroses. The false joint capsules of these pseudarthroses, along with any loose bodies from within them, should then be removed with straight pituitary rongeurs. If the pseudarthroses have complex bulky opposing bony surfaces, it will not be possible to remove the "rattler" intact after excising the ligamentum flavum from both its superior margin and anterior surface. In such cases, the lamina is best divided along one side of the spinous process with a forward-angled rongeur. The spinous process is then grasped with a large bone nibbler and with the dura under constant vision, one half of the "rattler" may be rotated carefully and twisted slowly until it separates from the deep soft tissues which bind it to the proximal portion of the pseudarthrosis. The opposite segment of the "rattler" is then removed in like manner. This done, assuming that it is the L5 lamina which has been removed, the L5 nerve roots on both sides remain obstructed by the proximal portions of the laminal pseudarthroses and their soft tissue coverings. Removal of all these tissues on both sides is necessary to leave the pedicles of L5 clearly defined, the L5 nerve roots decompressed and the joints between the superior facets of L5 and the inferior facets of L4 essentially intact (Figs. 5.6, 3, 4).

5.4. Direct Repair of the Bony Defects in Spondylolysis and Spondylolisthesis

While the Gill and White procedure just described has been shown to give good long-term relief of leg pains in adults, there is a place for the conservation of the "rattler" in young patients in whom spinal fusion may be deemed unnecessary. Direct bone grafting of the laminal pseudarthroses, with internal fixation using screws, has been described by Buck (1979).

6

The Surgical Management of Spinal Canal Stenosis

6.1. Lumbar Canal Stenosis

The causes of spinal stenosis may be classified as follows:

1. Congenital Causes
   a) Achondroplasia and other forms of dwarfism.
   b) Congenital small spinal canal, with short vertebral pedicles.
   c) Hemi-vertebrae with lumbar scoliosis.
   d) Congenital cysts arising from the dura or arachnoid, in an otherwise normal spinal canal.

2. Acquired Causes
   a) Degenerative spondylosis, including degenerative spondylolisthesis.
   b) Vertebral fractures, post-traumatic or pathological.
   c) Spinal infections.
   d) Paget's disease.
   e) Following some spinal operations.

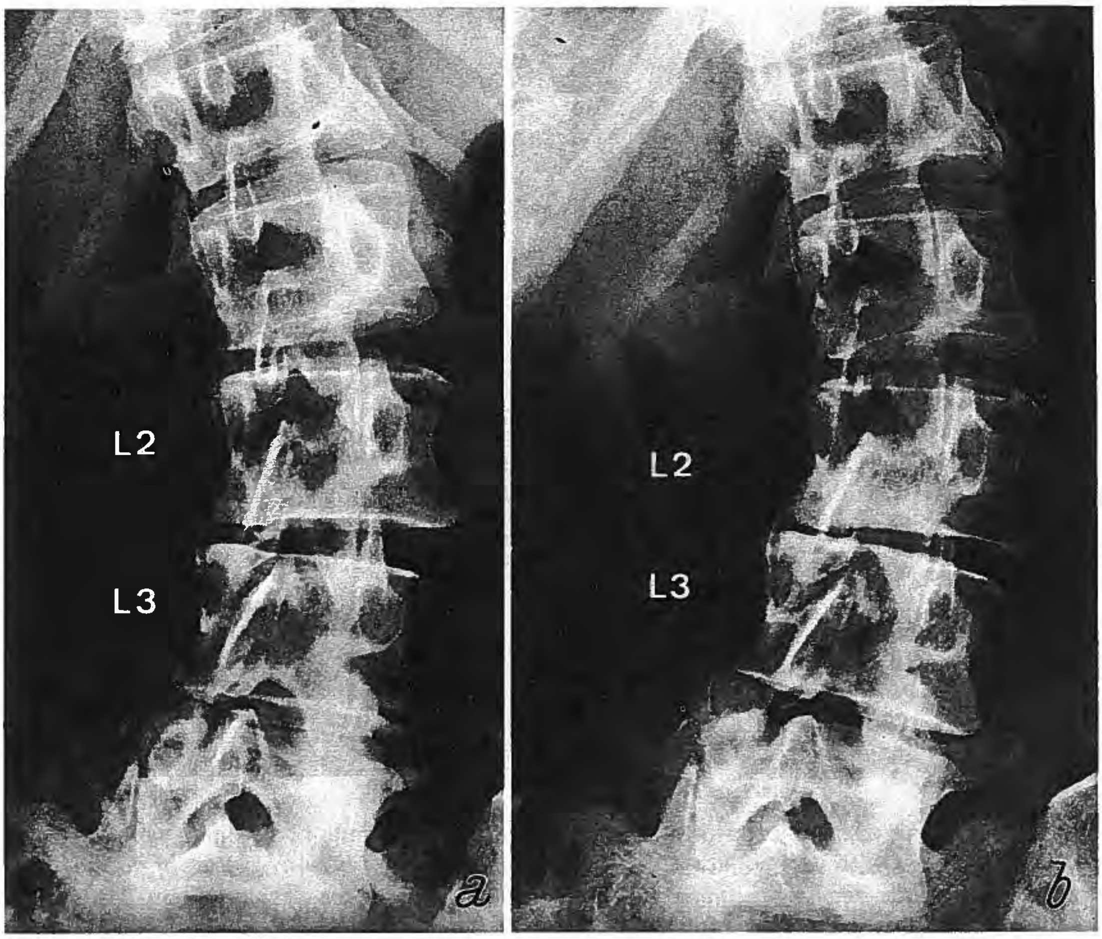
Radiographs have been chosen to illustrate some of the differences between cases of spinal stenosis of congenital and acquired origin (Figs. 6.1–6.5).

The experience of individual surgeons in treating cases of spinal canal stenosis due to different causes will vary, especially among those working in large cities where special units may be found, such as:

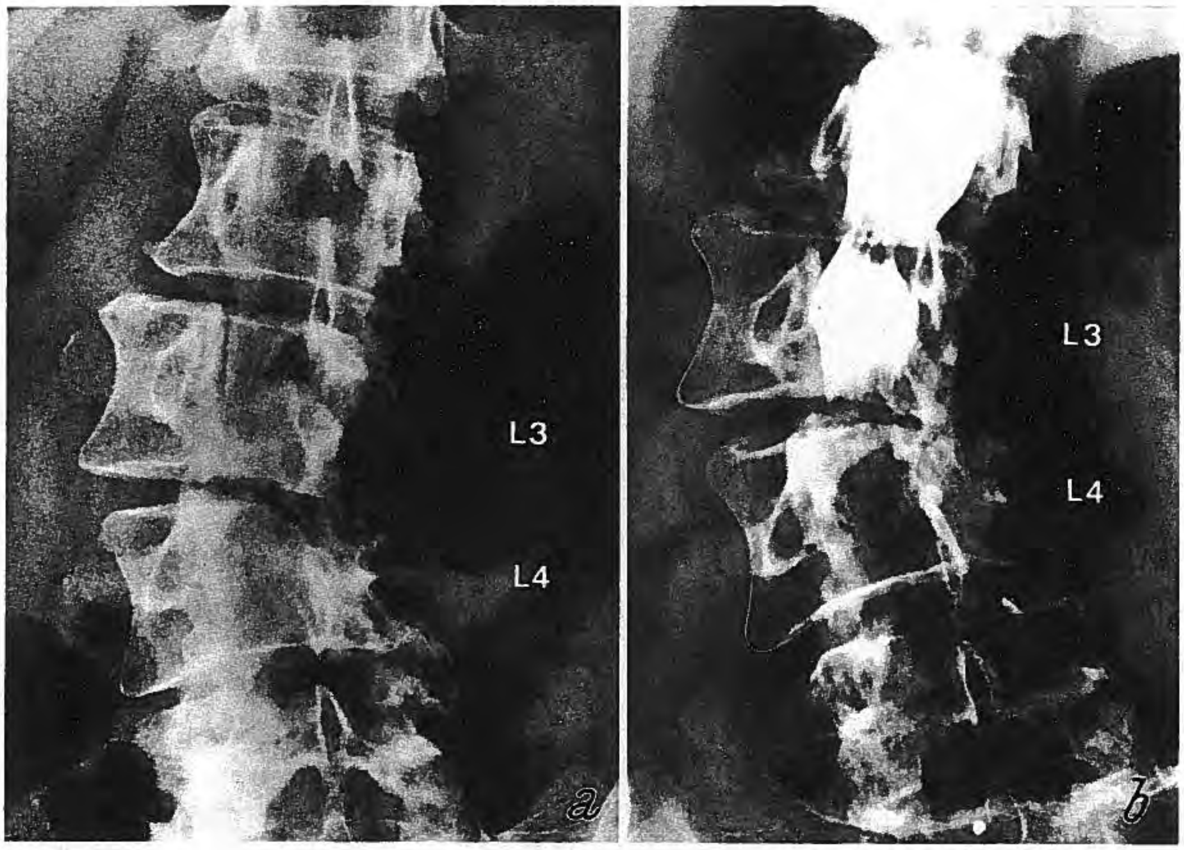
a centre for spinal injuries;
a cancer institute;
an unit for the study of dwarfism.

Since 1961, working in the orthopaedic department of a university teaching hospital with only a small children's section, my experience in treating cases with spinal stenosis of different causes has been as follows:

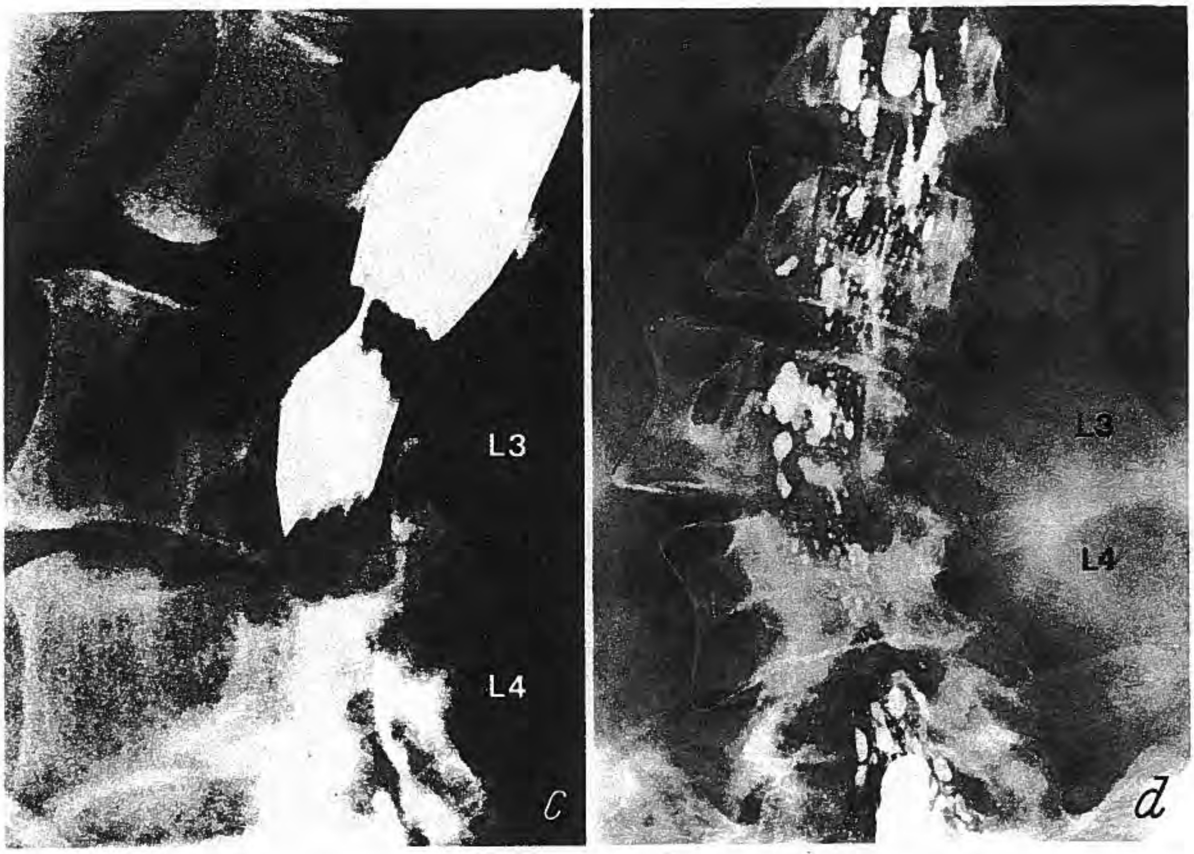
Figures 6.1. **a** An antero-posterior radiograph of the lumbar spine of a woman of 66 years showing congenital fusion of the vertebral bodies of L2 and L3 with resultant scoliosis, further aggravated by degenerative spondylosis at the disc between L1 and L2. This patient presented with a cauda equina claudication syndrome. **b** An antero-posterior radiograph of a myodil myelogram showing multi-level canal stenosis, most marked at the L1/2 and L2/3 regions. This patient's symptoms were greatly relieved following two level decompression of the spinal canal



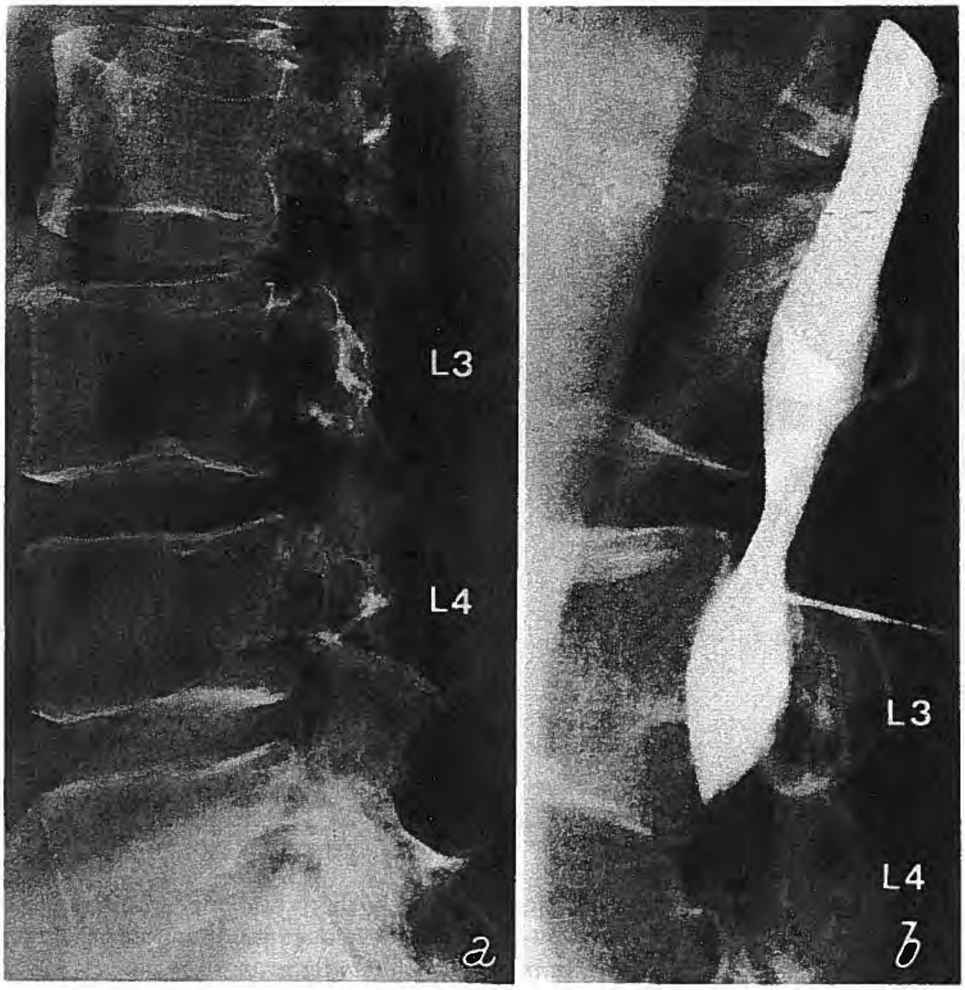
Figures 6.2. **a** An antero-posterior radiograph showing early disc degeneration between the bodies of L2 and L3 causing scoliosis in a patient with four lumbar vertebrae. **b** The same spine three years later showing increased disc-space narrowing with further increase in scoliosis. This form of degenerative lumbar scoliosis due to intrinsic disc disease is seen in middle-aged women, often with multiple discs involved. Many of these patients develop spinal stenosis



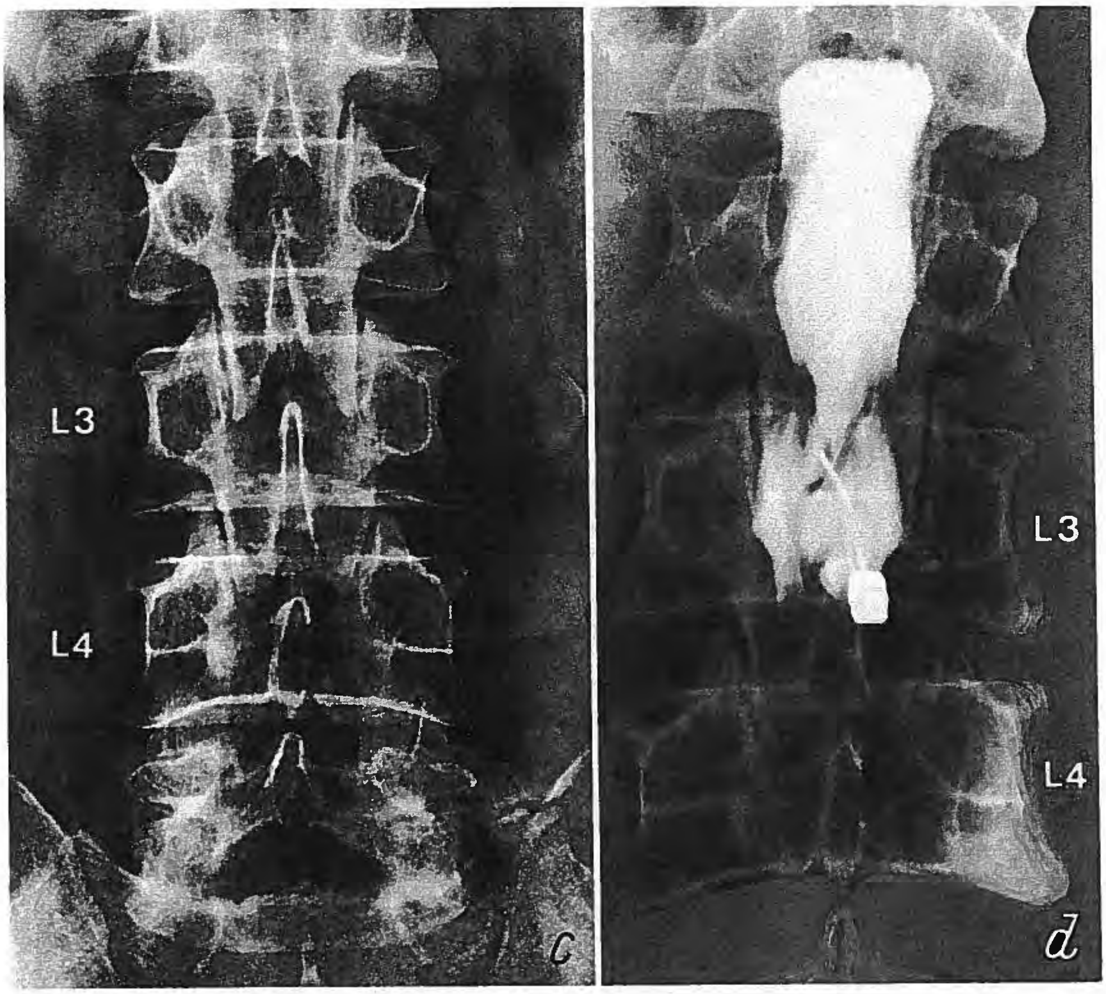
Figures 6.3. **a** An antero-posterior radiograph of the lumbar spine of a woman aged 55 years. Note the scoliosis with its apex at the L3/4 level. *This is one of the rare causes of degenerative scoliosis in middle-aged women due to acute vertebral end-plate necrosis.* The deformities resulting from this lesion are often complex with both kyphotic and scoliotic components contributing to the overall deformity. **b** An antero-posterior radiograph of the myelogram in this case showing a complete block at the L3/4 level with stenotic changes at L2/3 above



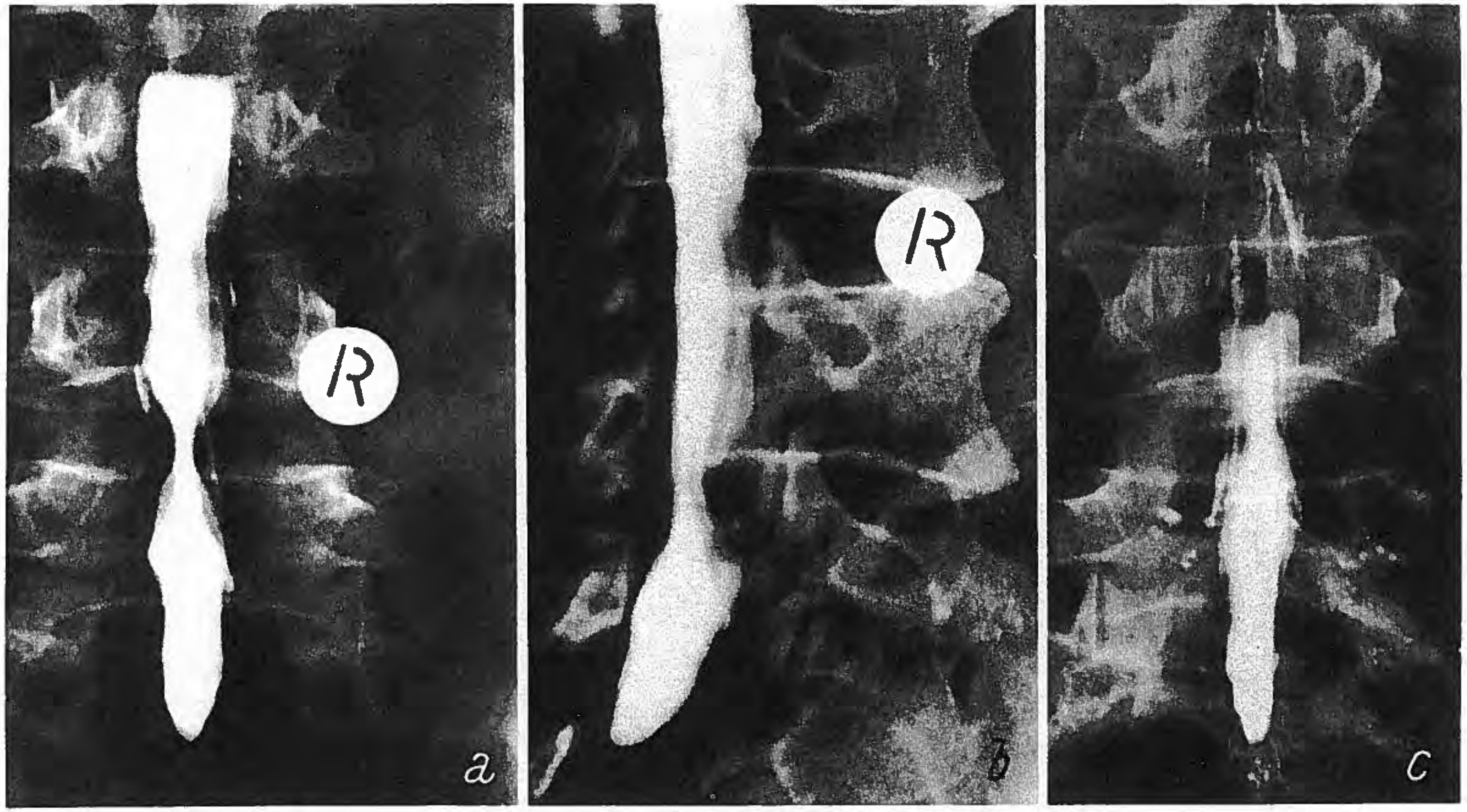
Figures 6.3. **c** A lateral radiograph of the same spine showing the myelogram with complete blockage of the flow of myodil at the distal border of L3 and a stenotic lesion at L2/3. At operation, the cause of this stenosis was due in part to secondary degenerative changes in the roofing structures of the spinal canal at L2/3 and L3/4, but the main cause of the complete obstruction at L3/4 was massive disc sequestration. **d** An antero-posterior radiograph of the same spine taken six months after operation in which multi-level canal decompression was carried out, together with excision of the disc fragment and localized interbody fusion at L3/4



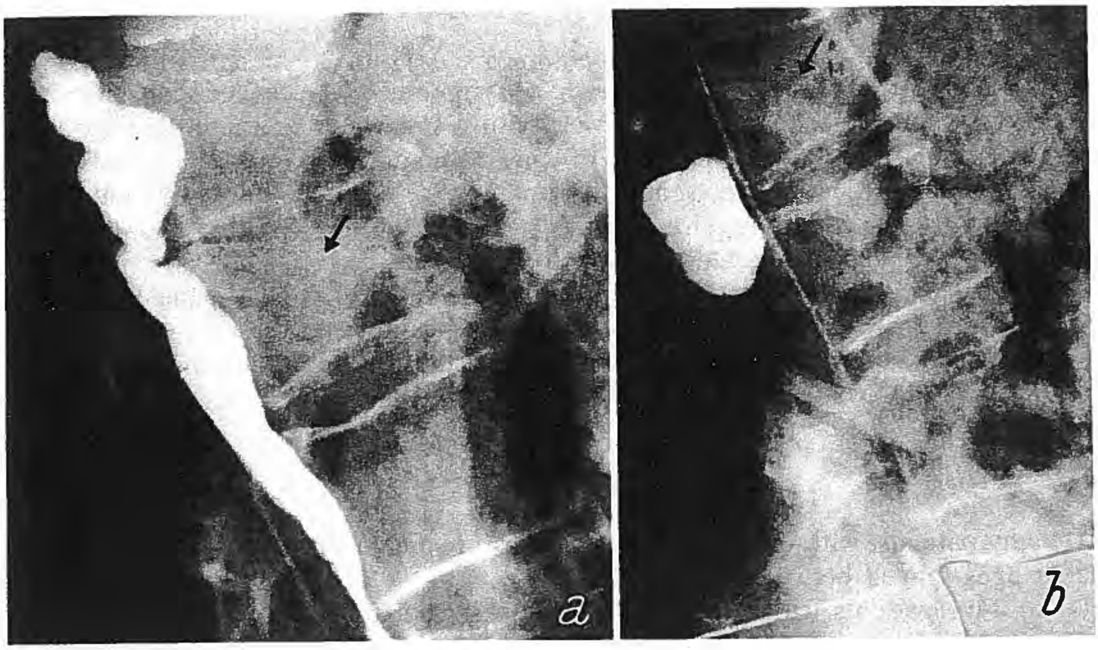
Figures 6.4. **a** A lateral radiograph of the lumbar spine of a male patient aged 58 years. Note the preservation of the disc spaces and there is no evidence of degenerative spondylosis. *The pedicles of L3 and L4 appear short.* **b** A lateral radiograph of the same spine showing a myelogram with complete spindling and obstruction of the column at the L3/4 level. This appearance is typical of spinal canal stenosis at a single level

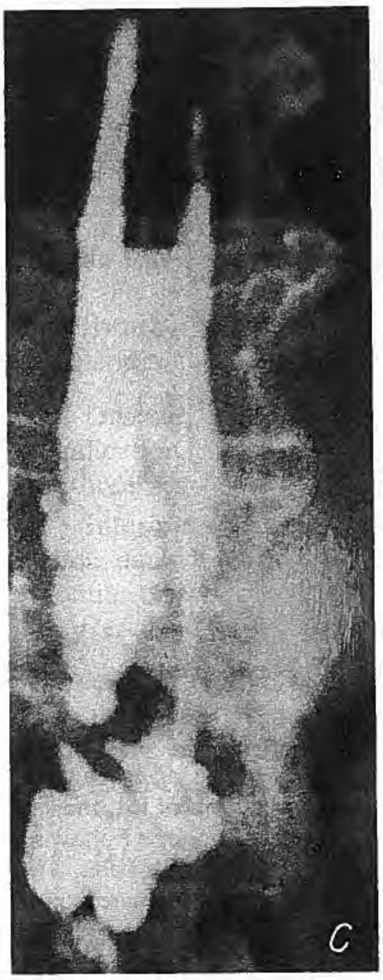


Figures 6.4. **c** An antero-posterior radiograph of the same spine. Note the orientation of the facets of L3/4. These are vertically orientated so that the medial margins of the inferior facets of the L3 lamina approach the mid-line in contrast to the normal anatomical arrangements seen in Fig. 6.9. **d** An antero-posterior radiograph showing the myelographic appearance in this patient with complete obstruction to the flow of Myodil at the L3/4 level. This patient presented with the classic clinical features of cauda equina claudication with pain and numbness in the legs and a sense of weakness after walking short distances



Figures 6.5. **a** An A-P radiograph of the lower lumbar spine of a man aged 55 years who presented with bilateral buttock and leg pain aggravated by walking and standing. The myelogram shows the classic appearance of spinal stenosis at the L 4/5 level, the hour-glass deformity being due to *facet intrusions* on both sides, contributed to in part by a bulky ligamentum flavum. **b** An oblique view of the same spine showing the myelographic defect at L 4/5 with the intimate relation of the inferior facet of the 4th lumbar lamina to the myelographic defect. Note that in both views of this patient's spine the intervertebral disc spaces are of normal height. **c** An antero-posterior radiograph of the same spine showing the post-operative appearance after a single level spinal canal and nerve root canal decompression. Residual myodil is present showing that the spindling defect is no longer present. The patient's symptoms were relieved and at follow-up ten years later he was symptom free





Figures 6.6. **a** A lateral radiograph of the lumbar spine of a woman aged 68 years. The black arrow points to a crush-fracture of the vertebral body of L1, sustained following a fall from a bicycle. The myelogram was taken twelve months after this injury for the investigation of pain at the thoraco-lumbar junction with marked upper abdominal pain and gross abdominal distension. This patient had a *post-traumatic arachnoid cyst* which extended distally to the middle of the body of L2 and proximally to the level of T11. **b** A lateral radiograph of the same spine following removal of the myodil. Note the remnants of myodil trapped in the arachnoid cyst just below the vertebral fracture marked by the black arrow. **c** An antero-posterior radiograph to show the spatial distribution of the arachnoid cyst which produced a functional spinal stenosis responsible for the symptoms described. This patient had an extremely thin, transparent dural sac in the region of the thoraco-lumbar junction. The arachnoid cyst was easily identified at operation. Symptoms were relieved by multi-level decompression of the thoraco-lumbar canal. The arachnoid cyst was not ruptured and in view of the fact that the dural sac was abnormally thin, no attempt was made to find a rent in it–related to the fracture of the vertebral body–through which the cyst emerged. The patient's symptoms were relieved and the troublesome abdominal distension disappeared soon after operation

a) Congenital

a) Two patients with dwarfism complained of symptoms suggestive of spinal stenosis. In one of these, an achondroplastic dwarf with a small lumbar canal, myelography was performed with only 1.5 mls. of myodil. Multi-level canal stenosis was demonstrated in the lumbar spine. The patient's symptoms subsided with rest. Neither of these patients required surgical treatment.

b) Ten adult patients. One presented with paraparesis.

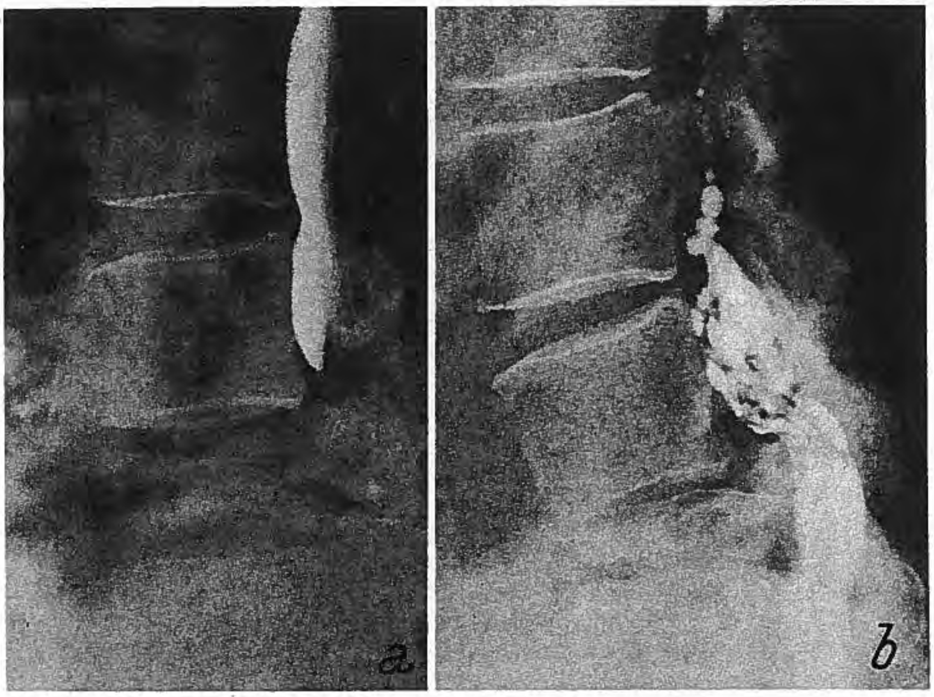
c) Three adult patients, two of whom were elderly women. One man aged 34 years presented with cauda equina claudication and paraparesis.

d) Three adult patients; in one the cause of the arachnoid cyst may have been traumatic (Figs. 6.6a–c).

b) Acquired

a) Many patients, with wide-ranging symptoms of spinal stenosis were in this group. Their ages ranged between 55 and 75 years.

b) Five patients with stenosis following vertebral fractures. Two patients with stenosis following pathological fractures (Figs. 6.7a, b).



Figures 6.7. a A lateral radiograph of the lower lumbar spine of a woman aged 59 years showing complete obstruction to the flow of myodil in a myelogram at the level of L4, the site of a pathological fracture of the vertebral body due to a primary tumour of bone. **b** Following decompression of the lumbar spinal canal, note the restoration of the flow of myodil. The patient's symptoms of referred leg pain were relieved and she lived for approximately nine months after this film was taken, dying with secondary pulmonary tumours. The primary lesion was sarcomatous

c) Ten patients.

d) Although Paget's disease is common in Australia, I have never seen a case of spinal canal stenosis which resulted from it and required surgical treatment.

e) Many patients (see Chapter 9).

Although Sarpenyer described congenital stricture of the spinal canal in 1945, Verbiest (1954) deserves much of the credit for focussing attention on the various clinical syndromes associated with stenosis of the spinal canal. He, along with other members of the International Society for the Study of the Lumbar Spine: Kirkaldy-Willis, Paine, Cauchoix, and McIvor (1974), Verbiest (1976), Weinstein, Ehni, and Wilson (1977) has made scholarly contributions to medical literature on this subject.

6.2. Clinical Features

a) Symptoms

Most patients describe a variety of symptoms which may include:

a) Back pain,	often aggravated by standing or walking.
b) Leg pain,	of variable distribution, unilateral or bilateral, fluctuating.
c) Paraesthesiae,	ranging from feelings of numbness and heaviness, sometimes with an associated burning pain, sometimes with a feeling of coldness.
d) Weakness in the legs,	ranging from unilateral loss of power resulting in sudden falls to paraparesis, related to walking and relieved by rest.
e) Restless legs,	uncontrolled leg movements experienced especially at night in bed.
f) Disturbances of bladder function,	frequency or incontinence after walking.

Despite wide-ranging descriptions of symptoms, all of these patients complain of claudication, related either to their pain, paraesthesia, weakness or, occasionally, to all three symptoms together.

Intermittent claudication of vascular origin can usually be distinguished from cauda equina or nerve root claudication on clinical grounds. Pain in the legs of vascular origin is cramp-like and centres on the calf or buttock muscles. Impairment of arterial circulation is indicated by:

loss of hair on the legs;
absent peripheral pulses;
bruits along the course of the main arteries in the lower abdomen or at the groins.

b) Physical Signs

There are no characteristic findings. Signs vary depending on the underlying pathological condition causing the stenosis.

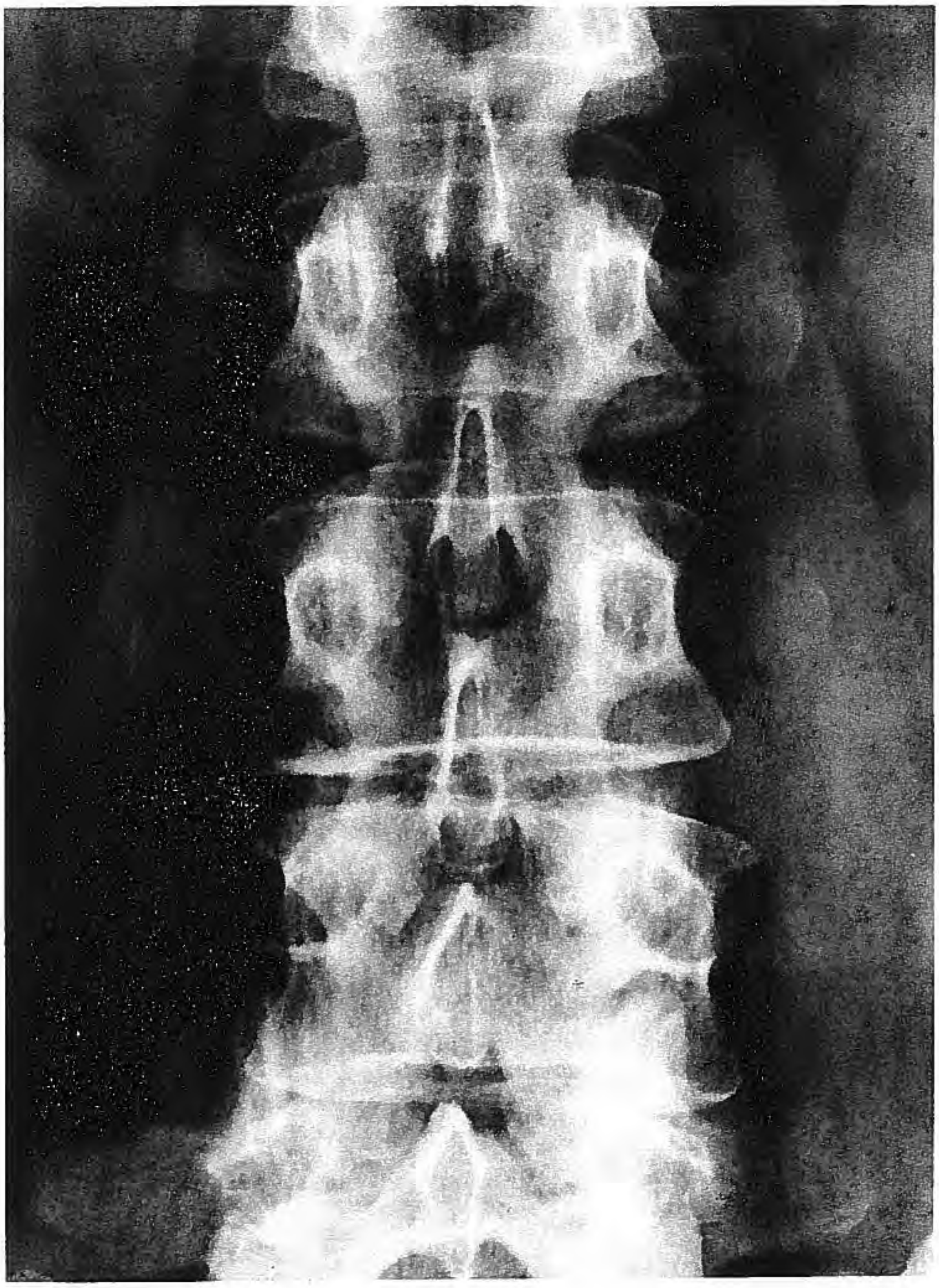


Figure 6.8. An antero-posterior radiograph of the lumbar spine in an adult in whom gross pathology is noted, particularly in the roof of the spinal canal. Although there is evidence of spondylosis at L3/4 with asymmetrical narrowing of the disc space, the major changes are in the laminal structures where facet hypertrophy, laminal thickening and spinous process interdigitation have reduced the interlaminar spaces at L2/3 and L3/4 to minute porportions

6.3. Radiological Investigations

a) Plain X-Rays

In congenital lumbar canal stenosis, certain findings can be important:

vertebral anomalies, with scoliosis;
narrowing of the diameter of the spinal canal, with short vertebral pedicles;
alterations in the pattern of orientation of facet joints.

In canal stenosis of degenerative origin the following findings can be important:

gross lumbar scoliosis, due to asymmetrical narrowing of the disc spaces or to acute necrosis of the vertebral end plate;
facet joint hypertrophy;
reduction in inter-laminar spaces and overriding of adjacent laminae (Figs. 6.8–6.10).

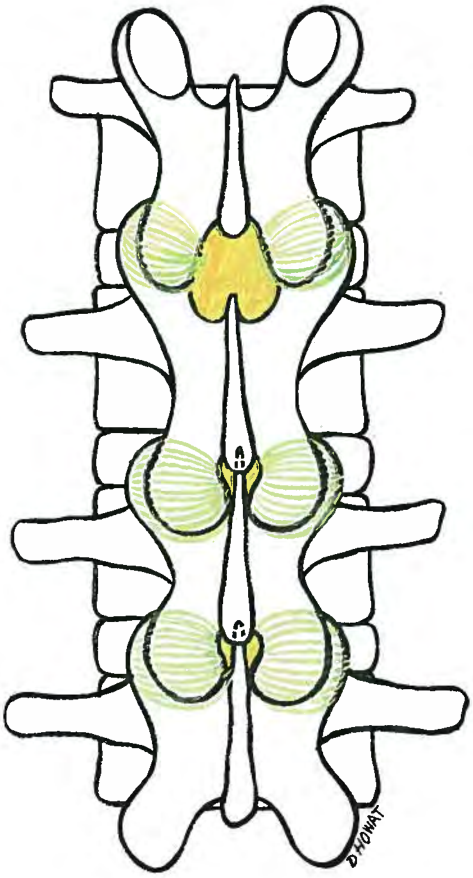


Figure 6.9. A drawing based on the X-ray shown in Fig. 6.8 to highlight the pathological changes which may occur in the roofing structures of the spinal canal leading to the development of multi-level canal stenosis. At the top of the drawing the ligamentum flavum is of normal proportions and there is wide separation between the medial margins of the capsules of the facet joints. In addition, the interspinous space is clearly defined. By contrast, at the lower two levels, note the interdigitation of the spinous processes, the hypertrophic changes in the facets and the almost complete occlusion from view of the ligamentum flavum at both these levels

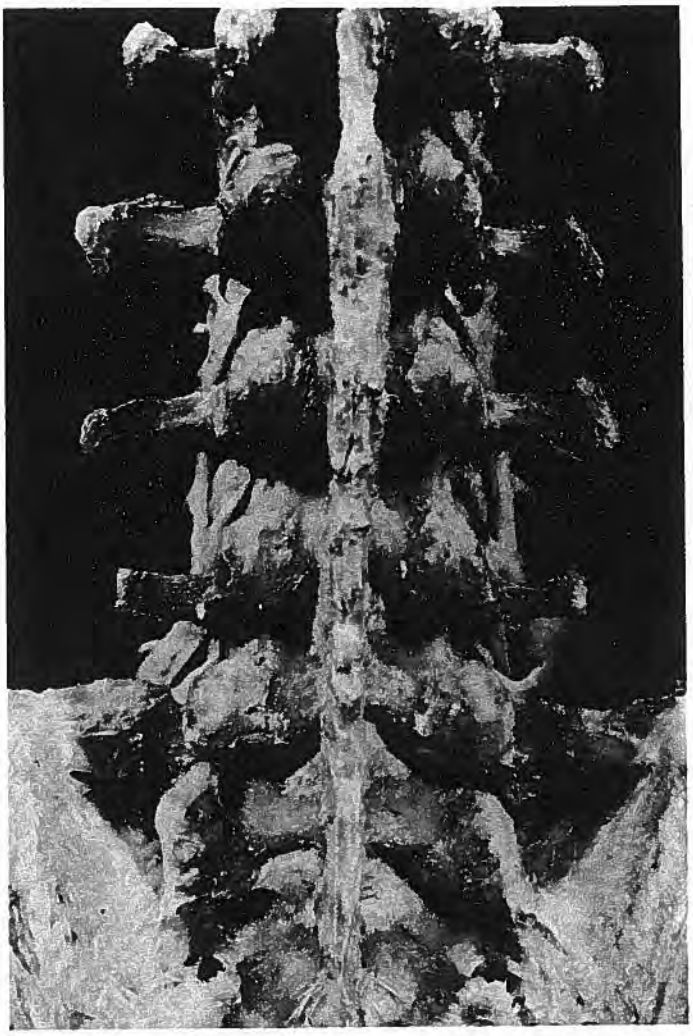
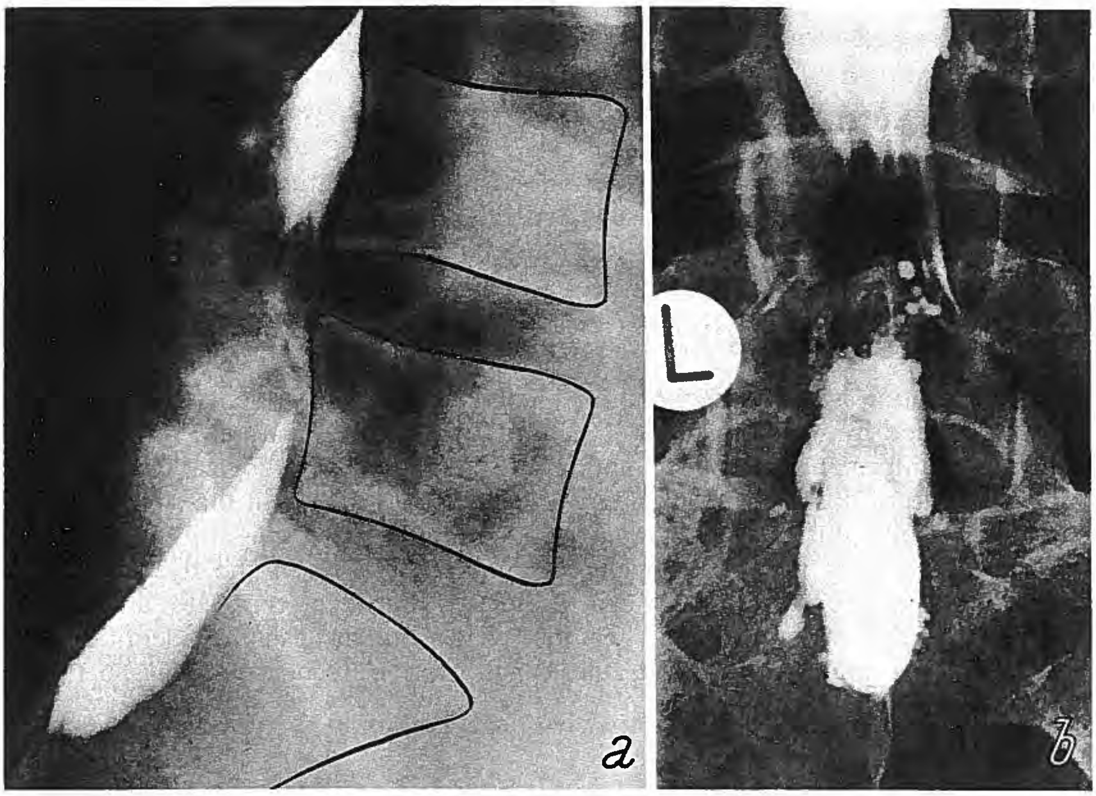


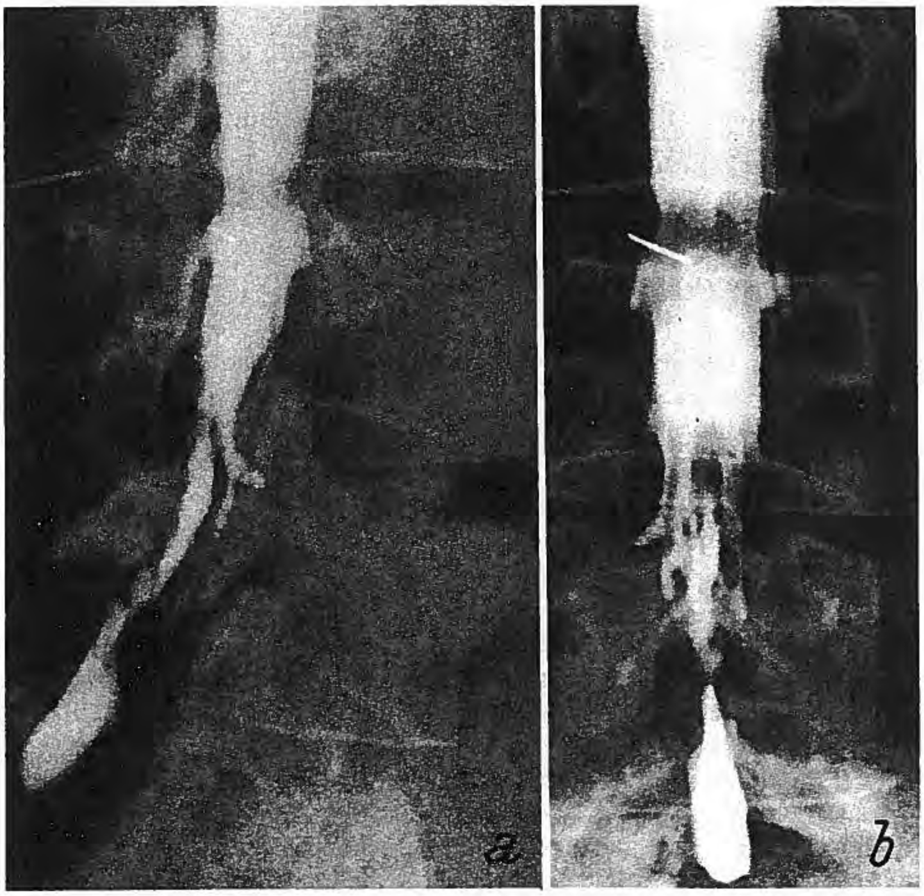
Figure 6.10. A photograph of a dissection of a normal lumbar spine viewed from behind. Note the orientation of the facet joints at L3/4, L4/5 and L5/S1. These are separated widely from the mid-line, so that the ligamentum flavum can be seen clearly at each level. Shadows are cast on the ligamentum flavum by the lower margins of the laminae, highlighting the anatomical feature of the superior attachment of the ligamentum flavum to the anterior surface of the superior lamina at a particular interspace. (Dissected by Dr. M. C. Crock)

Figures 6.11. **a** A lateral radiograph of the lumbar spine of a man aged 47 years presenting with classical symptoms of cauda equina claudication. Note the myelographic defect and the normal disc height at L4/5 and L5/S1. *This is an example of incomplete obstruction* and in such cases it is necessary to posture the patient at the time of myelography so that adequate studies of the flow of the dye can be obtained. What appears to be a complete obstruction may turn out to be incomplete if the patient is postured in the vertical or head down position. **b** An antero-posterior radiograph of the same spine showing the single level canal stenosis due to pathology in the roof of the spinal canal

Figures 6.12. **a** A lateral radiograph of the lumbar spine of a man aged 47 years showing the classical myelographic appearance of arachnoiditis of the cauda equina. **b** An antero-posterior radiograph of the same myelogram showing typical features of distortion of the column of dye due to arachnoiditis of the cauda equina (see Figs. 6.15a–c)



Figures 6.11



Figures 6.12

b) Computerized Axial Tomography

Although this investigation has revolutionized the investigation of spinal stenosis in the past few years, it has not superseded the use of either plain X-rays or myelograms (Lancourt *et al.,* 1979).

c) Lumbar Myelography

This investigation is the cornerstone for planning surgical treatment, being the most reliable method by which multi-level stenoses can be demonstrated. In addition, it can provide information about the nature and severity of pathological changes at or below the site of obstruction, providing the movement of dye in the spinal canal is studied carefully during myelography. For example, by tilting the patient into head-down or erect vertical positions, observing the flow of the dye with these changes in posture, distinctions can be drawn between complete and partial blockages, areas of arachnoiditis in the cauda equina can be identified and obstructions at multiple levels in the canal can be recognized (Figs. 6.11a, b, 6.12a, b).

6.4. Conservative Treatment

Conservative measures must always be tried. Many patients with disabling symptoms will improve following the use of spinal supports. Epidural injection of hydrocortisone may be useful, though if the patient's symptoms are made worse, this might indicate that the stenosis requires decompression.

6.5. Surgical Treatment

Elderly patients tolerate multi-level spinal canal decompressions satisfactorily. However, special care should be exercised in operating on older patients. Cardiac monitoring should be used during surgery. Blood loss can be considerable, up to 1,200 ml in cases requiring decompression over three or more segments. When anaesthetized, they should be turned slowly and with great care for positioning on the operating table.

a) Positioning

Use of the prone position on the operating table is essential, the chest and pelvis being supported on a suitable frame. Exaggerated postures should be avoided. The head and trunk should be kept almost horizontal, but the legs can be flexed slightly at the hips and knees (see Chapter 3, Figs. 3.8–3.11). Mental confusion due to cerebral oedema may occur in the post-operative period in elderly patients following operations performed under general anaesthesia in the prone position, if the table has been tilted towards the head-down position.

b) Surgical Pathology

In the *congenital group,* problems may arise simply because the spinal canal is too narrow, the structure and tissues of the vertebral column being otherwise normal. However, even in this group, the major complication of severe spinal stenosis may be found–arachnoiditis of the cauda equina.

In the *acquired group,* many pathological lesions will be found. The largest sub-group–(a)–provides the widest range of pathology, followed closely by patients in sub-group (e), many of whom may have been operated on in error, the underlying primary diagnosis of spinal stenosis having been overlooked.

Vertebral osteoporosis is often marked, the soft laminal bone being very vascular. *Laminar thickness* varies between 2.5–5.0 mm in the normal lumbar vertebrae. It may be increased to as much as 25.0 mm in some cases.

The normal *ligamentum flavum* is highly elastic, varying in thickness between 1.0 and 2.5 mms. Sometimes it is greatly thickened, retaining its elasticity. In other cases, while thicker than normal, it becomes inelastic and friable, with visible patches of ectopic calcification. Following spinal injuries, it may ossify.

Changes in the *facet joints* are common, with gangliform degeneration of joint capsules, hypertrophy of individual facets, osteophyte formation and intra-articular loose bodies.

Within the spinal canal, epidural fat may be absent in the stenotic area. The dural sac and contents show important changes; the dura may be thickened and opaque, or thin and extremely friable.

Arachnoiditis of the cauda equina may occur, identified on digital palpation of the dural sac at operation by loss of the normal soft balloon-like consistency, the affected segment being firm and rubbery to touch, like a par-boiled sausage.

Changes in the anterior wall of the spinal canal can be related to pathology of the intervertebral discs with herniation or sequestration of fragments. Osteophytes may arise from the vertebral bodies.

c) Technique

i) Exposure

Exposure of the affected vertebral segments is obtained using the techniques described on pp. 110–117. Identification of the affected level or levels should be confirmed by examinating the patient's X-rays. X-ray control is not usually necessary, providing the lumbo-sacral junction is identified as a routine.

In patients with anomalous fused lumbo-sacral articulations, the first mobile segment of the lumbar spine should be identified.

At each level, after self-retaining retractors have been inserted, the laminal interspaces should be cleared of remnants of muscle fibres and fatty tissues. When the inter-laminal spaces are obstructed by hypertrophic facets, and the laminae override each other, it may be difficult to gain access to the spinal canal. The partes interarticulares of the laminae on both sides should be clearly exposed. Particular care should be taken in these cases to avoid damaging the arteries that supply the cauda equina. These vessels arise from branches of the posterior portions of each lumbar artery, anterior to the partes interarticulares of each lamina on both sides of the spine. Use of diathermy to coagulate bleeding vessels should be avoided near the origins of these branches.

ii) Enlargement of Bony Canal

Adjacent spinous processes should be excised flush with the laminae. Next, the edge of the inferior margin of the superior lamina at the laminal interspace should be excised, using a rongeur of suitable shape. When the medial margins of the inferior facets meet near the mid-line, removal of this laminal edge may be difficult. Attention should then focus on the facet joints, their infero-medial margins being exposed and any associated degenerate capsular tissues or ganglia removed.

The most effective technique for enlarging the laminal interspace, to expose the underlying ligamentum flavum, is to excise the medial aspects of these facets, using a fine osteotome, directed laterally and caudally. The cutting edge of the osteotome will emerge from the facet to strike the inferior lamina and the "non-articular" inner segment of the subjacent superior facet. If the lamina is osteoporotic, this manoeuvre can be carried out with a straight, short pituitary rongeur.

When the ligamentun flavum has been widely exposed, it may be thinned with a rongeur and then removed in the usual manner to expose the spinal canal.

Using a Watson-Cheyne probe, the pedicles should be palpated above and below, separating the dura carefully from the walls of the spinal canal. Having identified the medial margin of the inferior pedicle at the interspace, the medial edge of the superior facet related to this pedicle should be excised flush with the inner margin of the pedicle. The line of this cut in the facet, where it merges with the lamina, should mark the lateral extent of removal of bone when the central segment of the lamina is removed. In this way, the partes interarticulares will be preserved at each vertebral level on both sides of the canal. Removal of the facets in toto should be avoided, as this will lead to serious vertebral instability in some patients.

Bleeding from the cut surfaces of the laminae should be controlled by the application of bone wax regularly as the decompression is proceeding. This will help to reduce blood loss significantly in elderly patients with osteoporosis.

Once the canal has been exposed on both sides, the dural sac should be inspected carefully and palpated (Fig. 6.13).

iii) Haemostasis

Haemorrhage from the internal vertebral venous plexus on either side of the dural sac should be controlled by packing strips of a suitable haemostatic agent–such as gelfoam–along the antero-lateral margins of the spinal canal. The gelfoam should be covered with moistened linteen strips until the posterior surface of the dura is outlined on either side by these strips and the field should, by then, be bloodless.

iv) Dural Opening

Arachnoiditis of the cauda equina should be suspected if the dura is opaque and non-pulsatile. Digital palpation will confirm the suspicion when the firm texture, described above, is felt. If this condition is diagnosed, the surgeon should first complete the decompression over the planned length of the spine. The dural sac

Figure 6.13. An antero-posterior tomogram of the lower lumbar spine taken following decompression of the spinal canal to show restoration of the normal contours of the dural sac following treatment for single level canal stenosis at L4/5. Note the smooth margins to the laminae on both sides of the vertebral column. The technique of spinal canal decompression should be such that the post-operative films have this appearance, with preservation of the partes interarticulares and greater portions of the facet joints on both sides. The lateral extent of laminal dissections should not proceed beyond the medial margins of the pedicles at each level. Multi-level decompressions of the lumbar canal may be carried out in this manner without fear of causing vertebral instability

should then be opened carefully in the mid-line over a segment firm to the touch of the surgeon's finger. The dura will be quite thick, but its cut edges will be distinct from the underlying greyish-pink thick arachnoid. The filaments of the cauda equina will not be visible, as they are ensheathed by the inflamed arachnoid membrane.

The aim in exposing the inflamed arachnoid membrane is to leave the dural sac widely open. Dissection should continue proximaly either to the level where the dural sac pulsates or to a point where cerebrospinal fluid can be seen contained by transparent arachnoid membrane.

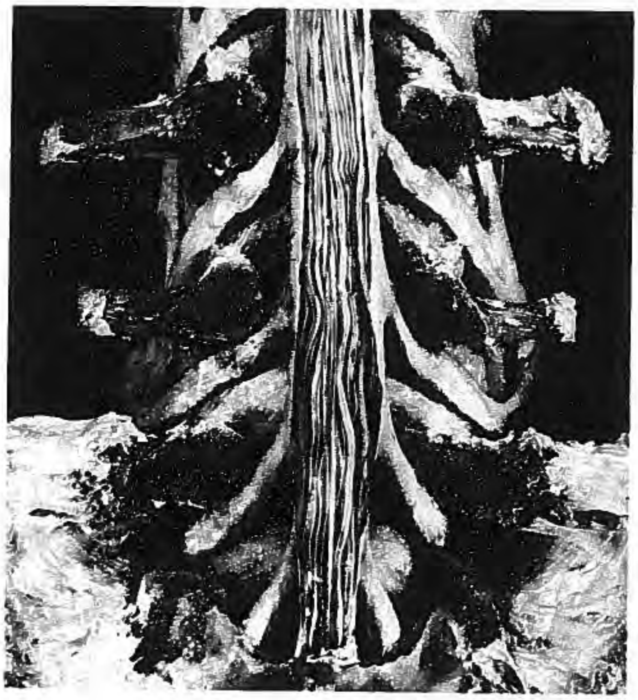
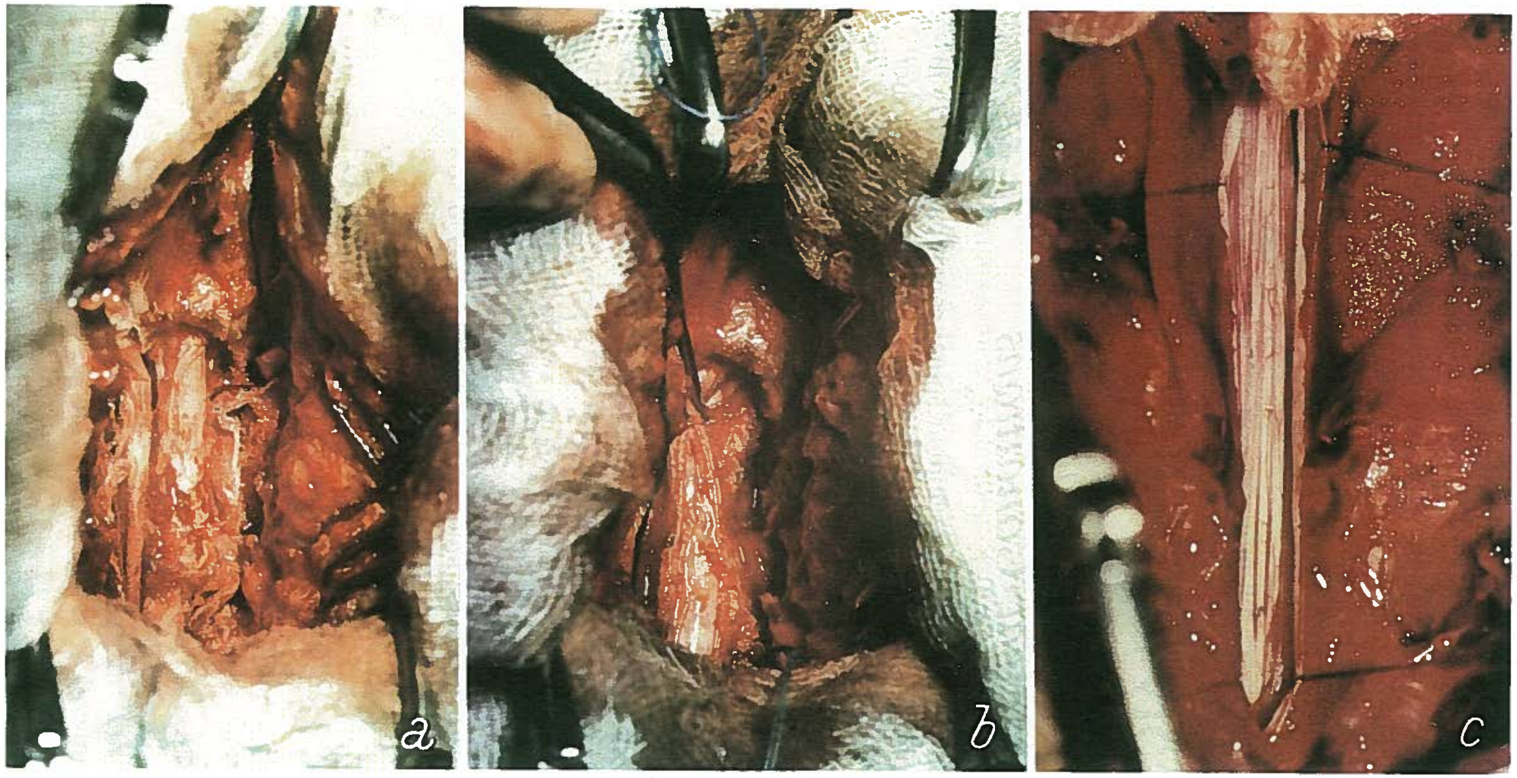


Figure 6.14. A photograph of a dissection of the lumbar spine of a woman aged 46 years. The posterior part of the dural sac has been removed to show the cauda equina which is still ensheathed in transparent arachnoid membrane. During explorations of the lower lumbar spine the dural sac is usually transparent and filaments of the cauda equina can be seen floating in the cerebrospinal fluid. (Dissected by Dr. M. C. Crock)

The margins of the opened dura should be fixed with a few interrupted silk sutures to the muscles along the lateral edge of the bony margins of the spinal canal, over the area of the decompression (Figs. 6.14, 6.15a–c).

Assuming that no other lesions, such as prolapsed disc fragments, have been found during the operation, the wound may now be closed, without drainage. Particular care should be taken to ensure that the lumbo-dorsal fascial layer is sealed.



Figures 6.15. **a** A photograph taken during operation to show the appearance of the dural sac in the lower lumbar spine in the patient whose myelogram is illustrated in Figs. 6.12a and b. The dura is totally opaque and on digital palpation, in contrast to the normal sensation of feeling a soft balloon, the consistency of the contents can be likened to that of a par-boiled sausage. **b** A photograph taken following opening of the dural sac. Note the markedly thickened glistening arachnoid. It is impossible to identify individual filaments of the cauda equina. **c** A photograph of the cauda equina extending from L2 to the upper border of L4 in a woman aged 52 years who presented with a complete block on a myelogram at the level of the lower border of L2. *Clinically, this patient had severe paraparesis* and at operation, classical features of multi-level lumbar canal stenosis were found along with severe arachnoiditis of the cauda equina. In this photograph, at the top of the picture, it is possible to identify individual filaments of the cauda equina with some blood vessels on the surfaces inside the arachnoid membrane which is normal at this level. In the lower half of the picture, note the thickening of the filaments of the cauda equina and the opacity of the arachnoid. In this remarkable case, when the dura was opened throughout the whole course of the lumbar spine, the cerebrospinal fluid leaked gradually downwards within the exposed arachnoid sheath, until it reached the level of the L3 vertebral body at its lower border. This patient's paraplegia recovered rapidly following operation for decompression of the canal, the dural sac being left widely opened following operation (see p. 174)

6.6. Results of Surgical Treatment for Arachnoiditis

Twenty cases of severe arachnoiditis of the cauda equina have been treated by this method. Managed post-operatively by early mobilization, the patients have been given Aspirin tablets, four daily, and multi-vitamin tablets, three daily, for three months; the rationale of this therapy being that the fine circulation in the vessels supplying the cauda equina should be thereby enhanced. Two of these patients had been paraparetic before surgery. Many had complained of intractable severe bilateral leg pain, and a number were addicted to narcotics as a result of prolonged usage for pain control.

Both paraparetic patients recovered full motor power in their lower extremities. At least four patients returned to work. Among those apparently addicted to narcotics, only two continued to require non-narcotic analgesics for pain control.

6.7. Recognition and Treatment of Associated Pathological Conditions

In the course of decompression operations in the lumbar spinal canal, particularly in patients with degenerative scoliosis, care should be exercised to ensure that other lesions are recognized and treated, for example:

disc prolapses;
nerve root canal stenosis.

Vertebral instability may occur following removal of a large volume of intervertebral disc tissue, or in rare cases of acute vertebral end-plate necrosis with massive disc sequestration leading to kypho-scoliosis. Only in exceptional circumstances such as these should localized spinal fusion be performed (Fig. 6.3d).

7

Surgery of the Cervical Spine

7.1. Introduction

The surgical management of lesions of the cervical spine is now dominated by the operation of *anterior interbody fusion.* This procedure was introduced for use in the neck in 1955 by Robinson and Smith. Their technique was modified when Cloward introduced special instruments for dowel grafting in 1958.

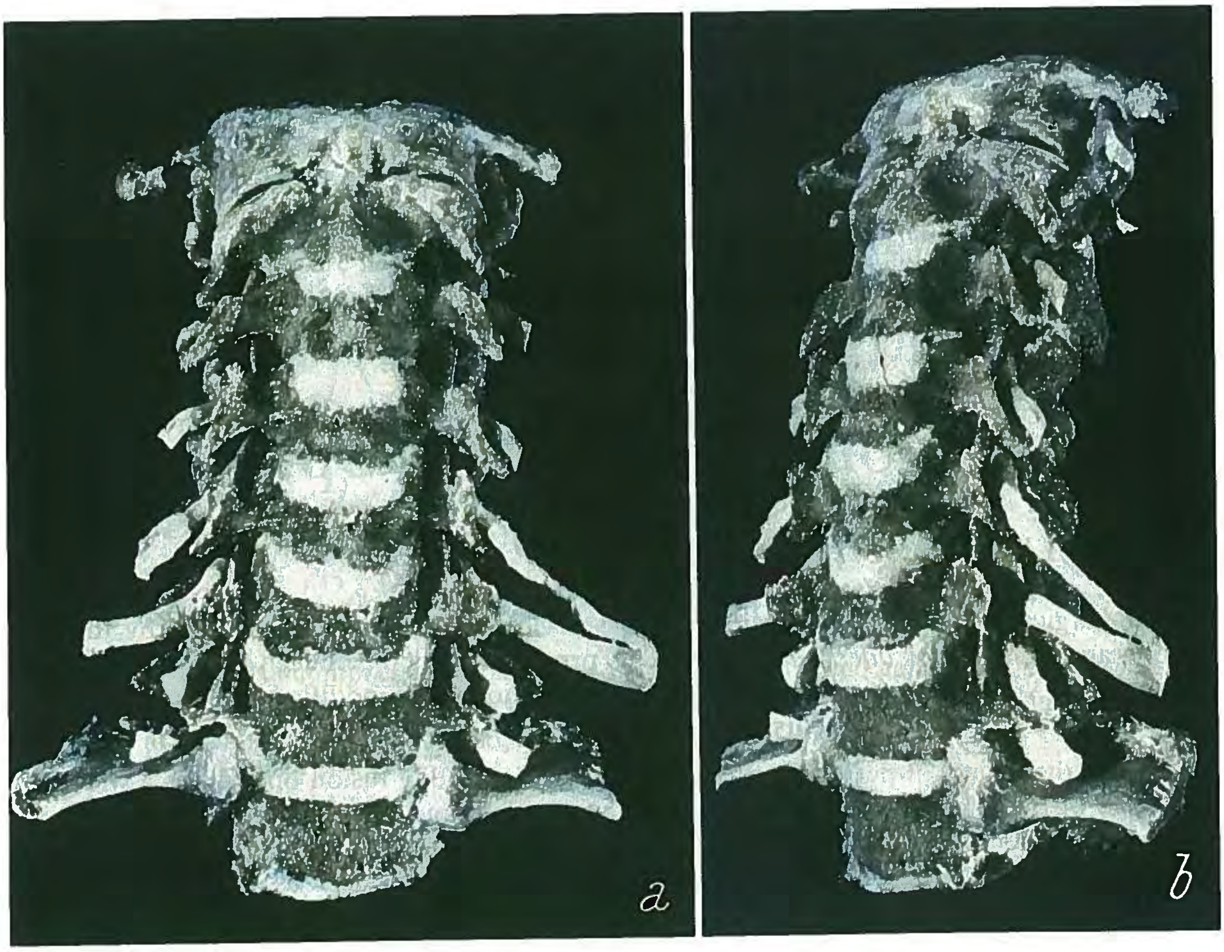
In the course of performing anterior cervical interbody fusion operations a wide range of pathological lesions can be dealt with safely and effectively. For example, some of the space-occupying lesions which project into the anterior wall of the cervical canal can be removed before the grafts are inserted, lesions such as central disc prolapses, sequestrated disc fragments, or osteophytic bars of bone. The incidence of severe neurological deficits, including quadriplegia, was formerly so high following the use of "laminectomies" for posterior approaches to these lesions that surgery in general–in the cervical spine–had a very poor reputation.

The operation of *cervical laminectomy* still retains an important place for use as follows:

1. For decompression of the spinal canal in cases of multi-level stenosis.
2. For the relief of persistent stenosis of the canal after anterior interbody fusion operations, rarely.
3. For drainage of epidural abscesses.
4. For the treatment of spinal cord tumours.

However, its use to gain access to lesions which lie anterior to the spinal cord has been abandoned.

Posterior cervical spinal fusion between the arch of C1 and the lamina and spinous process of C2–for the treatment of un-united fractures of the odontoid process–remains the treatment of choice for this problem. Apart from this indication, and that of internal fixation following open reduction of some fracture-dislocations in the neck, this operation has been superseded by that of anterior cervical interbody fusion.



Figures 7.1. **a** A photograph of a dissection of the cervical spine and the cervico-thoracic junction viewed from in front. All the soft tissues have been removed with the exception of the intervertebral discs and the vertebral arteries on both sides. The emerging nerve roots are also shown. Note the proximity of the vertebral arteries to the lateral margins of the intervertebral discs in the region of the unco-vertebral joints. Note also the dimensions of the intervertebral discs particularly in the transverse plane. They increase gradually in size from above downwards (dissected by Dr. M. C. Crock). **b** A photograph of the same specimen viewed obliquely from the left side showing the relationships of the vertebral artery and the emerging cervical nerve roots

7.2. *Indications for Surgery*

a) Cervical Spondylosis

In the preface to their book "Cervical Spondylosis and Other Disorders of the Cervical Spine", Brain and Wilkinson (1967) wrote: "Cervical spondylosis was hardly recognised twenty years ago". Now, fifteen years later, the most widely accepted indications for surgical treatment in the cervical spine would be for problems complicating that condition. Occurring as a disorder localized to one intervertebral segment or in a more generalized form, it gives rise to a variety of syndromes which can be related largely to the variable pathology resulting from the disc-space narrowing and osteophyte formation which characterize the condition.

Surgical treatment may be indicated in the management of cervical spondylosis as follows:

a) For the relief of persistent or recurrent neck pain, neck stiffness and occipital headache, in the absence of abnormal neurological signs.

b) For the relief of neck pain and brachial neuralgia, with or without abnormal neurological signs.

c) For the relief of symptoms or signs resulting from cervical myelopathy, complicating stenosis of the cervical spinal canal due to the projection of spondylitic osteophytes into the anterior wall of the canal.

d) For the relief of dysphagia. This is a rare complication which may follow the development of a massive osteophyte projecting forwards and compressing the oesophagus. Simple excision of the osteophyte may suffice to relieve the dysphagia.

e) For the relief of stenosis of the vertebral artery or arteries due to mural pressure by osteophytic outgrowths from the regions of the unco-vertebral joints. The results of surgery for this problem are unpredictable and often unrewarding.

b) Cervical Disc Lesions

Cervical disc prolapses are uncommon. Sequestration of relatively large volumes of disc material into the cervical spinal canal may follow manipulation of the spine, performed in the course of conservative treatment for the relief of neck and arm pain. Surgical treatment may be indicated for the management of these lesions and again, there would be general agreement among surgeons on the specific indications for operation. These are in common with those outlined in Chapter 3, p. 103, for the management of lumbar and thoracic disc prolapses.

c) Spinal Injuries

Following spinal injuries, without associated neurological damage, spinal fusion may be required occasionally, as follows:

a) For the treatment of persisting *vertebral instability* after dislocations or subluxations.
b) For the treatment of non-union of fractures of the odontoid.

d) Inflammatory Disorders

Rheumatoid arthritis involving the upper cervical spine may result in instability between the first and second cervical vertebrae. Complications resulting from this disease at the base of the skull sometimes pose most challenging problems in surgical management (Von Torklus and Gehle, 1972). These patients are usually frail with delicate skin, making it difficult to fit supporting braces. Roy-Camille (1980) has designed plates for the fixation of the occiput and upper cervical spine, fixed with screws, passing into the inner table of the occiput and into the cervical vertebral pedicles. Posterior cervical fusion is not always applicable because of the severe osteoporosis of the laminae and erosion of the posterior arch of C1. Trans-oral fusion may be useful.

e) Infective Lesions

Acute haematogenous osteomyelitis affecting the cervical spine may lead to acute or chronic compression of the spinal cord due to associated epidural abscess formation or to pathological subluxation of the vertebrae. Patients presenting with quadriplegia need urgent investigation, appropriate surgical treatment being planned on the results of myelography. In the case illustrated in Chapter 8 (Figs. 8.4a–c), it was on the basis of the myelographic findings that the decision was taken to perform a decompression laminectomy to drain the epidural abscess. Subsequently, the associated spinal deformity was treated conservatively, using skull traction in extension. Spontaneous interbody fusion followed, union occurring without significant residual spinal deformity.

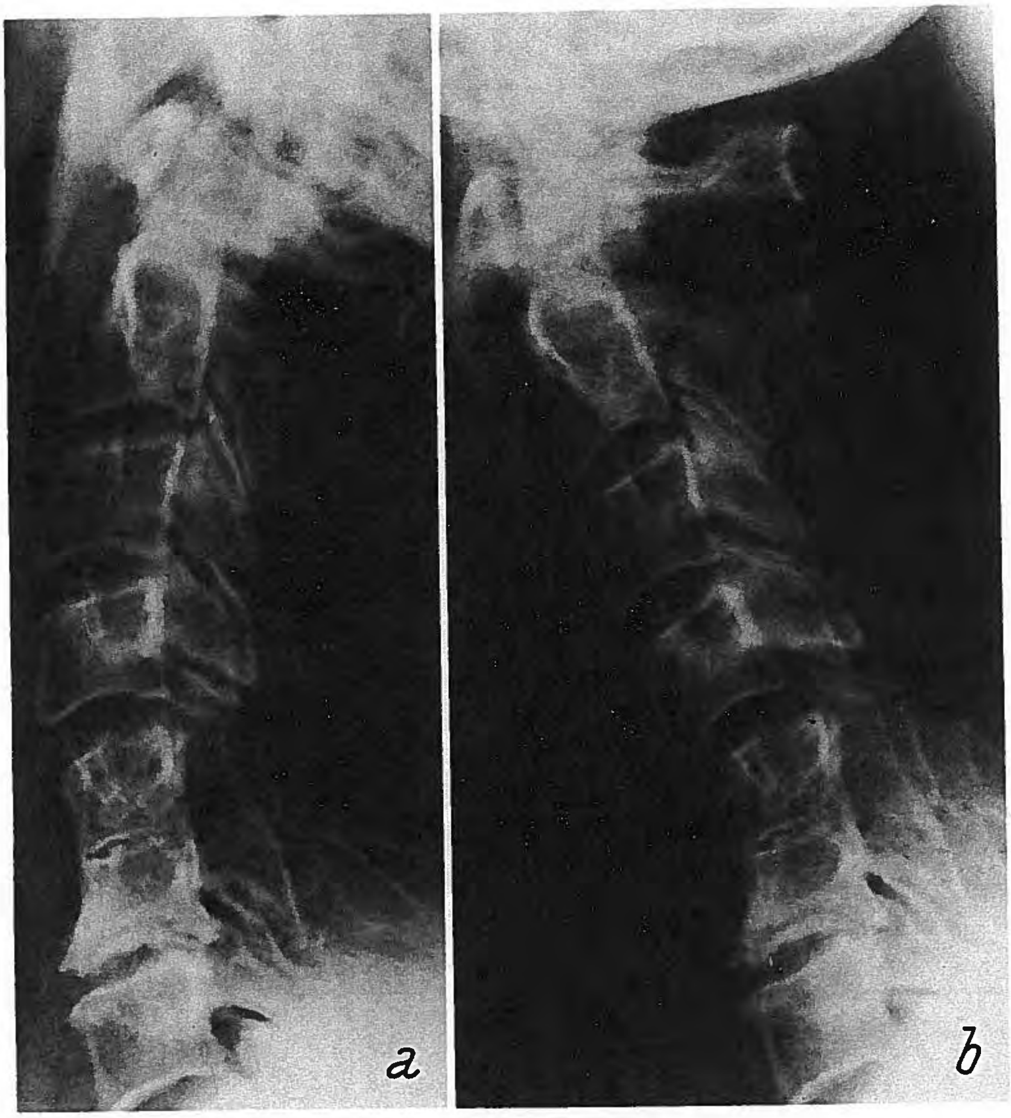
f) Tuberculous Infection

This may cause gross deformity in the neck. Trans-oral fusion of C1/2 involving the facet joints on both sides of the odontoid may be required.

More commonly, the disease affects lower cervical vertebrae where it is best treated by local debridement of carious tissue and anterior interbody fusion, see Chapter 8 (Figs. 8.12a, b).

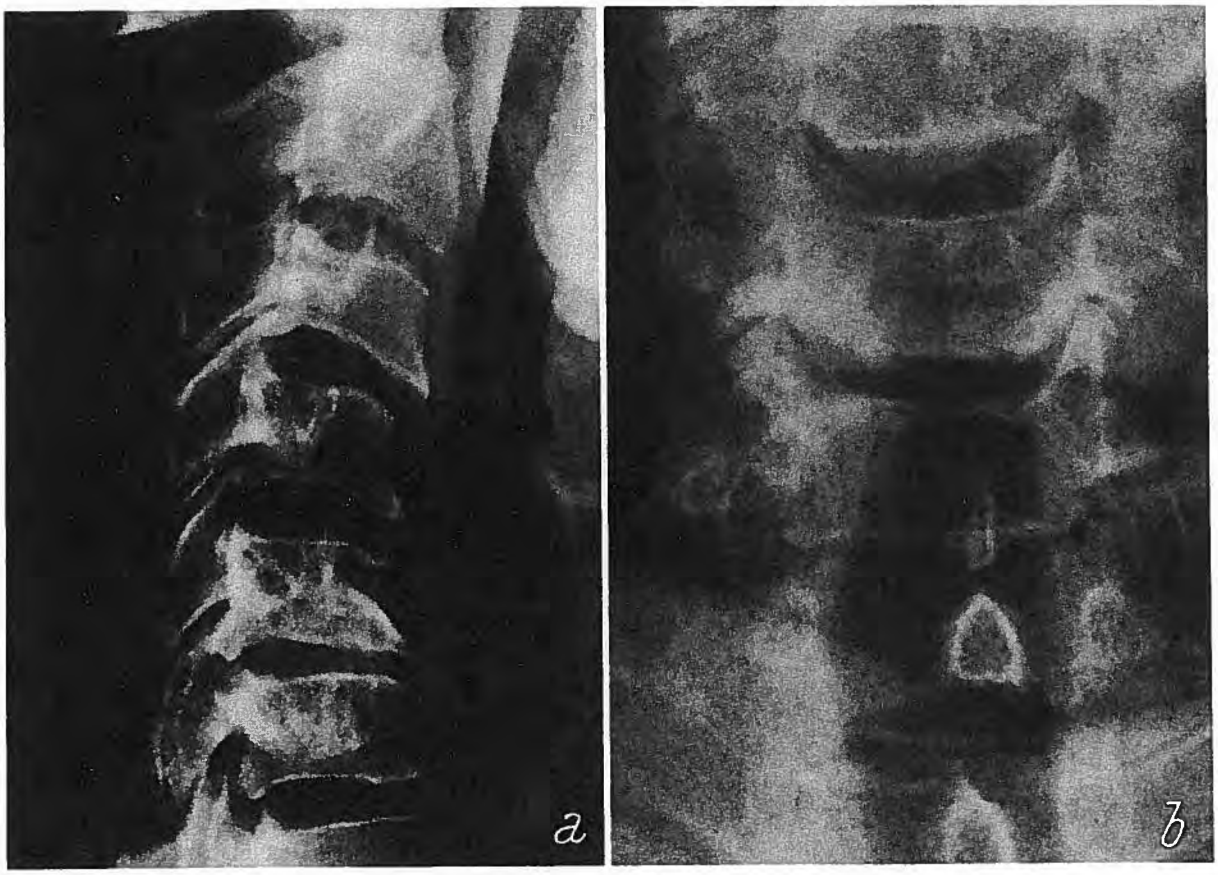
g) Congenital Abnormalities

Congenital fusion of cervical vertebral bodies is relatively common. Severe degenerative spondylosis is usually found in the adjacent vertebral segment below the fusion early in adult life. Occasionally vertebral instability will be found in the segment above the congenital fusion. Anterior cervical interbody fusions may be required for the treatment of either or both of these lesions (Figs. 7.2–7.8).



Figures 7.2. **a** A lateral radiograph of the cervical spine of a patient aged 40 years. Note the *congenital fusions between the bodies of C5 and C6.* Advanced degenerative changes have occurred at the disc between C6 and C7 with large osteophytes projecting posteriorly into the spinal canal. The disc between C4 and C5 appears normal in this view. **b** A lateral radiograph of the same spine in flexion showing instability at the C4/5 level

Figure 7.3. A lateral radiograph of the cervical spine of a woman aged 45 years showing *advanced cervical spondylosis* affecting the discs between the vertebral bodies of C4/5, C5/6 and C6/7. Large osteophytes project backwards into the spinal canal. This is an example of *post-traumatic disc degeneration* and post-traumatic cervical spondylosis, the patient having fallen from the height of 40 feet at the age of 8 years, injuring her neck. (Reproduced by kind permission of the Editors from: Handbook of Clinical Neurology, Vol. 25, Fig. 1, p. 483. Amsterdam-Oxford: North-Holland. 1976)



Figures 7.4. **a** A lateral radiograph of the cervical spine of a patient aged 55 years showing *localized advanced cervical spondylosis* at C5/6 with marked disc space narrowing and large osteophytes projecting backwards into the cervical spinal canal. **b** An antero-posterior radiograph of the spine of the same patient showing the advanced degenerative changes which affect the unco-vertebral joint regions, with osteophytes projecting laterally into the spaces through which the vertebral arteries pass on both sides

Figure 7.5. A detailed view of the facet joint between C1 and C2 on the left side of the specimen illustrated in Fig. 7.22. Note the relationships of the vertebral artery to this joint, from which the bulk of the capsule has been excised. In the operation of trans-oral fusion of C1 and C2, grafts are inserted into this joint space after removal of the articular cartilage and sub-chondral bone plates. The lateral capsule of the joint should be carefully preserved to avoid damaging the vertebral artery on the lateral aspect of the joint

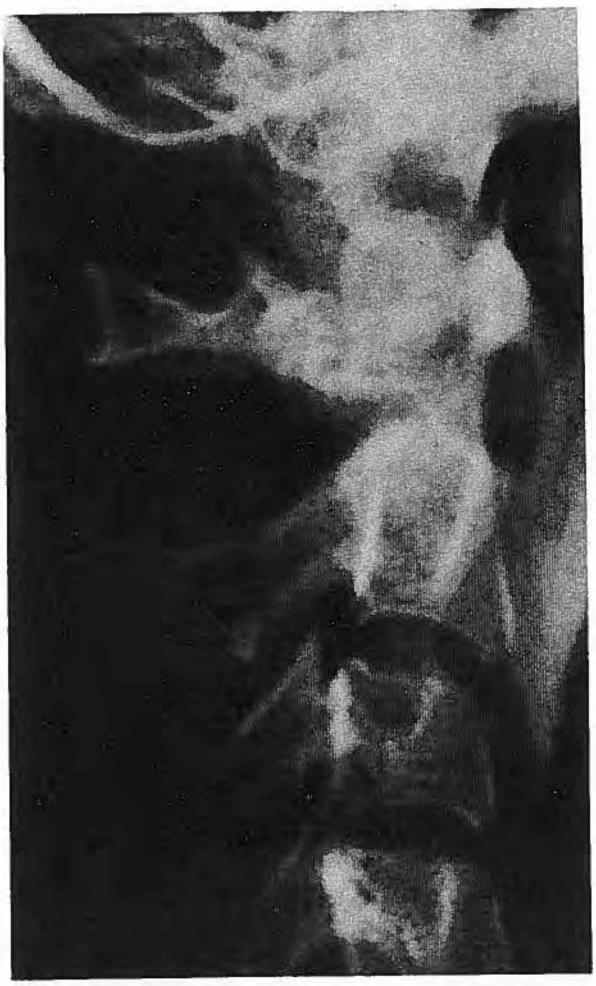
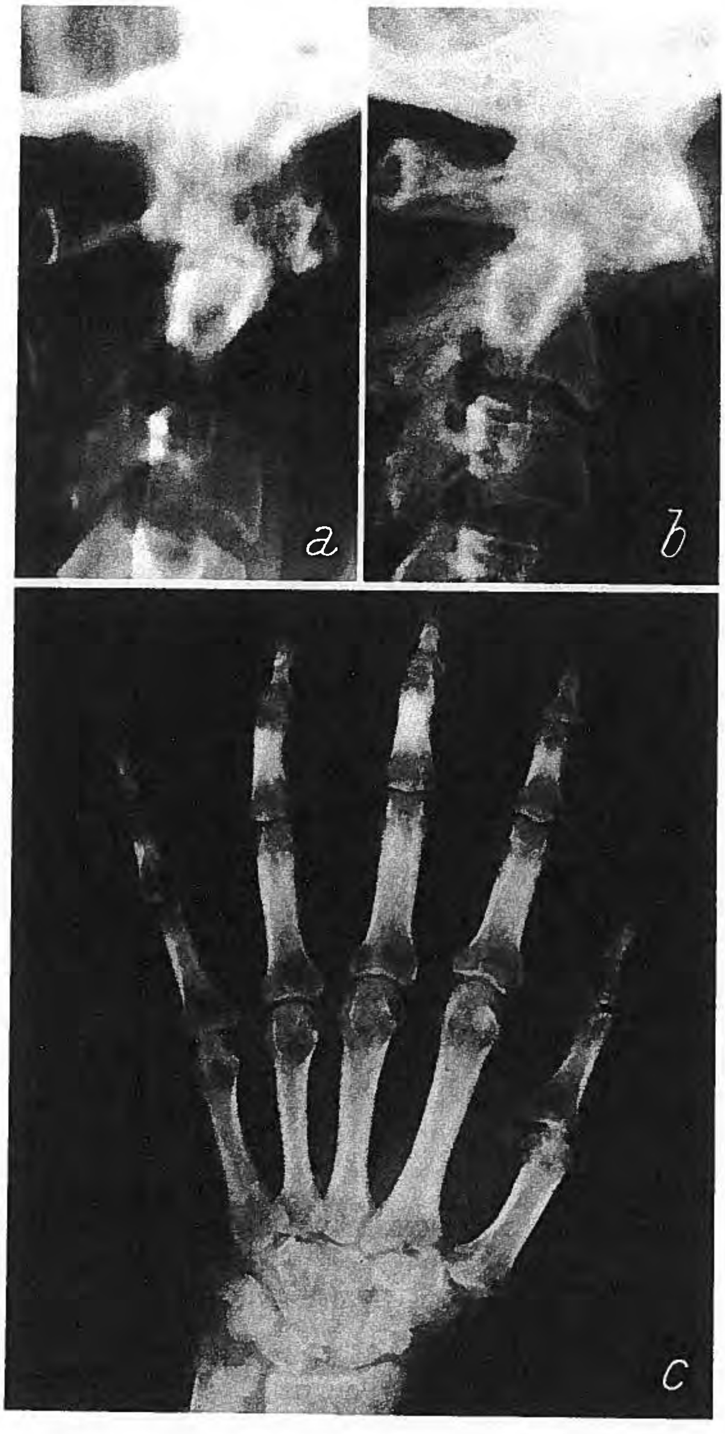


Figure 7.6. A lateral radiograph of the upper cervical spine of the patient aged 22 years, showing an *un-united fracture of the odontoid* following a neck injury sustained in a motor vehicle accident



Figures 7.7. **a** A lateral radiograph of the upper cervical spine in a woman aged 30 years, showing erosive changes in the region of the odontoid peg due to rheumatoid disease. **b** A radiograph of the same area of the spine in flexion, showing *instability between C1 and C2 due to rheumatoid joint disease* at that level. **c** A radiograph of the bones of the wrist and hand of the same patient showing the changes of juxta-articular osteoporosis in all the digital joints due to *rheumatoid arthritis*

Figure 7.8. A lateral radiograph of the cervical spine of a patient showing *gross kyphotic deformity* with localized degenerative changes between the vertebral bodies of C5/6 and C6/7–*following an extensive laminectomy* for the treatment of syringomyelia

7.3. Controversial Indications for Surgery After Spinal Injury Without Spinal Cord Damage

The incidence of neck injuries following motor vehicle accidents has increased dramatically in the past twenty years. In particular, the number of rear-end collisions, which occur when a moving vehicle strikes the rear-end of a stationary one, has increased enormously in most cities with large numbers of motor vehicles.

The much vaunted "whiplash injury of the neck" is usually sustained by the occupants of stationary cars in accidents of this type. *There is no consensus of opinion among surgeons* about indications for the use of surgical treatment in such patients.

Biomechanical studies have shown that enormous forces are transmitted through the head and cervical spine following this mechanism of injury.

Acting on the results of many of these investigations, car manufacturers have modified seat designs, incorporating head supports and restraining straps for the trunk. Such measures have been quite effective in reducing the morbidity arising from head and neck injuries in many of these accidents.

Despite the improvements in car design and the growing awareness of the hazards of neck injuries that may follow rear-end collisions, many patients still sustain injuries which cause protracted disability. Opinions among doctors vary widely, not only on the question of the causes of the persisting symptoms in these patients, but also on the methods of treatment which should be used to treat them.

The range of symptoms described may include the following:

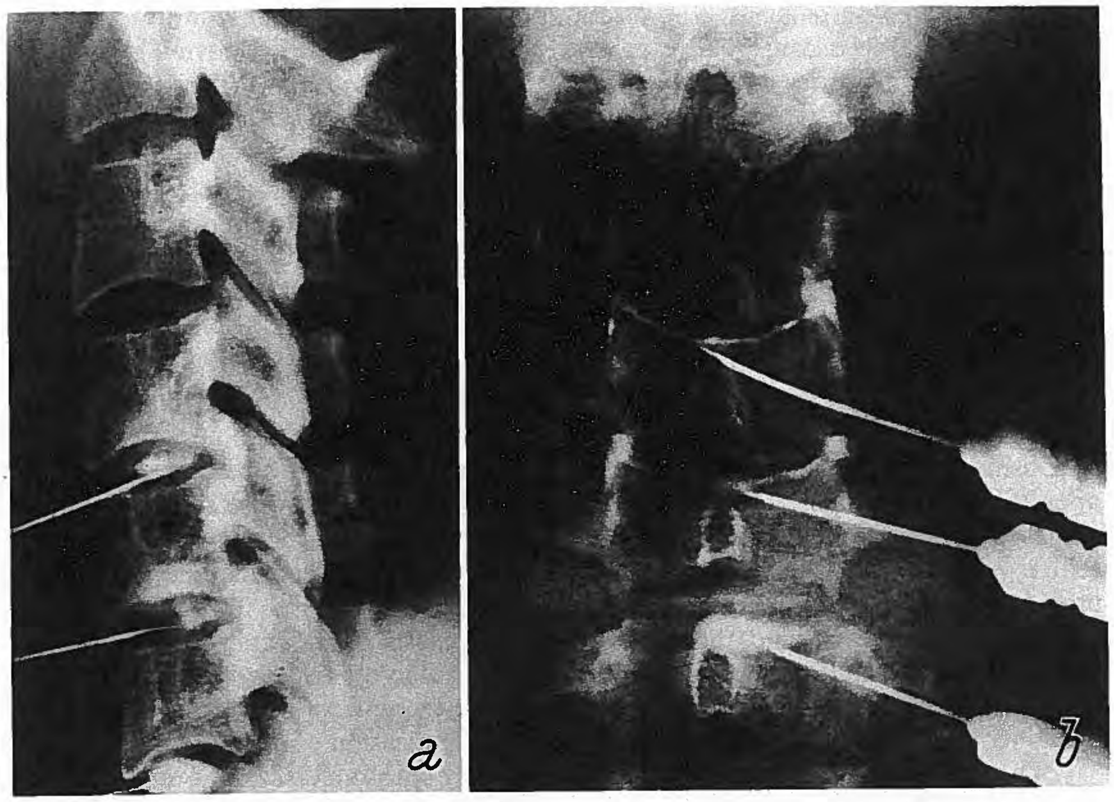
- Severe neck pain, neck stiffness.
- Occipito-frontal headaches, often with orbital pain.
- Earache and intolerance for loud noise.
- Mental depression.
- Defective memory after the accident.
- Giddiness.
- Varying patterns of arm pain with paraesthesia.
- Feelings of heaviness or weakness of the arms.
- Exacerbation of pain following physical activity or after physical exercise in the course of physiotherapy treatment.

Clinical examination is usually unremarkable. Apart from minor degrees of restriction of neck motion, there may be no objective abnormal physical signs, with particular reference to neurological examination. The only striking findings may be that they appear to be in severe pain, looking pale and downcast.

Having cared for many hundreds of victims of whiplash injuries of the neck in the past twenty years, a number of facts have impressed me:

1. The adverse effects of injuries are likely to be greater and disability more protracted following high speed impacts when the "victims" have been seated in vehicles *without head rests* on their seats.
2. These patients often seek treatment from many different doctors, each of whom may order new X-rays of the spine.
3. Many patients attend specialists only to be discouraged from further attendance if they fail to improve over the course of a few months.
4. The patients are often confused by conflicting advice about the diagnosis of their problems and by diametrically opposed views about treatment as they move from one doctor to another in their search for relief.
5. Despite the fact that abnormal neurological findings are rarely found on clinical examination–many of these patients will be subjected to cervical myelography, which is almost invariably normal. That information is often used, then, to re-enforce the advice that there is no surgical treatment indicated in their case.
6. These patients do not "get better with the passage of time" or after settlement of their court action.
7. Insurance payments to which they are legally entitled may be summarily reduced or stopped on the advice of a doctor acting for the insurance company on the basis of:

    a) Negative physical findings, except for the fact that the patient looks ill and pain-ridden.



Figures 7.9. **a** A lateral radiograph of the cervical spine in a girl aged 20 years showing discograms between the vertebral bodies of C4/5, C5/6 and C6/7. Extra-thecal leakage of dye has occurred in both of the upper discs while the C6/7 discogram is of normal appearance. **b** An antero-posterior radiograph of the spine of the same patient, showing a normal discogram at C6/7, with marked disruptive changes at C4/5 and C5/6 discs, in both of which dye leaks transversely across the vertebral interspace towards the unco-vertebral joint regions. This patient was suffering from *post-traumatic internal disc disruption* following a whiplash-mechanism of neck injury. Symptoms of intractable neck pain and occipital headache were relieved by anterior interbody fusions between C4/5 and C5/6. Reviewed 16 years later, she remained symptom free without radiological evidence of disc degeneration above or below the sites of the fusions

   b) Normal spinal radiographs.
   c) Normal myelogram.

8. The only useful diagnostic test, indicated after failure of carefully supervised conservative treatment–in a patient with a history of significant mechanism of injury–is Cervical Discography, to identify the level, or levels, of cervical disc disruption.
9. Many of the patients can be cured after cervical disc excision and interbody fusion.

Neglect of the use of cervical discography has been disastrous for those unfortunate patients suffering from *post-traumatic internal disc disruption* after injuries to the cervical spine (Figs. 7.9a, b).

Unquestionably, soft tissue injuries of the neck may occur in cases following "whiplash injury". Disability from muscle tears, haematomas and ligament "strains" cannot be the cause of protracted disability of the order of magnitude described by many patients. When conservative measures of treatment have been tried for four to six months after injuries of this type, and have proven ineffective, then it is time to think of the possibility of a non-prolapsing disc injury–post-traumatic internal disc disruption–as the underlying cause of the continuing symptoms. Time then to order cervical discograms.

7.4. Cervical Discography

The test is performed on the conscious patient with light sedation. The needles used for this investigation are smaller in calibre than those used in the lumbar spine (Fig. 7.10). They are usually inserted through the right side of the neck, anteriorly, by pushing the mid-line structures of the neck across to the left side with the operator's index finger. Control X-rays are taken in antero-posterior and lateral planes to ensure accurate placement of the tip of each "discogram needle" in the centre of the nuclear zones of the discs before dye is injected (see Chapter 2, pp. 44–56).

Spread of dye beyond the zone of the nucleus pulposus may occur, into the unco-vertebral joint areas on both sides, while leakage backwards into the spinal canal (extra-thecal) may indicate a posterior disc disruption. Spread of dye results from incompetence of annular fibres and is not an indication of disc prolapse as such.

The pain response provoked by injection of dye into the disc is not related to the volume injected or to the resultant increase in intra-discal pressure; rather, it is due

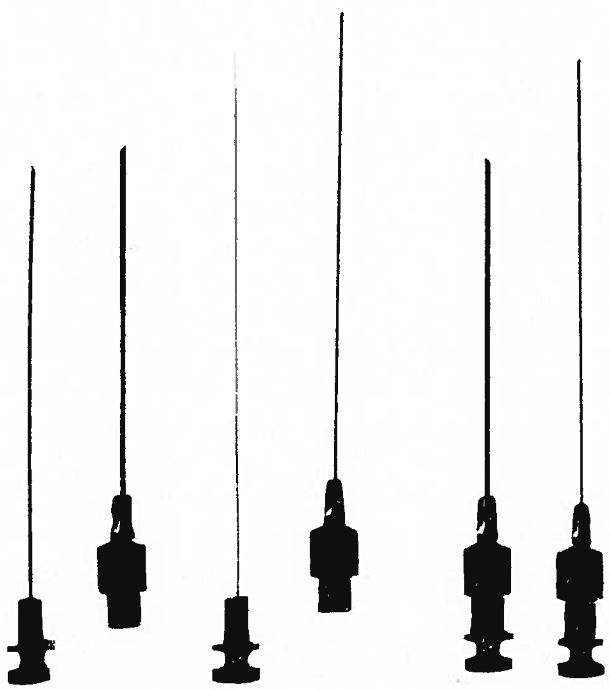


Figure 7.10. A photograph showing a gauge 25 "discogram needle" on the right of the picture with a gauge 22 "guide needle" alongside. On the left of the picture the stilettes are shown alongside their respective needles

to irritation by the dye of the sensitized pain fibres within the disrupted disc itself. Hence, the pattern of pain distribution is not strictly segmental and it does not follow the dermatomes in the upper limbs–as has been suggested by many writers. Use of cervical discography should be reserved for the investigation and demonstration of non-prolapsing disc disorders. By contrast, neither myelography nor C.T. scanning will help to identify the level of a disc with internal disruption. These find their proper application in the investigation of cases with disc pathology producing space-occupying lesions in the vertebral canals.

On December 14, 15, 16 in 1965, Holt performed *30 lumbar discograms* in volunteers at the Menard Penitentiary in Illinois, U.S.A. In a number of "patients" good pictures could be obtained in only two of the lower three lumbar discs.

How is it that the medical profession accepted this *experiment* as evidence that discography was not useful?

The identification of isolated examples of disc disruption, confirmed by discography in patients whose plain radiographs were normal, correlated with the clinical syndromes and relieved by disc excision and cervical interbody fusion should help to cast doubt on the results of that three day sortie into discography performed in patients without symptoms–(for what return?)–in a penitentiary.

7.5. Technique of Anterior Cervical Interbody Fusions

a) Instruments

Dowel cutting instruments permit these operations to be performed accurately at each attempt. Their use in most cases is preferred to the use of chisels or osteotomes for this reason and for the added safety afforded during operation by the safety devices built into the design of Cloward and Crock cutters. Photographs of essential instruments are found in Figs. 7.11–7.16, with descriptive legends outlining details of their assembly and use.

b) Positioning

Patients are placed supine on the operating table. A small wedge-shaped pillow should be placed under the shoulders, with a rolled towel supporting the hollow of the neck, the occiput resting in a rubber ring. The patient's eyes should be protected and the anaesthetic tubes securely fixed to the face (Fig. 7.17).

c) Incisions

Right-sided hemi-collar incisions can be used for approaches to any of the cervical discs, from that between C2 and C3 vertebrae to the lowest in the cervical spine. The use of longitudinal incisions is not recommended as they may result in unsightly scars.

The platysma muscle is exposed by separating subcutaneous fat from its superficial surface before the muscle is cut in the line of the skin incision. Its edges are then under-cut, using blunt dissection to raise flaps for several centimetres

Figure 7.11. A photograph showing the Crock instruments used for dowel cutting in the operation of anterior cervical interbody fusion. On the right of the picture is a Hudson brace. Cutters of three sizes are shown. The starter centre pieces have been removed from each of these. On the right of the cutters is a pusher, which fits inside the cutters and can be used to eject the starter centre pieces or graft bone. On the left of the cutters a pusher is shown with a tubular segment of metal measuring 12.5 mm in depth. When this "dummy" is slotted into the cutter it acts as a guard, preventing the cutter from penetrating deeper than 12.5 mm into the cervical vertebral bodies. Dummies are provided in three sizes, 10 mm, 12.5 mm and 15 mm, for use according to the vertebral dimensions in individual cases. On the left of the photograph, two tooled gouges are shown, which will fit into the cuts made into adjacent vertebral bodies. Their use is illustrated in Figs. 7.20, 7.24 a. *Note that the cutters have circular rings marking their outer surfaces, at intervals of 5 mm.* Instruments manufactured exclusively by Thomson & Shelton Instrumentation Company, 6119 Danbury Lane, Dallas, TX 75214, U.S.A.

Figure 7.12. A photograph of Cloward's equipment for cervical spine fusion operations, with spiked tubes allowing adjustment to determine the depth of cuts made into the vertebral bodies on either side of the disc space during interbody fusion. Note the twist drills which are used to remove the bone and disc tissue. *With this system* inevitably some *disc tissue is ground into the adjacent vertebral bodies* and *this may lead to non-union of grafts on occasions*

Figure 7.13. A photograph of the self-retaining retractor designed by Cloward for use in anterior cervical fusions

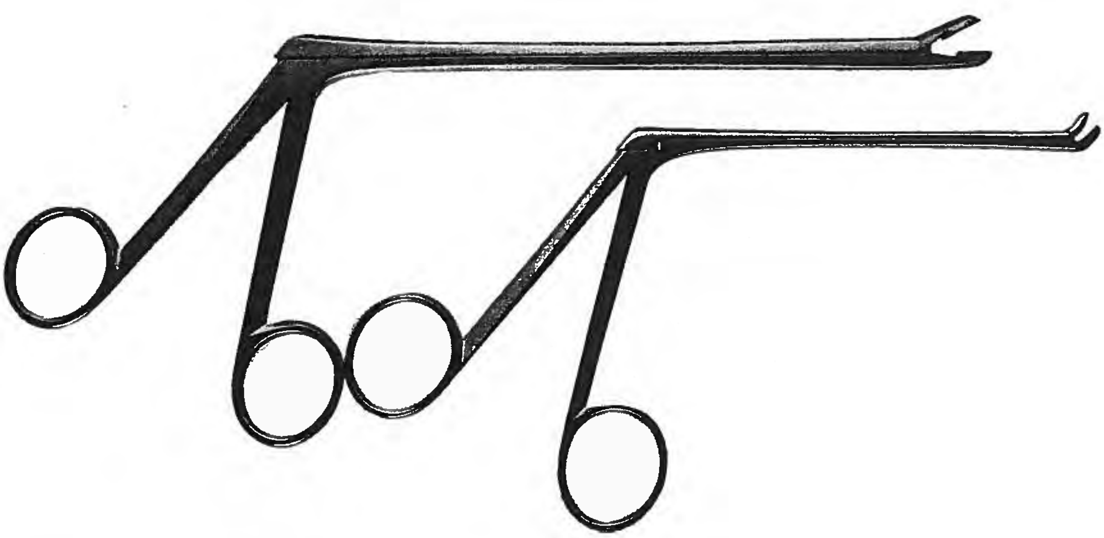


Figure 7.14. A photograph showing fine, straight and forward-angled pituitary rongeurs suitable for use during anterior cervical interbody fusion operations, for removing remnants of vertebral end-plates and disc tissue following curettage of the disc space

Figure 7.15. A photograph of two cervical retractors with smooth excavated ends designed to be held transversely across the anterior surfaces of the cervical intervertebral discs

Figure 7.16. A photograph of a Bayonet forceps with a fine tip, essential for use in cervical spine operations

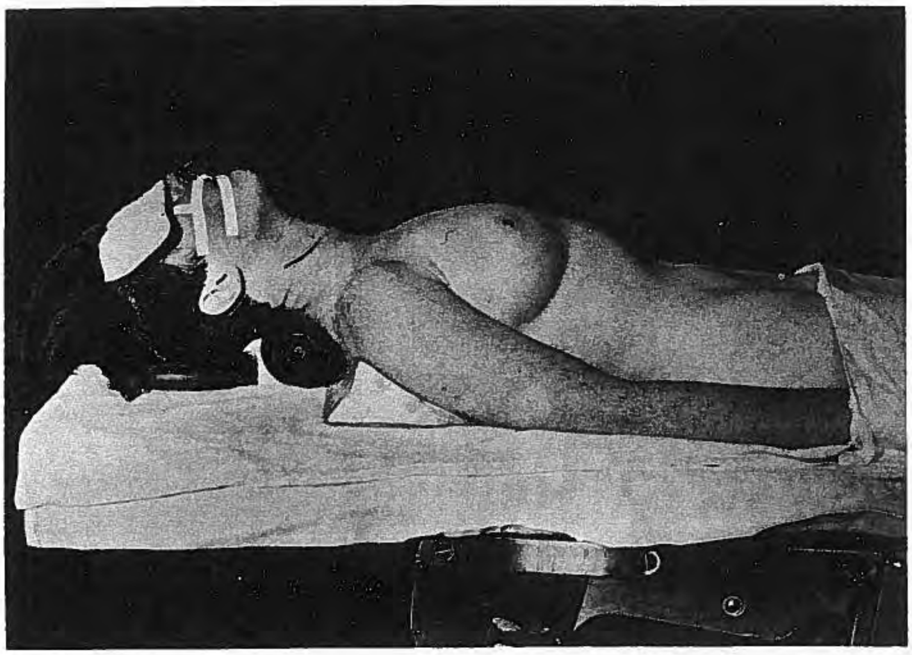


Figure 7.17. A photograph of a patient postured on the operating table for anterior cervical interbody fusion. Note the triangular-shaped pillow underneath the shoulders, the rolled towel (in black) under the neck, and the rubber ring on which the occiput rests. The endotracheal tube and the reinforced rubber airway adjacent to it are strapped to the patient's face. Note the pad covering the eyes, to prevent pressure on the orbits during surgery. Assistants have been known to press on the eyes during anterior cervical interbody fusion operations. *Irreparable ocular damage has been reported from this cause.* Note also the outline of the hemi-collar incision extending from the anterior border of the sterno-mastoid muscle to just behind the mid-line. Through this incision two or three cervical discs can be exposed. For exposure of the disc between C2 and C3 vertebral bodies, the incision needs to be placed in the sub-mandibular region, care being taken to avoid damaging the mandibular branch of the facial nerve. Note that both arms are by the patient's side, to allow traction on the hands for lowering the shoulders while control X-rays are being taken during the operation

upwards and downwards. The encircling layer of deep cervical fascia is then incised along the anterior border of the sterno-mastoid muscle, allowing access to the space between the carotid sheath laterally and the mid-line structures of the neck medially. The fascia along the lateral edge of the superior belly of the omohyoid muscle is cut with Metzenbaum scissors until the lateral edge of the oesophagus can be seen. Inserting his index finger into the space now created, the surgeon can palpate the front of the vertebral column. By moving his finger deliberately and carefully along the antero-lateral margin of the vertebrae, a plane of cleavage can be opened easily in the loose fascia between the carotid sheath and the mid-line structures of the neck over a distance sufficient to allow exposure of one, two or three of the cervical intervertebral discs.

Most cervical fusions are performed at the levels of C4/5, C5/6 or C6/7. Having cleared the space as indicated, retractors may then be inserted, orientated transversely and applied to the anterior aspect of one of the intervertebral discs. Up to this point the only major anatomical structures encountered will have been the ones already mentioned. Only occasionally will it be found necessary to ligate and divide an anterior cervical vein or some un-named venous tributary of the internal jugular vein. The superior thyroid vessels may be seen, but it is rarely necessary to ligate and divide them.

The pre-vertebral fascia, that thin, filmy, opalescent membrane which sheaths the paravertebral muscles and the cervical column itself, is split longitudinally in the mid-line and the retractors re-positioned to give a clear view of the intervertebral discs and anterior aspects of the vertebral bodies. The medial edges of the right and left-sided longus colli muscles can be seen clearly and, using fine bayonet forceps (Fig. 7.16), the vessels related to the muscles at their attachments along the antero-lateral aspects of the vertebral bodies are coagulated with diathermy. These muscular attachments are then separated from the vertebrae and discs, so that the cervical retractors may be replaced once again, to provide definitive clear exposure of the disc or discs to be removed. The risk of obstructing the carotid vessels during operation is reduced by this method.

d) The Thyroid Gland

Before planning cervical discography and anterior cervical spine surgery in any patient, the surgeon should examine the patient's thyroid gland. On three occasions in twenty years of practice, I have had patients in whom thyroidectomy has been required before satisfactory access to the anterior aspect of the cervical vertebral column was possible.

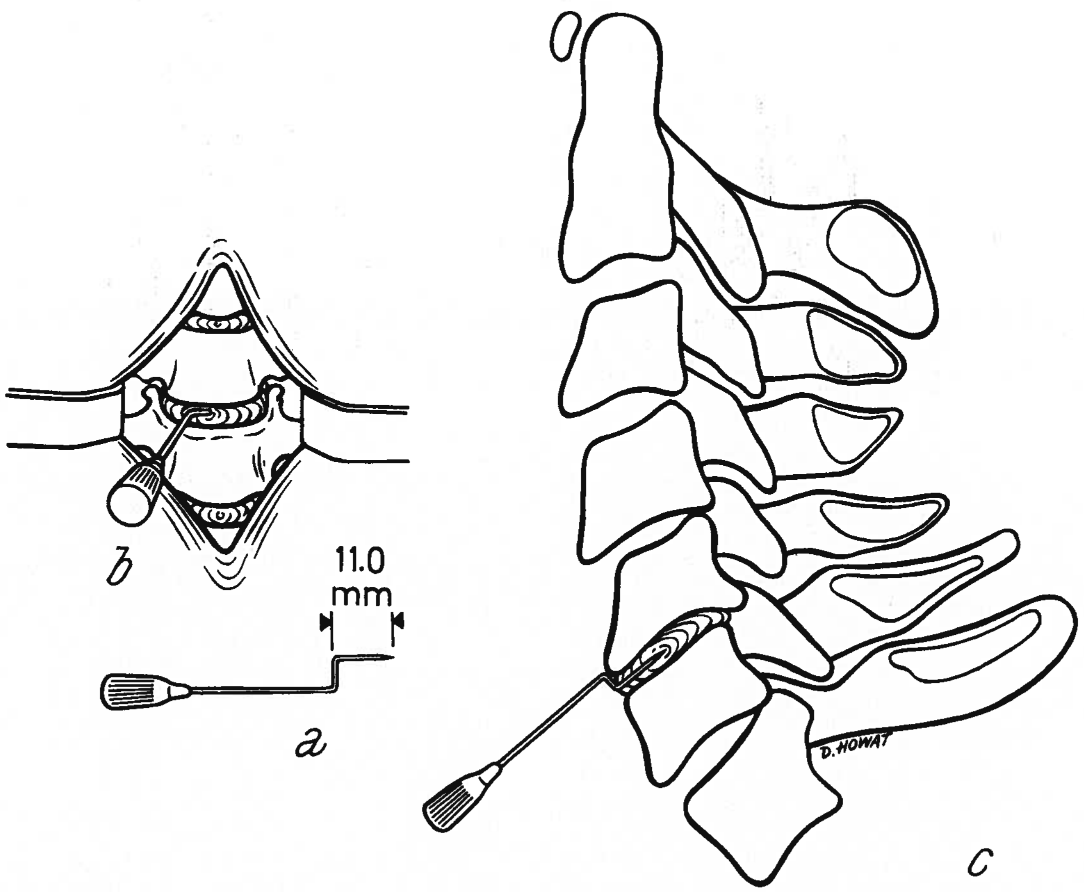
e) Control X-Rays to Identify Individual Intervertebral Discs

The use of a specially bent disposable needle is recommended before lateral X-rays are taken. The needle serves a dual purpose, allowing also the precise measurement of the antero-posterior width of the disc space (Fig. 7.18). Never remove the needle before the control X-ray has been exhibited in the operating room.

f) Preparation of the Dowel Cavity

The relevant anatomy of the spine and the steps in this critical phase of the operation are illustrated in detail in Figs. 7.18–7.24. Once cutting instruments have been applied to the vertebral bodies *the potential hazards of injuring the vertebral arteries or the neural structures in the spinal canal must be borne in mind* (Figs. 7.1a, b).

Having made the preliminary cut across the disc space, the starter centre piece is removed from the cutter. The surgeon then selects the "safety dummy" of pre-determined size, by re-checking the antero-posterior measurements of the disc space. He then personally assembles the cutter ready for use by inserting the "dummy", which is held in place by the "pusher device". Both the assistant surgeon and theatre sister should check the preparation of the cutter with the "dummy" and cross-check the disc space measurements before the surgeon re-inserts the cutter–after stage one–to commence the final preparation of the dowel cavity.



Figures 7.18. **a** A drawing to illustrate the use of a bent needle recommended by the author for use during control X-rays in the neck. A disposable 19 gauge needle is prepared by bending it in the jaws of an artery forceps. A right-angle bend is made near the tip and the measurement between the tip and the first right-angle bend taken. Usually 11.0–12.5 mm is satisfactory, depending on the size of the patient. **b** A drawing to depict the front of a cervical intervertebral disc with the needle in place for control X-ray during operation. **c** A drawing of the cervical spine shown from the side depicting the use of the bent needle for control X-ray. The right angle bend *prevents penetration of the needle into the cervical canal,* a potential risk if a straight needle is inserted. *It has the added advantage of allowing precise measurement of the intervertebral disc space on the control X-ray* when it is brought back into the theatre

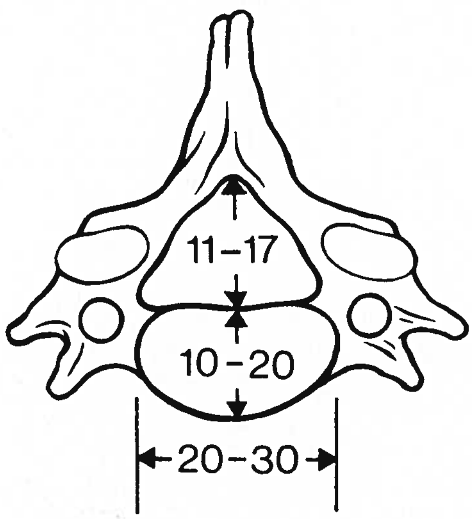
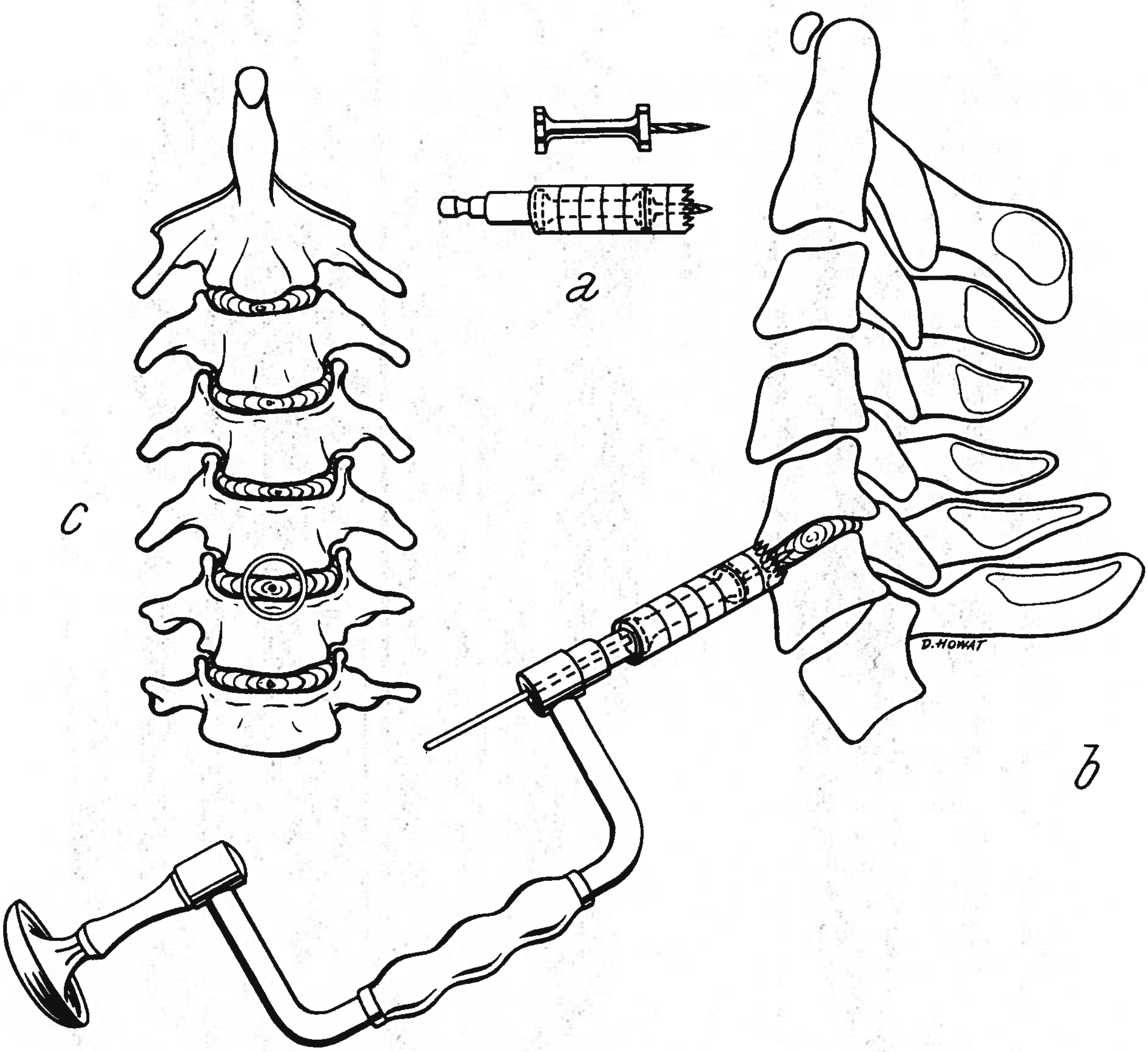


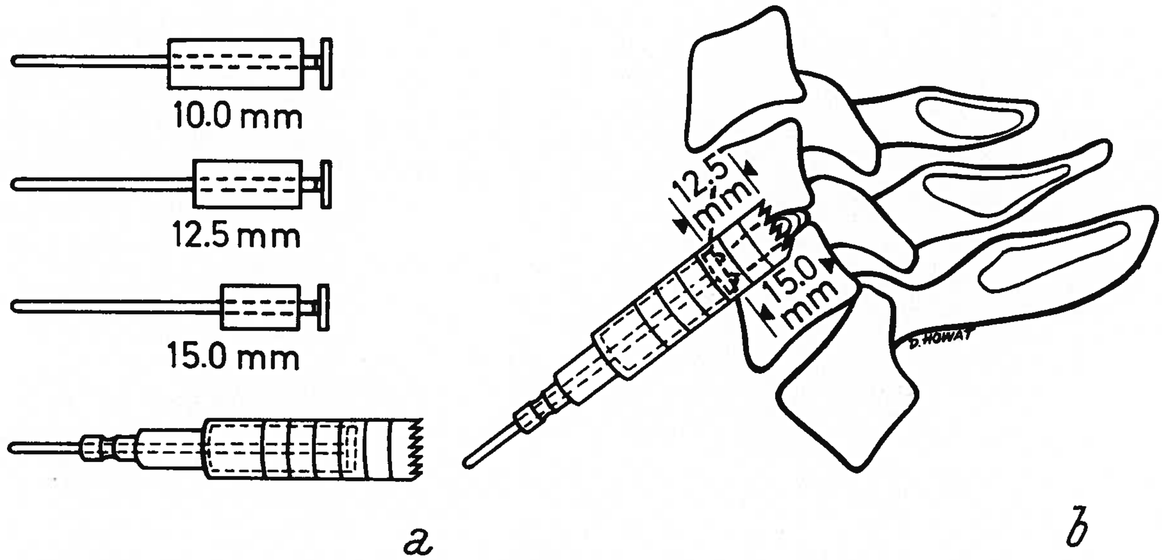
Figure 7.19. A drawing of a typical cervical vertebra *with the ranges of measurements in millimetres* of the transverse and antero-posterior diameters of the vertebral body and the antero-posterior diameter of the cervical canal



Figures 7.20. a A drawing showing a starter centre piece at the top. Below it, the starter centre piece is shown in outline, assembled in the zero-size cutter. Note the circumferential markings on the cutter, each separated from the other by 5 mm. **b** A drawing of the cervical spine, viewed from the side, showing the cutter assembled on a Hudson brace with the starter centre piece in position and the pusher within the tube. The drawing depicts the method of commencing the preparation of a dowel cavity between the vertebrae of C5 and C6. **c** A drawing of the cervical spine viewed from in front, showing the outline of the cut in the mid-line between the vertebral bodies of C5 and C6, at the first stage of preparation of the dowel cavity

Errors made at this stage may lead to catastrophic accidents during the operation.

Having re-fitted the cutter into the preliminary circular slot cut during stage one (Fig. 7.20), it should be oscillated clockwise and counter-clockwise, avoiding wobbling motion as the Hudson brace is being rotated. No force is to be exerted on the proximal end of the brace, other than that required to steady it with one hand, while the surgeon's other hand holds the off-set central bar through which the oscillating motion is transmitted to the cutter.



Figures 7.21. a A drawing to show the range of metal dummies available for insertion into the zero-size cutter, allowing the preparation of dowel cavities of pre-determined depth, depending on the depth of the disc space in individual patients. *The depth of the space is checked at operation by control X-ray with the use of the bent needle as indicated in Fig. 7.18.* At the bottom of the drawing, note the dummy assembled inside the cutter. **b** A drawing to depict the cutter in use, *demonstrating the mechanism of safety protection provided by the 12.5 mm dummy* which has been inserted after removal of the starter centre piece. *Note also that the surgeon is able to count the rings on the outer side of the cutter, providing a double safety factor.* (See pp. 199–202 for a detailed description of the technique for cutting the dowel cavity)

As the cutter advances slowly into the vertebral bodies and intervening disc tissue, *the operator becomes aware of a grating sensation* at its cutting end, from which an audible grating sound is emitted. The "dummy" inside the cutting cylinder will abut against the anterior surface of the disc and adjacent vertebral margins when the cutter has reached the depth that is determined by the length of the "dummy" (Fig. 7.21). Further penetration of the cutter into the vertebral bodies is thereby prevented. At this stage, the grating sensation ceases and the cutter spins smoothly and silently. For added safety, while the cutter is being oscillated, the surgeon may check the measurement of its advancement by counting the rings on its outer surface.

In the third stage of the preparation of the cervical dowel cavity, special tooled gouges are used to displace the fragments of vertebral bodies and intervertebral disc

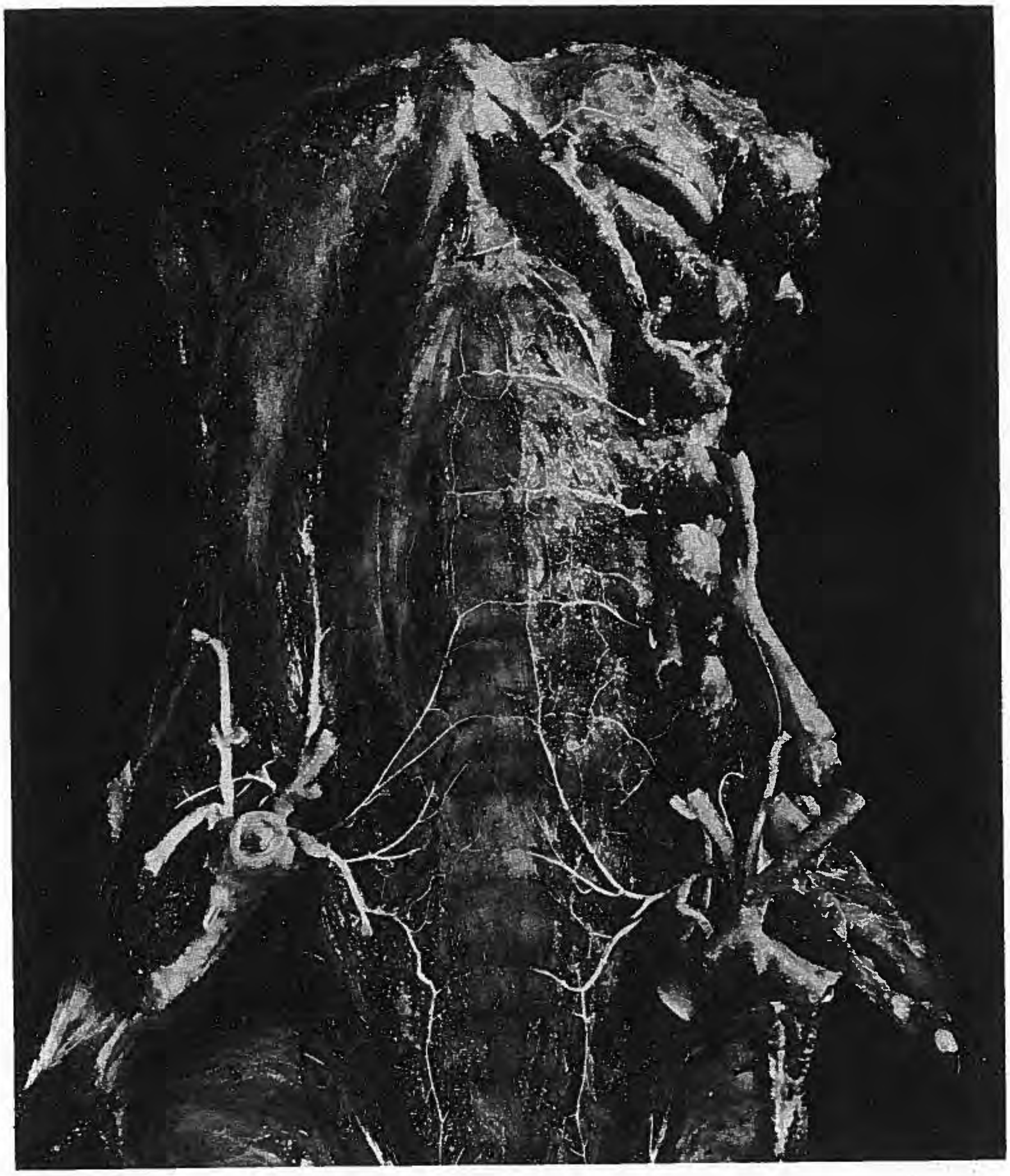


Figure 7.22. A photograph of a dissection of the anterior aspect of the cervical and upper thoracic spine of a female child aged 3½ years, showing the origins and courses of arteries supplying the antero-lateral aspects of the vertebral bodies. The longus colli muscles have been removed from the left side of the specimen. The pre-vertebral fascia has also been removed but the anterior margin of the longus colli at its attachment to the antero-lateral aspects of the vertebral bodies on the right side is intact. Note the vertical chain of arterial anastomoses running along the margin of this muscular attachment, forming a parallel vascular channel with corresponding vessels on the left side of the vertebral column. (Dissected by Dr. H. Yoshizawa, reproduced from: Crock, H.V., Yoshizawa, H.: The Blood Supply of the Vertebral Column and Spinal Cord in Man. Wien-New York: Springer. 1977)

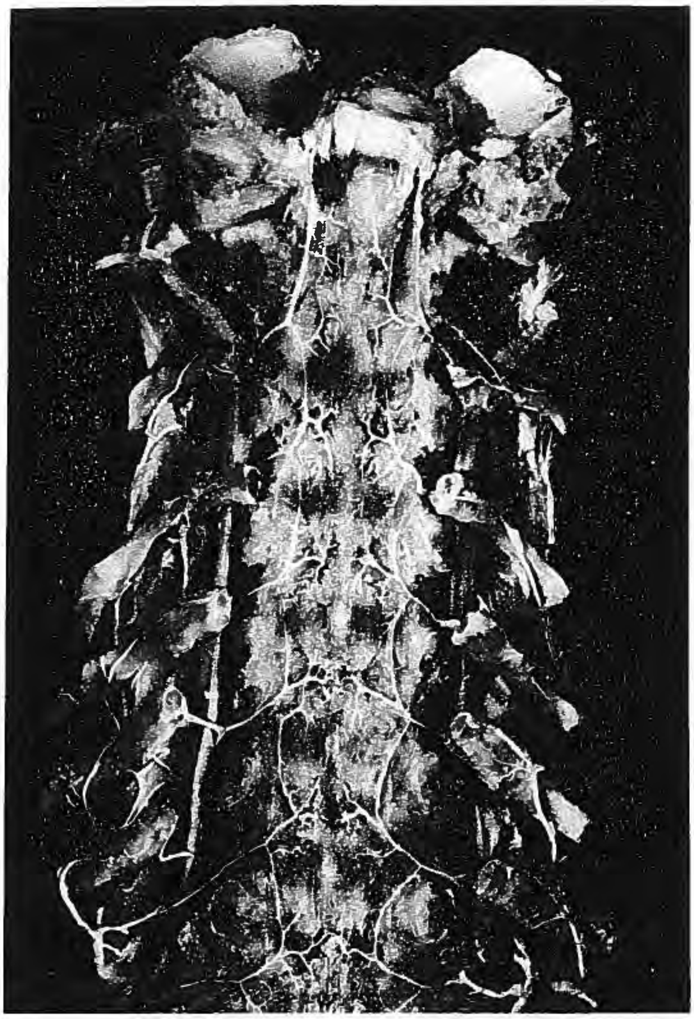
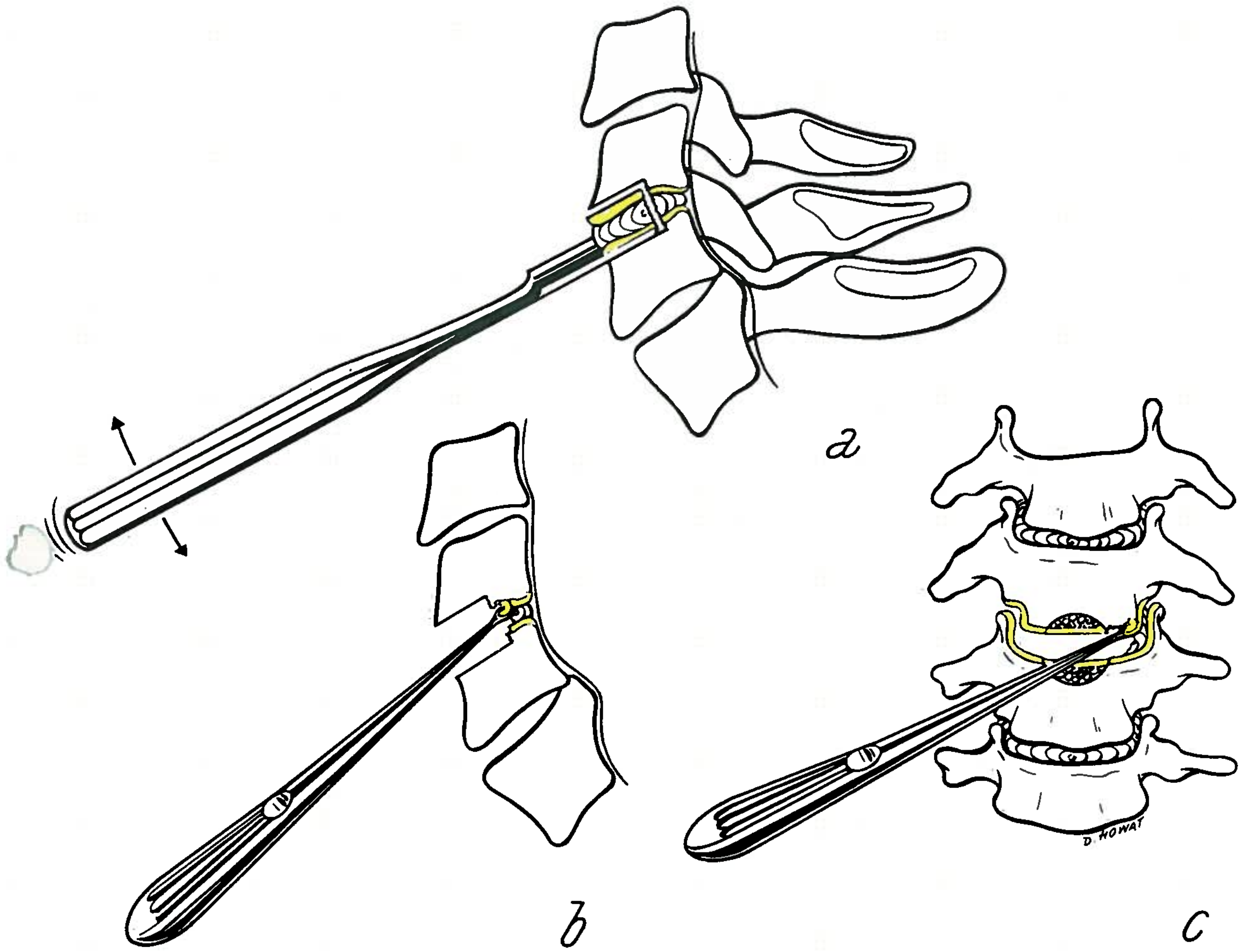


Figure 7.23. A photograph of a dissection of the posterior aspect of the cervical and upper thoracic spine of a male aged 34 years. The posterior aspects of the vertebral bodies have been exposed and portions of the posterior longitudinal ligament have been removed from a number of vertebral bodies in the lower part of the specimen. In the upper part of the specimen on both sides, the origins of the anterior spinal canal branches of the vertebral arteries can be seen. In the neck, these vessels form the familiar arcuate arterial pattern on the anterior surface of the spinal canal which is found along its length. The vessels contribute to the intra-osseous arterial supply of the vertebral bodies, anastomosing with branches from the vascular chains demonstrated in Fig. 7.22 on the anterior aspect of the vertebral column. In the operation of anterior cervical interbody fusion the blood supply of the vertebral body remains largely intact, ensuring rapid vascularization of grafts



Figures 7.24. **a** A drawing to show the method of use of the tooled gouge for removal of the plug of the vertebral bodies and disc following the use of the cutter as depicted in Fig. 7.21b. **b** A drawing to illustrate the use of a fine curette (2 mm cup) for removal of the vertebral end-plate remnants shown in yellow–after the plug of disc tissue sandwiched between vertebral end-plate margins has been displaced with the gouge and removed with a straight pituitary rongeur. **c** A drawing depicting the use of the fine curette (2 mm cup) showing the prepared dowel cavity from in front with the curette removing remnants of vertebral end-plate cartilage and disc tissue in the region of the left-sided unco-vertebral joint. It is possible to remove virtually all disc tissue and vertebral end-plate remnants in this manner

from the spine (Figs. 7.24a–c). If the disc has been of normal dimensions, after using the gouge in the manner illustrated, first on one side of the disc, then on the other, it is usually possible to remove the plug of bone and intervening disc tissue in one piece.

In cases of advanced spondylosis, where the opposing vertebral end plates are sclerotic, being separated by thin unyielding remnants of disc tissue, it may be necessary to curette the remnants of the disc tissue from between the arcuate segments of vertebral bodies before these bony fragments can be displaced with the gouges.

When the base of the dowel cavity has been exposed, brisk haemorrhage may occur from arteries and veins in the vertebral bodies. This is controlled easily by applying small quantities of bone wax to the cut surface of the vertebral bodies, only at the site of bleeding.

The fourth and final stage of preparation of the intervertebral space now commences, leading up to the actual impaction of the bone graft. Vertebral end-plate cartilage remnants are removed with a fine curette (1 or 2 mm cup)–disc remnants attached–as illustrated in Figs. 7.24b, c. Care is taken to avoid damaging the vertebral arteries (Figs. 7.1a, b).

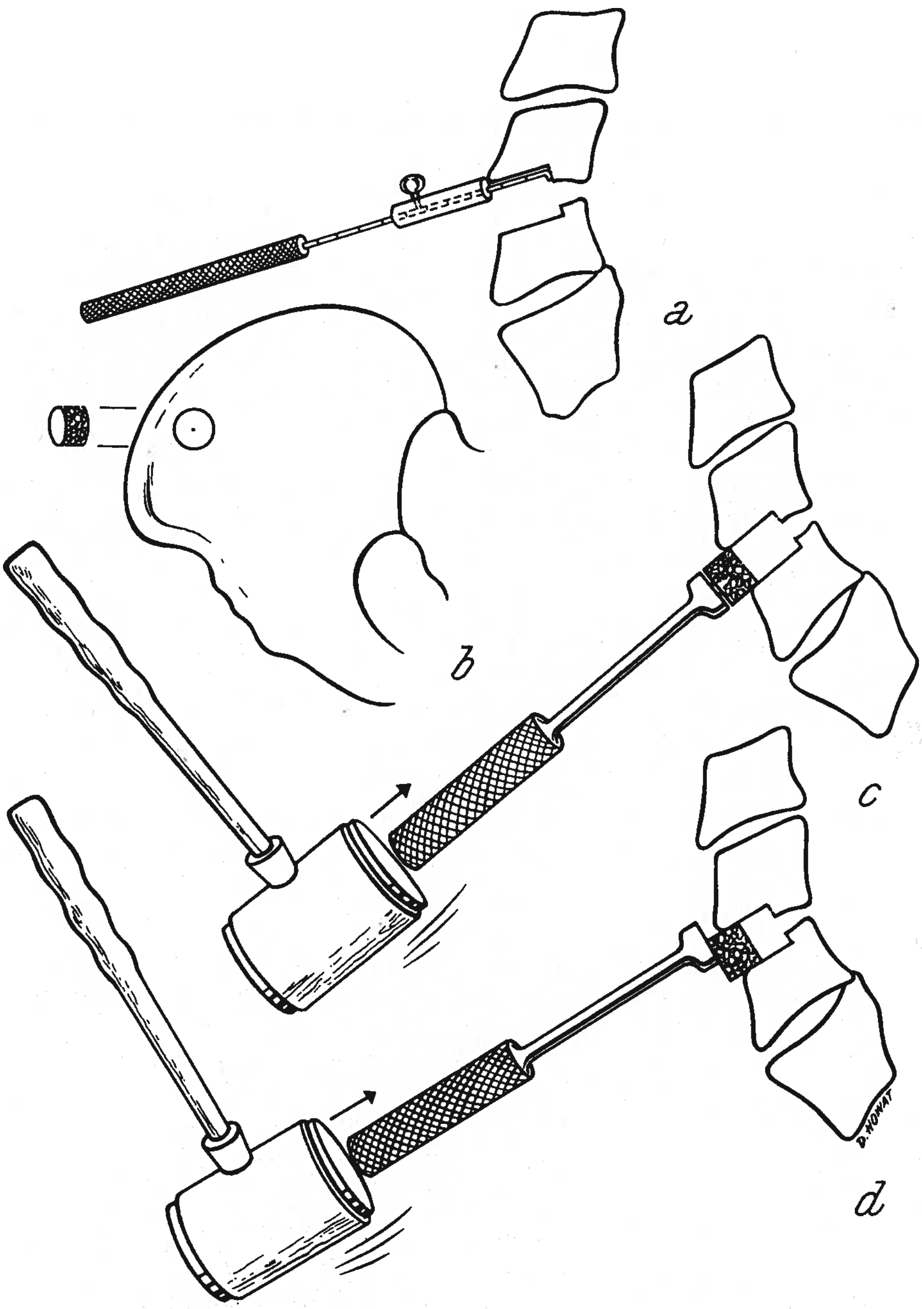
Longitudinal traction applied to the skull by the anaesthetist will result in opening up of the intervertebral space, allowing the surgeon to see the posterior longitudinal ligament in the depths of the dowel cavity. Through visible defects in this ligament in cases of sequestration of disc fragments into the cervical spinal canal, it is possible to remove the displaced disc tissue from the canal.

Excision of osteophytic bars of bone from the anterior aspect of the cervical spinal canal may be required in cases of cervical myelopathy. Depending on the transverse width of the disc, two overlapping dowel cavities may be cut, allowing a wider exposure for this delicate–and potentially dangerous–task. The use of high speed drills is recommended by some surgeons. My personal preference is for the use of strong fine angled curettes to fragment these bars, allowing their removal piecemeal with the help of fine pituitary rongeurs. One should aim to make the initial entry into the cervical canal from the side of the intervertebral disc space.

g) Graft Preparation

While waiting for the control X-ray film to be developed, autogenous grafts should be cut from the anterior third of the iliac crest. If only a single graft is required, this may be cut through a small vertical skin incision placed 2 or 3 cms behind the anterior superior iliac spine, splitting the fibres of tensor fascia lata in the line of the

Figures 7.25. a A drawing of the cervical spine, viewed from the side, showing a prepared dowel cavity between two vertebral bodies with a *depth gauge inserted to measure the depth of the cavity before the graft is inserted.* **b** A drawing of the pelvic crest to show the site of removal of a plug of bone which is cut from the outer table and through the inner table. The measurement of this graft between the two cortical faces varies, depending on the size of the patient's pelvis. Grafts should be trimmed so that the anterior and posterior margins are parallel. The depth of the anterior iliac crest between the inner and outer cortical tables varies between 5 and 15 mm. In patients in whom the pelvis is thin (3–5 mm between outer and inner cortices), it may be necessary to cut grafts vertically downwards from the top of the crest, by the method used in lumbar interbody fusions. **c** A drawing to show the initial stages of impaction of the graft, *the measurement of which has been checked carefully with the measurement of the prepared dowel cavity. At this stage the anaesthetist is asked to elongate the neck by applying traction under the angles of the mandible.* **d** Final seating of the graft is sometimes necessary if the anterior margin is not flush with the anterior vertebral margins after the use of the initial impactor which has a central nipple on it, as illustrated in (c) above. The manoeuvre shown is performed with a plain-ended impactor and *it is important to note that the impactor is placed half-way across the graft and half-way across the adjacent vertebral body so that when a blow is struck with the hammer it is impossible to drive the graft too deeply into the dowel cavity,* the impactor coming to rest on the anterior vertebral margin; thus it is prevented from plunging too deeply into the prepared dowel cavity. *Accurate seating of the graft is essential if the complications of graft rotation or post-operative prolapse are to be avoided*



Figures 7.25

skin cut. *The cutting cylinder must be one size larger than that used to prepare the dowel cavity in the neck.*

When more than one graft is required, the skin incision should run parallel to the iliac crest about 1 cm below it. The fascia lata is cut 1 cm below its upper attachment to the iliac crest and the muscles of the outer table of the ilium stripped down sufficiently to allow easy access for removal of the desired number of grafts. During wound closure, a suction drain tube should be inserted. The sutures should be placed deeply into the muscle mass from within-out, allowing the bulky muscle to be pulled up towards its former site of attachment on the outer wall of the iliac crest. If the sutures approximate only the fascial coverings near the margins of the incision, a noticeable ugly defect results in the muscle bulk below the iliac crest.

For rare indications, long stout grafts may be required to bridge multiple vertebral levels, where, for example, a cervical kyphotic deformity is being corrected (Fig. 7.8), or after excision of vertebral bodies for tumour or infection. Fibular grafts have been advocated for use in such circumstances. In my view, it is preferable to use long grafts cut from the ilium, to include both cortical surfaces, with cancellous bone between. These grafts will vascularize more rapidly than full fibular grafts, the latter being useful only in exceptional circumstances.

h) Graft Impaction

The final critical manoeuvres required to seat the graft in the dowel cavity are illustrated in Figs. 7.25 a–d. Before insertion of the graft, the surgeon must always measure the depth of the dowel cavity and the depth of the graft. *Great force is never required during impaction.* Soft tissue should be carefully retracted from the margins of the cavity and the neck should be gently elongated by traction applied to the skull before the graft is inserted.

i) Wound Closure

After the grafts have been inserted, a careful inspection should be made of the anterior aspect of the vertebrae; any bleeding points should be coagulated, especially along the medial margins of the longus colli muscles.

The neck wound may be closed then, without drainage, except after multi-level fusions or in rare circumstances after associated thyroid surgery.

j) Post-Operative Management

Patients complain of little pain after this operation–in contrast to those who have had cervical laminectomies.

Nursed with the head raised on two or three pillows, they should have collars fitted after returning to bed from the operating room (Figs. 7.26, 7.27). Patients are more comfortable when they wear an appropriate neck support after cervical fusion.

Dysphagia is common in the first few days after surgery; restriction of the intake of solid foods is advisable, but special measures in management are rarely required. During an anterior cervical interbody fusion at the C2/3 level, in one case, a small pharyngeal laceration occurred. This was sutured. Nothing was given to the patient by mouth for three days, intravenous fluid replacement being administered during that time, with prophylactic chemotherapy and no ill-effects resulted.

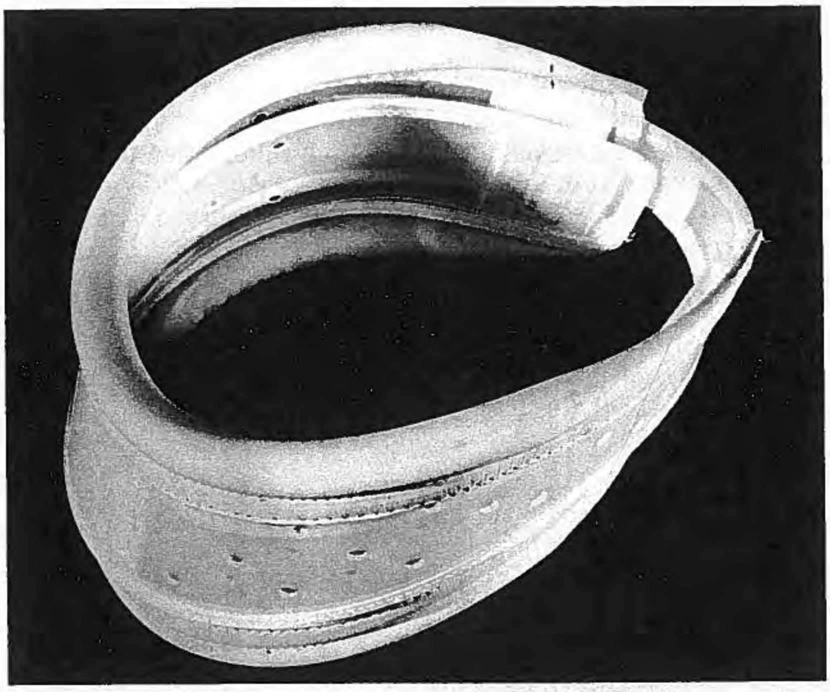


Figure 7.26. A photograph of a light plastic collar of adjustable height suitable for use in the post-operative period after single level anterior cervical fusion operations. This type of collar is also suitable for use in the conservative management of patients with neck pain after neck injuries, or for the treatment of recurring symptoms of neck pain and occipital headache due to cervical spondylosis

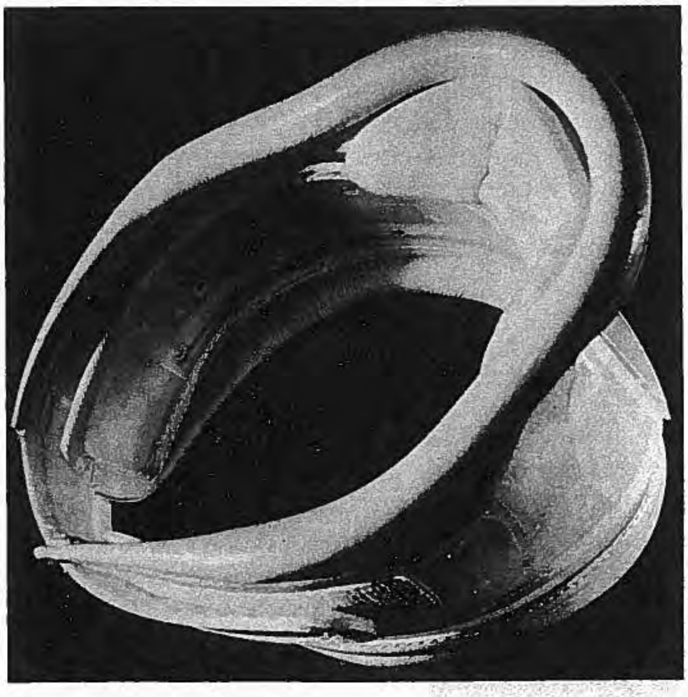


Figure 7.27. A photograph of an adjustable plastic cervical collar with supporting chin piece suitable for use after multi-level cervical fusions

Within twenty-four hours of operation, patients should be encouraged to get out of bed and to walk short distances. Their stay in hospital averages 12 days.

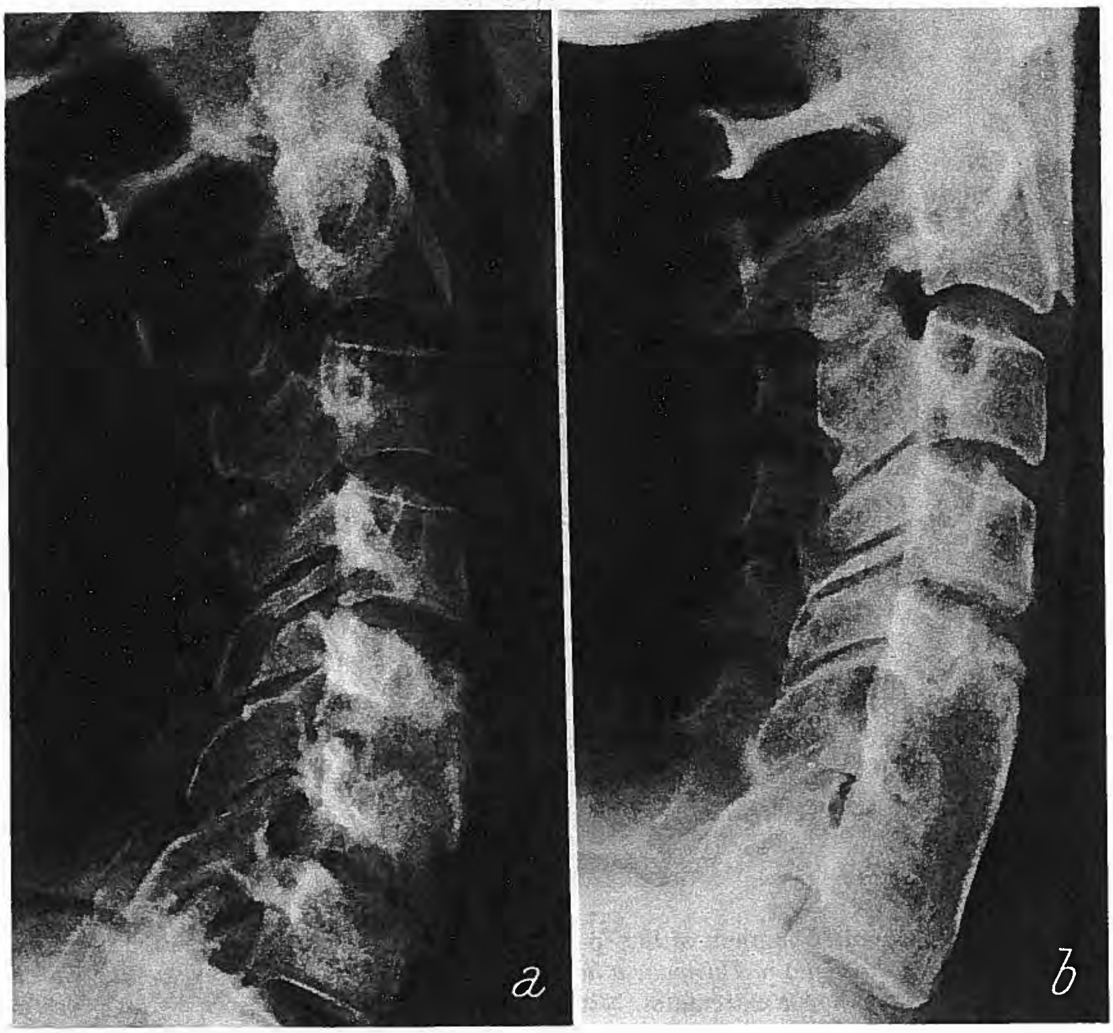
Travel by car should be avoided for six weeks and then allowed only in vehicles with head rests fitted or built into the seats. Until the graft or grafts have incorporated with the vertebrae, a collar should be worn at all times when travelling.

7.6. Radiological Changes After Interbody Fusion

The appearances of grafts at different levels in the neck and at varying periods after operation are shown in Figs. 7.28–7.31.

Figure 7.28

Union with this method can be expected in about 96% of cases. Mal-union with kyphosis may occur, if the shape of the grafts at the time of operation was unsatisfactory because of the size and contour of the pelvis at the donor site. In such cases, X-rays should be taken at intervals of one, two and four weeks post-operatively. If the grafts rotate during that time, with resultant kyphotic deformity of the neck, the patient should be re-admitted to hospital and nursed with the head in traction and the neck in extension for several weeks. A collar of the



Figures 7.29. **a** A lateral radiograph of the cervical spine of a man aged 34 showing the appearance at three months following anterior interbody fusions at C5/6 and C6/7. Early incorporation of the grafts in satisfactory position is evident. The indication for the operation in this case was to control intractable neck pain and headache with some referred shoulder pain *following post-traumatic internal disc disruption demonstrated by discography.* **b** A radiograph of the same spine taken five years later showing complete remodelling of the fused segments between the vertebral bodies at C5/6 and C6/7

Figure 7.28. A lateral radiograph of the cervical spine of a man aged 24 years taken five months after an anterior *cervical fusion* performed at the C4/5 level for *post-traumatic internal disc disruption.* The fusion is solid and union has occurred without spinal deformity

Figure 7.30. A lateral radiograph of the spine of the patient whose pre-operative films are illustrated in Figs. 7.4a and b. *This patient had clinical evidence of cervical myelopathy* with a spastic gait and weak upper extremities. Note the positioning of the interbody graft which is already incorporating. *Note also that the large osteophyte has been excised completely from the front of the cervical vertebral column*

Zimmer or SOMI type should be fitted thereafter, with the neck held in the corrected position, checked by lateral X-rays taken with the collar applied.

In general, collars should be worn for two or three months, until early union of the grafts can be expected. Instruction in the use of gentle mobilizing neck exercises should be given at that time. Should restriction of neck movements persist beyond six months after fusion, the neck may be manipulated with gentle longitudinal traction and rotatory motions to right and left, under a short-acting general anaesthetic.

Figure 7.31. A lateral tomogram of the upper cervical spine in a man aged 24 years showing an *anterior interbody fusion at the C2/3 level* six months after operation. The indication for treatment was for *persisting subluxation of C2 on C3 following a neck injury* sustained in a motor vehicle accident when his car overturned

7.7. Complications

The list of *potential complications* following anterior cervical interbody fusion operations includes:

1. Quadriplegia.
2. Unilateral blindness produced by the pressure of an assistant's hand resting on the globe.
3. Vascular catastrophes involving the vertebral or carotid arteries.
4. Severe venous haemorrhage following damage to the jugular vein.
5. Oesophageal laceration.
6. Horner's syndrome.

Reviewing my own experience with the use of this operation during twenty years, I have had to deal with a range of minor problems and with only a few serious complications.

a) Minor

These have included dysphagia and transient Horner's syndrome.

b) Major

In *one case, a large haematoma* in the neck required re-exploration for evacuation of the blood clot and coagulation of a small bleeding vessel in the margin of the longus colli muscle on one side.

In *one case*—the lady was very thin—*troublesome venous haemorrhage* occurred when a small un-named vein was avulsed from the wall of the internal jugular vein. This was controlled with the use of a 6/0 atraumatic vascular stitch inserted into the medial wall of the internal jugular vein at the site of avulsion of the venule. This incident is mentioned because there is an important lesson to be learned from it. Anterior approaches to the cervical spine can be very difficult and time-consuming in heavily built patients with short thick necks. In very thin patients, however, it is often possible to complete an anterior cervical interbody fusion at a single disc level within one hour. The case just cited shows that caution and vigilance must be exercised at all times. A surgeon can never afford to approach this particular operation lightly, as problems may arise unexpectedly in any patient.

In *one case,* already referred to in the text above, a *small pharyngeal laceration* occurred.

Graft rotation with resultant *acute cervical kyphosis* has required surgical treatment in only *two cases* in twenty years. However, unrecognized mal-union, with minor degrees of cervical kyphosis has been identified on X-rays taken three or four months after operation in a small number of cases.

Infection of neck wounds, with vertebral osteomyelitis occurred in *four patients.* One patient was diabetic, two others were heavy smokers with bronchitis and in the fourth, infection arose apparently spontaneously early after operation.

These cases all resulted from infections with staphylococcus aureus organisms. All required drainage of large pre-vertebral abscesses. Use of chemotherapeutic agents was determined on the results of sensitivity tests following culture of the organisms. Chemotherapy was used for at least three months, and in two of these patients its use was continued for one year after operation. Recurrent septicaemic episodes occurred in both when the use of Cloxacillin was discontinued after three months.

Finally, I have had experience with the management of *one case* of *quadriparesis resulting from neglect in treatment of a chronic wound infection in the neck.* This patient presented with a small discharging sinus in the line of the neck incision which had been used at the time of anterior cervical fusion four months earlier. He was unable to stand or walk and had also severe paresis of both upper limbs. Lateral X-rays revealed a large pre-vertebral abscess, with a severe kyphotic deformity at the site of bone grafting.

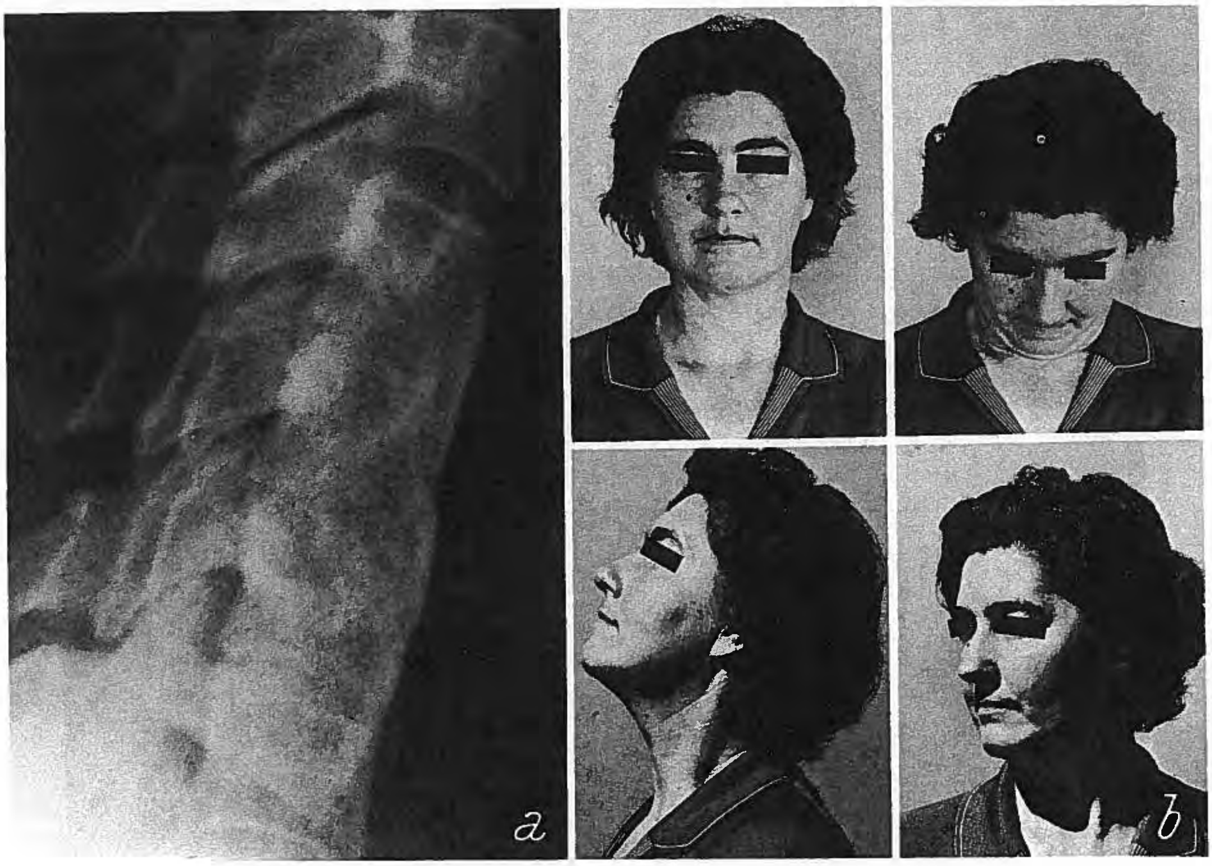
The abscess was drained under general anaesthesia. Long-term chemotherapy was administered. The patient was nursed with skull traction with neck extended over a rolled towel. See Chapter 9, p. 238 for further details. The quadriparesis recovered and spontaneous interbody fusion followed, with correction of the kyphotic deformity.

7.8. *Results of Operation*

Technically, excellent results can be achieved using this technique for anterior cervical interbody fusion. Non-union of grafts may occur in about 4% of patients.

Return to work is usual between four to six months following operation. I believe that it is unwise to persuade patients to return to work within one or two weeks of this operation–a claim made by some of its proponents–but foreign to my experience.

Neck motion is slightly restricted after multi-level fusion (Figs. 7.32a, b), though normally full after single level grafting.



Figures 7.32. a A lateral radiograph of the cervical spine of a woman aged 46 showing a three-level anterior cervical fusion between the bodies of C4/5, C5/6 and C6/7 taken five years after operation for the relief of intractable neck pain and occipital headache with some referred arm pain, in the absence of neurological signs. This patient had *post-traumatic multi-level disc disruption* following a high speed rear-end collision which had inflicted a whiplash-mechanism of injury on her cervical spine. **b** Four photographs of the patient whose X-ray showing multi-level cervical fusion is reproduced alongside, to demonstrate the ranges of motion of the neck after a fusion of this extent. Flexion and extension movements and the range of lateral rotation are all restricted. However, the functional result is regarded as satisfactory by the patient who has remained symptom free for 15 years since this operation

7.9. Posterior Cervical Spinal Fusion

The indications for these procedures have been set out above. Details of surgical technique will not be discussed as they involve simple manoeuvres which are in common use. However, radiographs showing the appearance of conditions requiring these procedures, with post-operative X-rays are found in Figs. 7.6, 7.33, and 7.34, together with photographs of suitable braces and a Minerva jacket which may be used post-operatively (Figs. 7.35–7.37).

Figure 7.33. A lateral radiograph of the upper cervical spine of a man aged 22 years who sustained a severe head injury following a motor vehicle accident in which the odontoid peg was fractured. C1/2 fusion is solid, though the reduction of the odontoid fracture is incomplete. The patient had no neurological signs or symptoms following union of the graft. At operation the grafts were held in place with heavy braided nylon which does not appear on the X-ray film

Figure 7.34. A lateral radiograph of the upper cervical spine showing an extensive occipito-cervical fusion performed for the treatment of an un-united fracture of the odontoid. The film was taken three months after operation

Figure 7.35. A photograph of an adjustable cervical collar of the Zimmer type, providing more effective immobilization following multi-level cervical fusions or in the later stages of management of C1/2 fusions after removal of halo-jackets or Minerva jackets

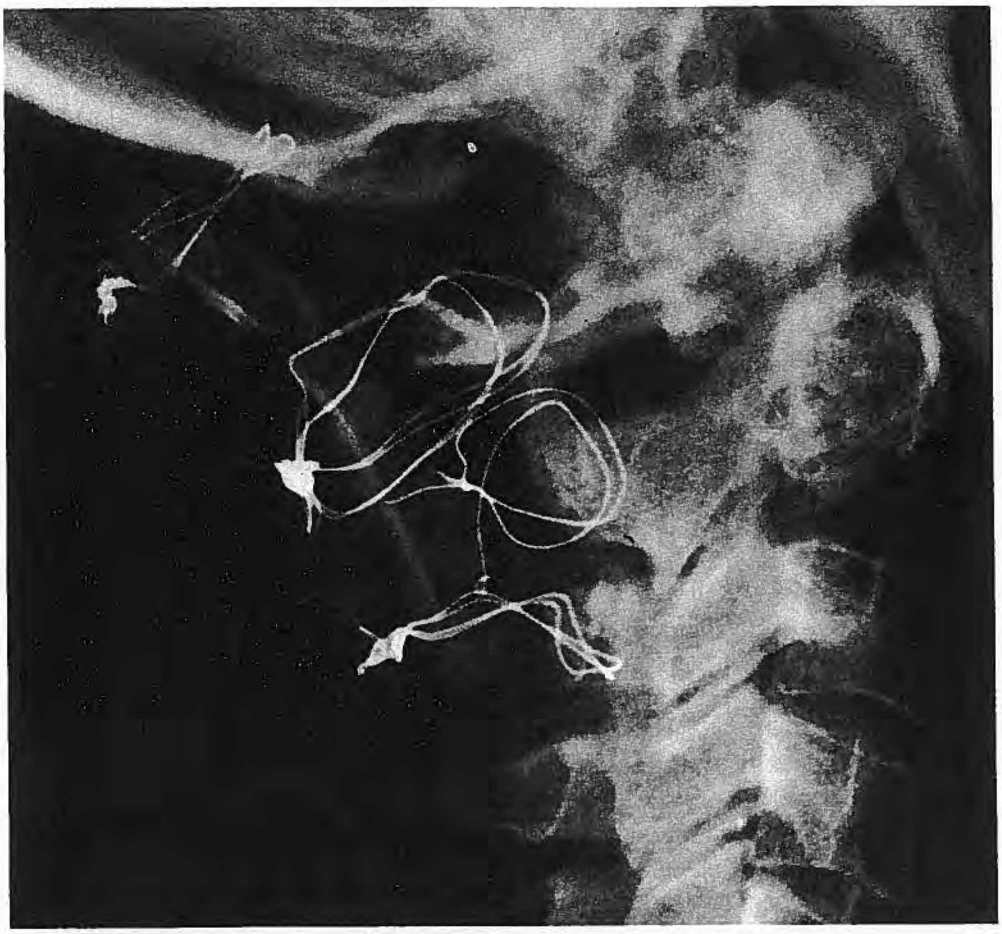


Figure 7.34

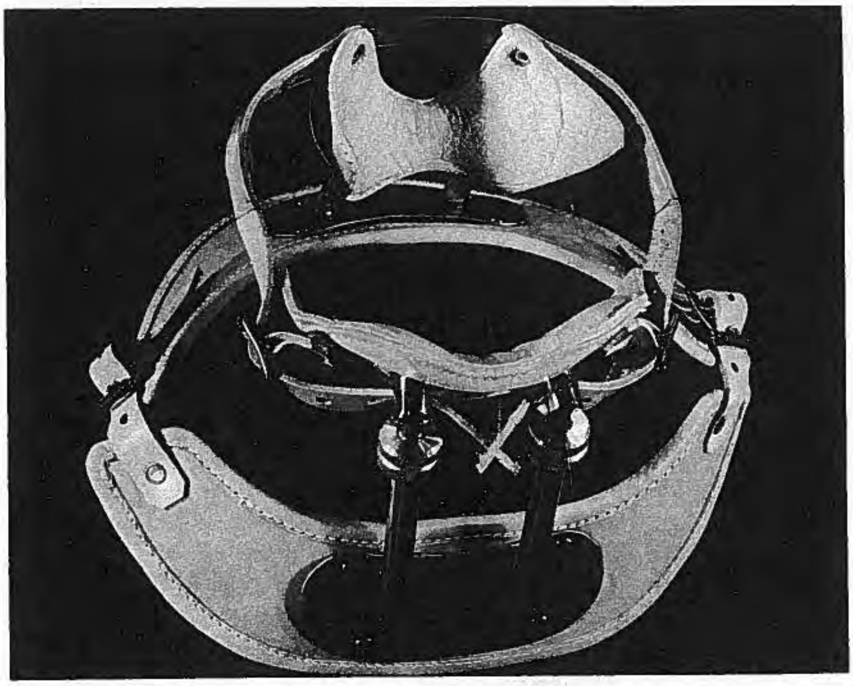


Figure 7.35

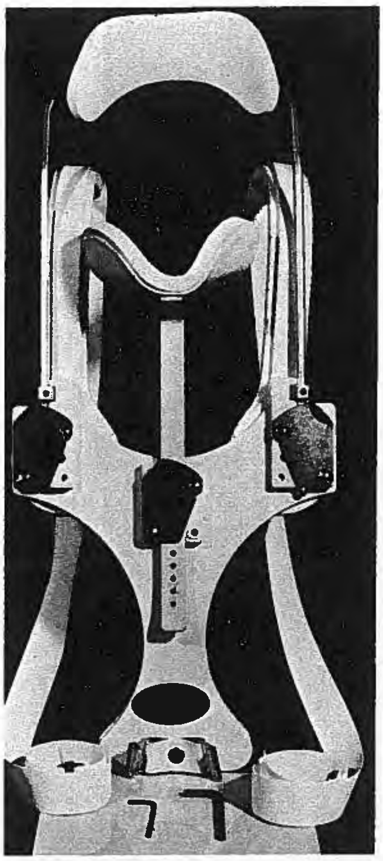


Figure 7.36

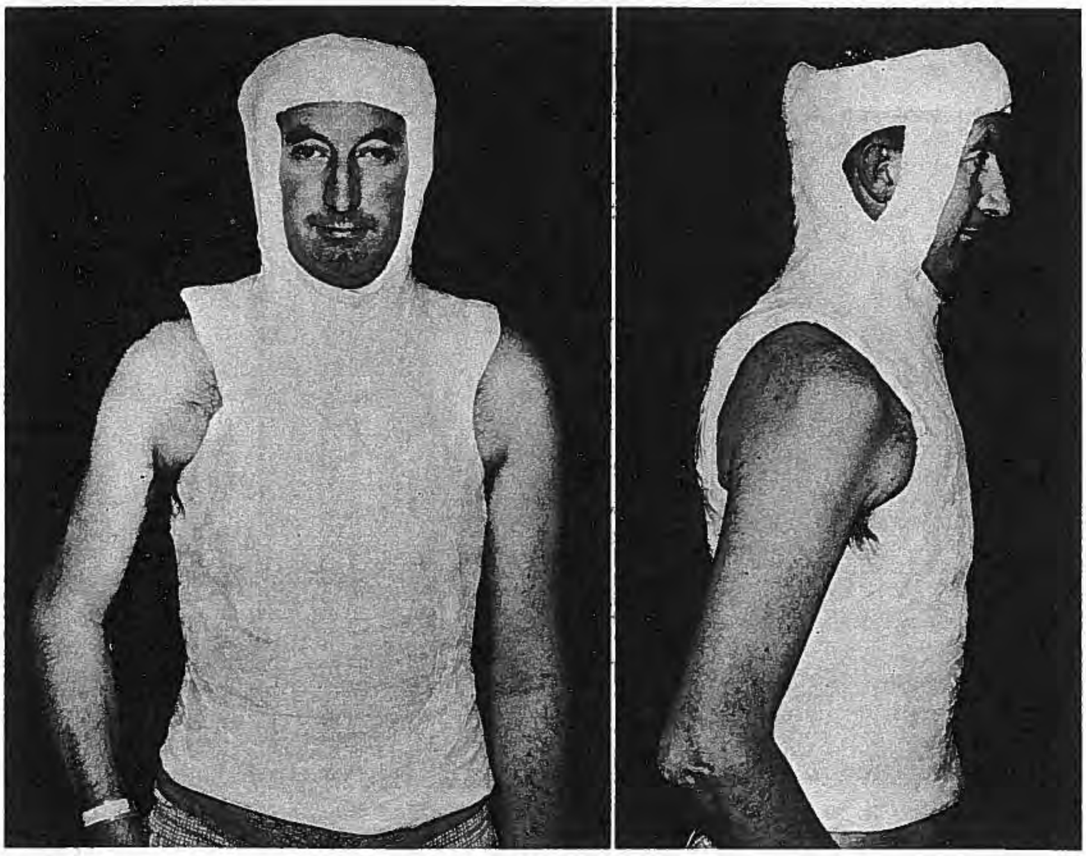


Figure 7.37

7.10. Cervical Laminectomy

a) *Positioning* (Fig. 7.38)

The prone position, using a neurosurgical headrest, provides satisfactory conditions for operation.

b) *Exposure*

The techniques used in this approach to the laminae are identical to those described for exposure of the lumbar spine, except that the scale and mobility of the bones is different, the cervical spine being small and very mobile. Smaller instruments are therefore required for use in this area (Fig. 7.39).

Having identified the lamina or laminae to be removed, the spinous processes should be excised. Then, using a Leksell-type rongeur, with thin cutting blades, the inferior surface of the superior lamina at the interspace can be removed piece-meal, while the thin ligamentum flavum is still intact. Having enlarged the inter-laminar space, the ligamentum flavum can be reflected and excised, after passing a small moistened patty beneath it, propelled gently laterally on the tip of the curved end of a Watson-Cheyne dissector. This done, on both sides of the canal, preparation is then made to perform a foraminotomy. The soft tissues and veins are separated carefully from the remnants of the roof of the spinal canal, one side at a time. The pedicles can be identified using the curved tip of the Watson-Cheyne probe. Venous bleeding should not obstruct the surgeon's view, unless the manoeuvres just described have been carried out carelessly or too quickly.

Using a forward-angled 45° rongeur with a 1 or 2 mm cup, it is then possible to open the roof of the intervertebral foramen, protecting the dura and nerve root sleeve with a patty on the end of a fine sucker. When this has been done, the regional veins will distend remarkably–if a stenosis in the region has been relieved. Some brisk venous haemorrhage may then occur. This is best controlled by the application of small fragments of gelfoam (or its equivalent) packed lightly in place with an overlying moist patty. The use of coagulating currents, through low voltage diathermy machines, is still widespread. However, I have not found it necessary to resort to this method of haemorrhage control, which I believe to be potentially dangerous if used at multiple levels in the cervical spine. There is a significant risk of damaging the fine

Figure 7.36. A photograph of a *SOMI brace* which provides an adjustable occipital support and an adjustable mental support fitted to a sternal plate which is suspended over the shoulder and fixed firmly to the trunk with adjustable straps. On cine-radiography this is one of the most effective devices for immobilizing the cervical spine. However, there are problems with its management as it tends to ride up when the patient lies in bed

Figure 7.37. A photograph showing a patient viewed from in front and from the side, fitted with a Minerva jacket for immobilization of the upper cervical spine following occipito-cervical fusion. Although variations of halo-jackets are available, *this useful method of spinal immobilization is illustrated for the benefit of surgeons who do not have access to more expensive commercially available braces such as the halo with thoracic jacket and pillar supports.* Before the Minerva jacket is fitted, the patient should be placed on a tilting bed so that he is used to standing in a vertical position, and then the jacket can be put on when he is able to stand without dizziness for periods in excess of 30 minutes

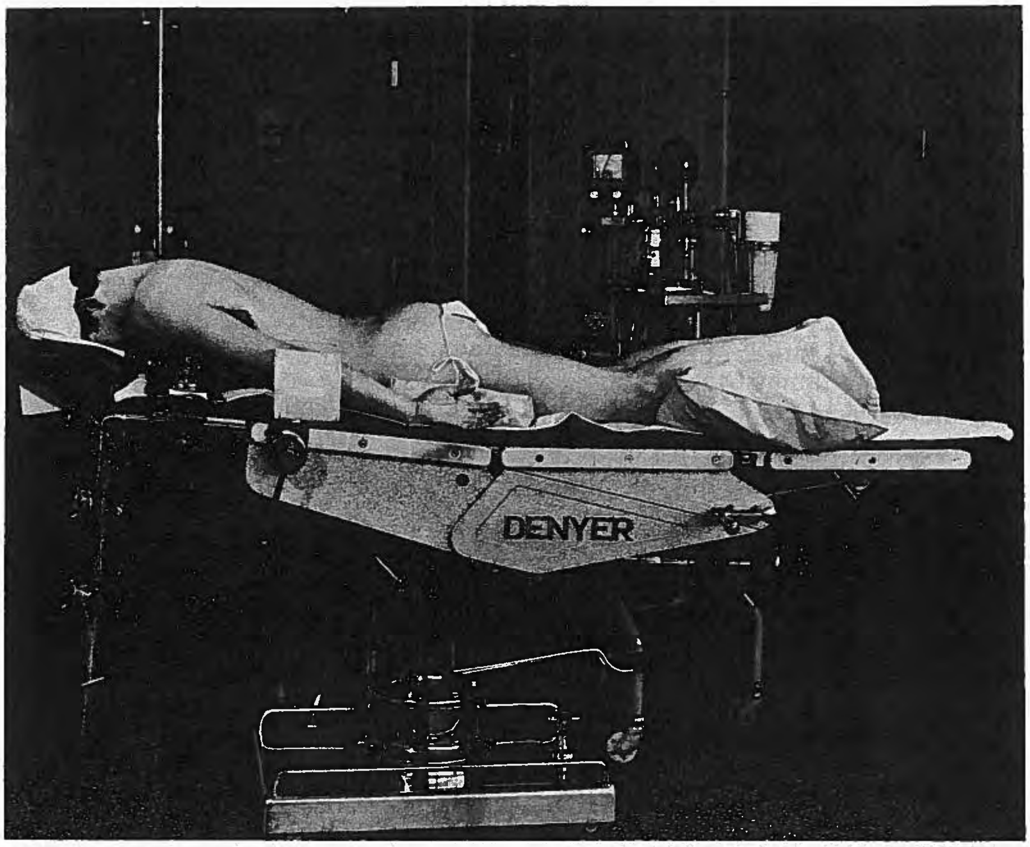


Figure 7.38. A photograph to show the arrangements for posturing the patient on an operating table for posterior approaches to the cervical spine. When the patient is in the prone position for operations on the cervical spine, particular precautions must be taken to ensure that the anaesthetic tubes and airways are securely fastened, with all their linkage points strapped to prevent accidental separation during the surgery. When the patient is in this position, the skin of the neck is often lax. Strapping should be applied across the hairline transversely and fixed to the head support. Further strapping is then attached across the vertex of the skull running from the transverse strapping to the front of the headrest. In addition, long strips of strapping should be applied just lateral to the spinous process of C7 on both sides, running down the back to the buttocks. This will ensure that the skin of the neck is tightly stretched and it makes the incision and its subsequent closure much easier. Note also the inclination of the table. If the head is raised any further, then *the potential risk of air embolism must be borne in mind*

segmental arteries which join the anterior median longitudinal arterial channel of the cervical spinal cord if diathermy is used to excess in the region of the intervertebral foramina within the cervical canal (Crock and Yoshizawa, 1977).

On completion of the "laminectomy" and foraminotomies, the partes interarticulares of the laminae being preserved, along with the bulk of the facet joints, the wound should be closed with suction drainage. Before this is done, all haemorrhage should be controlled, using haemostatic agents in the cervical canal as described, and diathermy in the muscle layer.

Facets should be preserved, except in cases of trauma, when facetectomy may be required to allow reduction of a fracture-dislocation. Localized inter-laminar posterior cervical fusion should be performed then, using inter-spinous wire fixation.

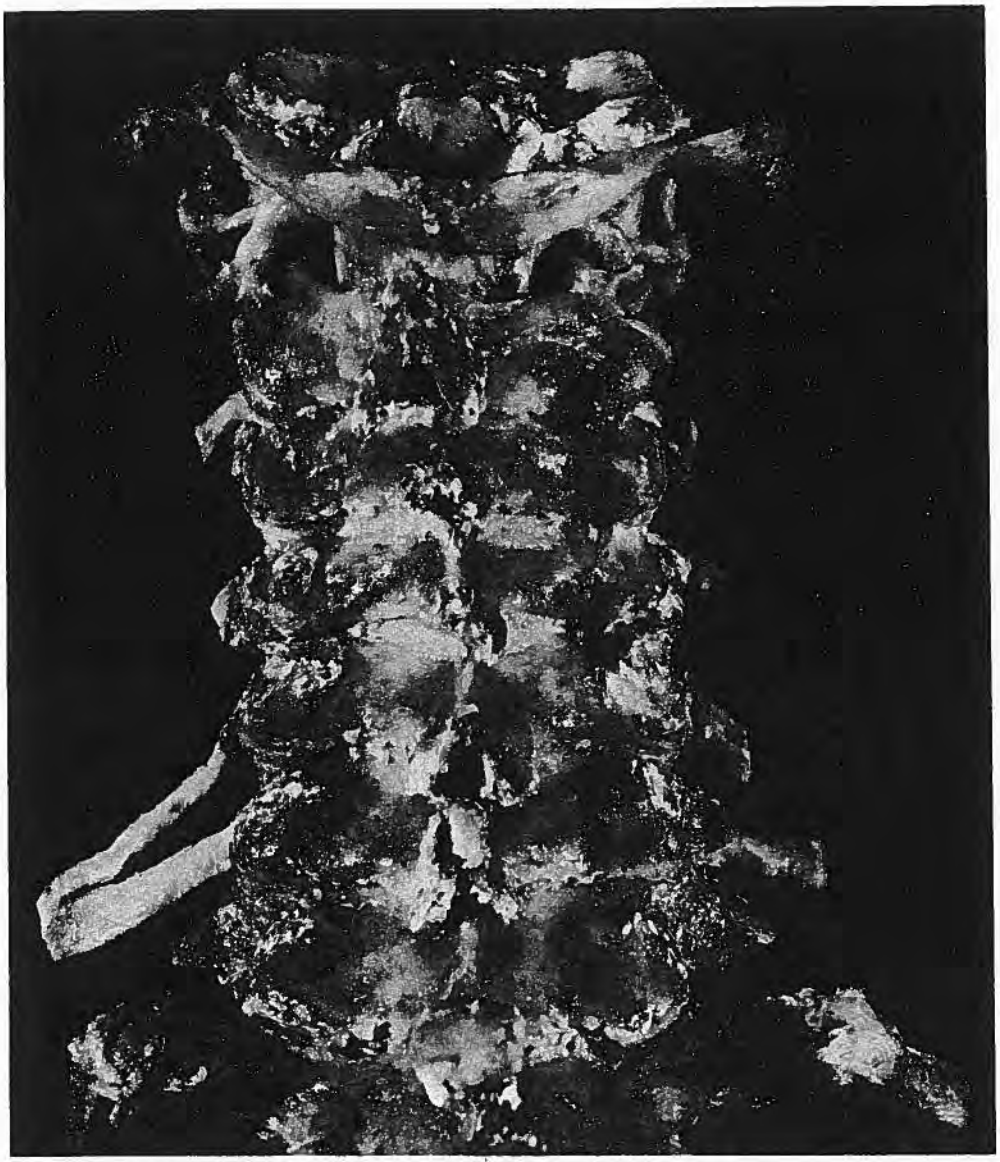


Figure 7.39. A photograph of a dissection of the cervical spine viewed from behind. All the soft tissues have been removed except the ligamenta flava, the dural sac and the emerging nerve roots. At the level of C1 and C2, note the relationships of the emerging nerve roots to the vertebral arteries on both sides. The facet joints from C2 distally can be seen orientated in the coronal plane. In the cervical spine the inter-laminar spaces are very narrow at all levels, and only a few millimetres of ligamentum flavum can be seen in the normal state. (Dissected by Dr. M. C. Crock)

c) Post-Operative Care

Patients complain of severe pain after posterior cervical spinal operations. Adequate analgesia should therefore be ordered.

The use of soft collars for short periods can be recommended after decompressions of the cervical canal.

8

Spinal Infections

8.1. *Acute Vertebral Osteomyelitis*

a) Introduction

In clinical practice, acute inflammatory lesions of the spine are relatively uncommon. For this reason alone, diagnosis of vertebral osteomyelitis is often delayed, so that patients may not receive specific treatment for the disease until they present with major complications.

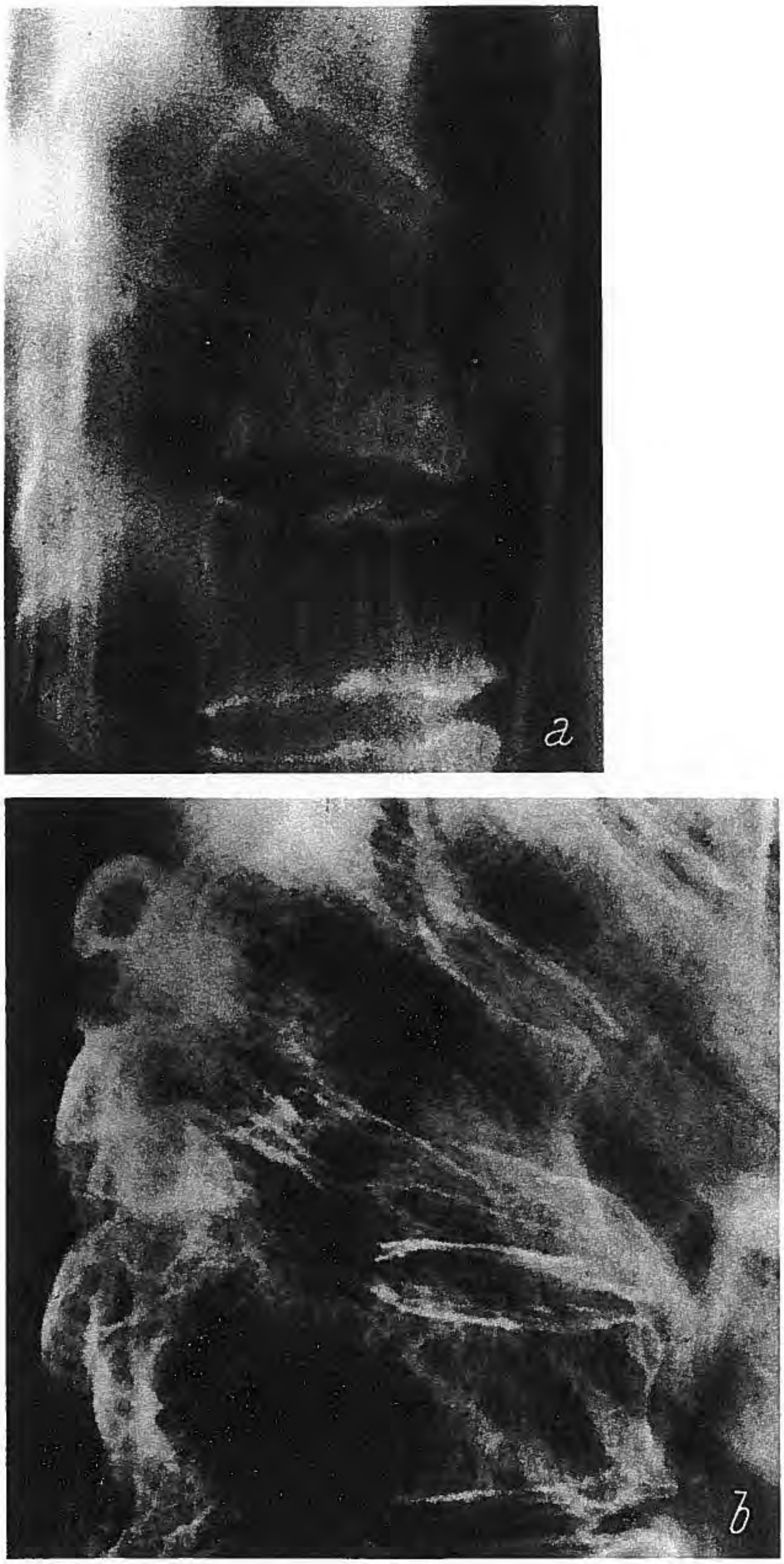
The virtues of specialist hospitals are often hailed but cogent arguments favour the retention of specialist units in large general hospitals, where orthopaedic surgeons and neurosurgeons can be consulted readily about the surgical problems relevant to bone disease, not the least important of which are infective lesions of the spine.

Most referred cases of vertebral osteomyelitis will come from physicians. Vertebral infections follow repeated episodes of bacteraemia or septicaemia which may occur in many debilitating medical diseases such as: pneumonia, chronic bronchitis and diabetes mellitus (Figs. 8.1a, b). One of the most elusive causes of pyrexia of unknown origin is sub-acute bacterial endocarditis. Acute vertebral osteomyelitis may complicate the course of this disease before the underlying pathology of the cardiac valvular disease is recognized and even before positive blood cultures have been obtained.

Some cases will be referred from general surgical wards, having been admitted with abdominal pain and fever (Fig. 8.2).

A third significant source of referred cases in general hospitals is from the urology department. Following urethral or bladder surgery, some patients will present with spinal pain due to vertebral osteomyelitis following gram-negative septicemia.

Some general hospitals in particular localities in large cities often admit many drug addicts and alcoholics, in whom complaints of severe spinal pain should raise the suspicion of underlying vertebral infection. A wide range of organisms, including fungi, may be identified either in blood cultures or from needle biopsy specimens in the drug-addicted patient.



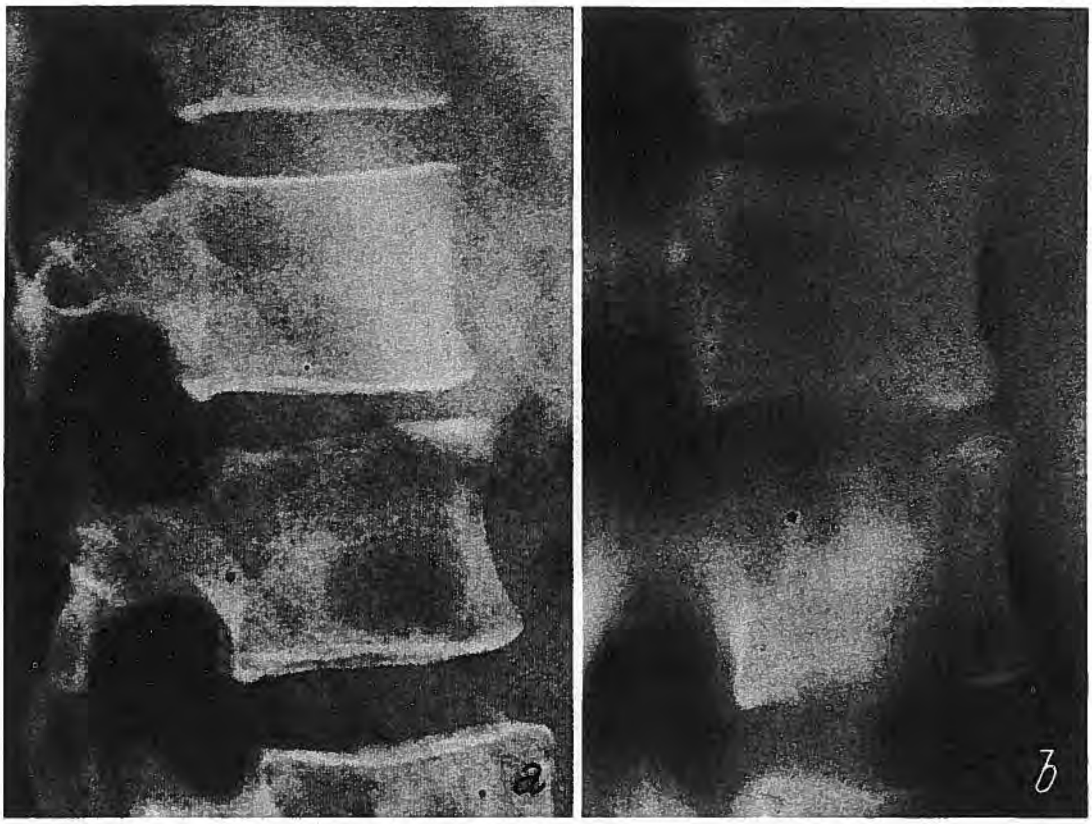
Figures 8.1

Organisms lodge in the complex vascular bed, in the region of the vertebral end-plates, in children and adults (Crock and Yoshizawa, 1977). The pathological changes induced vary enormously depending on the bacteriological characteristics of different organisms.

Although the radiological appearances may be similar, in the case of staphylococcal infections chondrolytic activity destroys cartilage and disc tissue, whereas in tuberculous disease these tissues are not destroyed. The loss of disc height shown on X-rays in cases of spinal tuberculosis is due to osteitis with pathological fracture, the disc tissue simply collapsing into the adjacent carious vertebral bodies (Figs. 8.3 a, b).

Figure 8.2. A lateral tomogram of the lower lumbar spine of a woman aged 59. Note the changes in the upper half of the body of the 5th lumbar vertebra in the region of the vertebral end-plate, with erosion and narrowing of the intervertebral disc space. The patient presented with acute abdominal pain, overshadowing back pain. The lesion was due to an acute osteomyelitis of the body of L5 complicating bronchitis

Figures 8.1. a A lateral tomogram of the mid-thoracic spine of a woman aged 66 who had been under treatment for chronic bronchitis for three months prior to her presentation with back pain and paraplegia. Gross destruction of the vertebral body of T7 is noted with pathological fracture-dislocation. **b** A lateral X-ray of the same area taken four years after conservative treatment of this lesion with long-term chemotherapy. Considerable remoulding of the vertebrae at the site of the dislocation had occurred and the paraplegia had recovered in part



Figures 8.3. **a** A lateral radiograph of the lumbar spine of a 32 year old patient who presented with a history of *low back pain and weight loss.* She had not complained of pain in the region of this lesion. The film is centred on the disc between T12 and L1 at the thoraco-lumbar junction. Note the narrowing of the disc space. **b** A lateral tomogram of the same area of the spine in the same patient. Note the extensive erosive changes in the upper vertebral end-plate of the lower vertebra at the level of the narrowed disc space. *This lesion was tuberculous* and, at operation, intact disc tissue was found within the cavities of the lower vertebral body

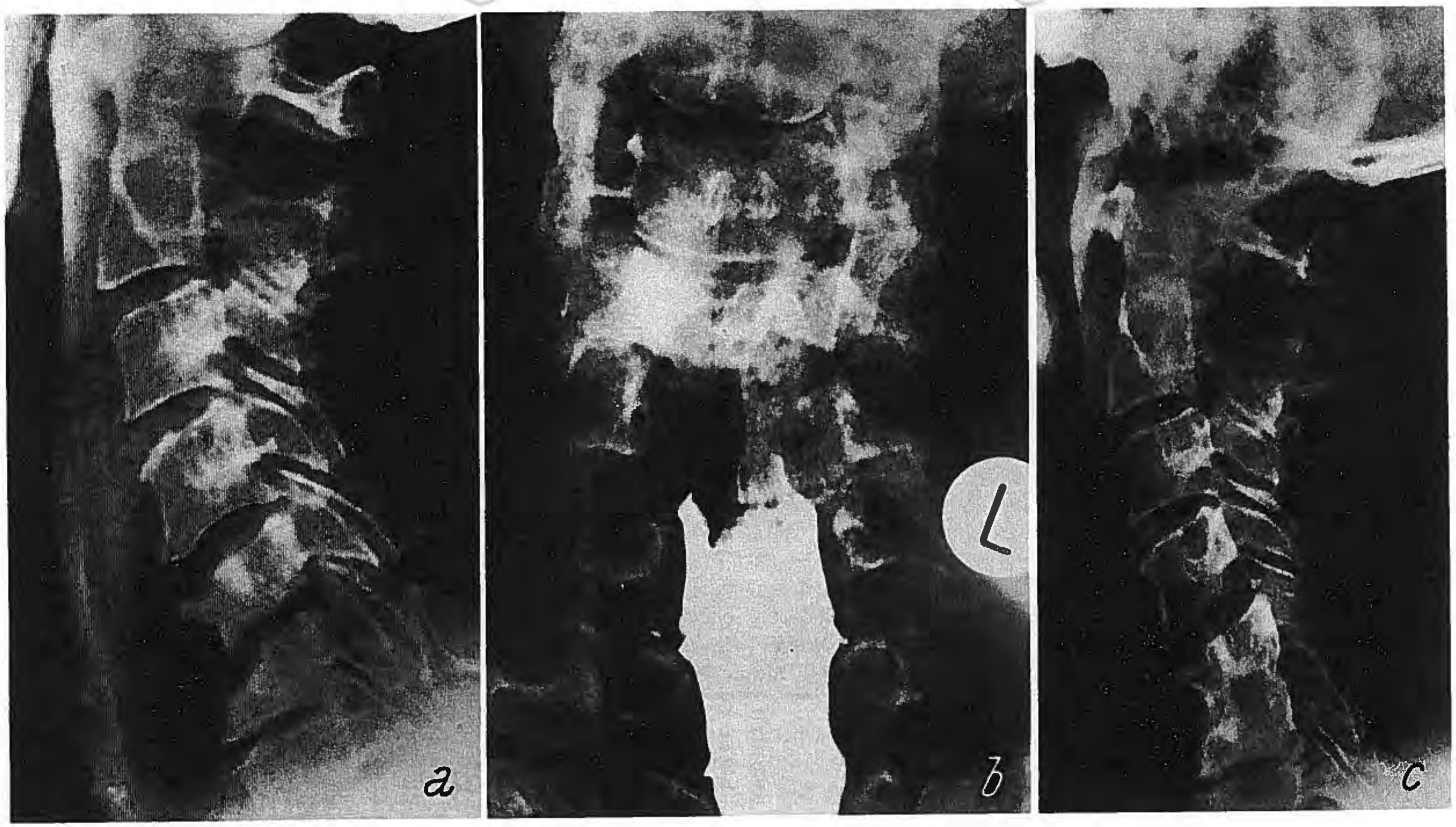
b) Clinical Findings

The sudden onset of excruciating spinal pain in a febrile patient, should immediately arouse the suspicion of the diagnosis of vertebral osteomyelitis. Physical signs include:

marked local tenderness in the spine;
paraspinal spasm and rigidity, or psoas spasm causing fixed flexion deformity of the hip;
local spinal deformity;
rapidly advancing neurological deficits in cases with spinal epidural abscesses (Figs. 8.4a–c).

c) Investigations

Full *blood examination* should be carried out urgently, and repeated samples of blood taken for bacteriological cultures, both aerobic and anaerobic.



Figures 8.4. **a** A lateral radiograph of the cervical spine of an alcoholic male patient aged 54 years who presented with severe neck pain of sub-acute onset. Note the extensive changes in the vertebral bodies of C5 and C6 with vertebral end-plate erosion in the adjacent vertebral margins of these vertebrae; the disc space is also reduced in height. Note in particular the wide separation of the gas shadow in the pharynx and oesophagus from the anterior aspects of the cervical vertebral bodies, indicating the presence of a pre-vertebral abscess. This patient became quadriplegic within 48 hours of presentation. (By courtesy of Mr. B. J. Dooley and Mr. J. K. Henderson.) **b** An antero-posterior radiograph of the spine of the same patient showing complete obstruction to the flow of a Myodil column upwards at the level of C6 and C7. **c** A lateral radiograph of the spine of the same patient taken 15 months after operation. The spinal canal was decompressed from behind and a large epidural abscess aspirated. Treatment then consisted of splinting the neck in traction with hyperextension; chemotherapy was administered for twelve months. Note the restoration of the normal relationships between the pharynx and oesophagus and the anterior surfaces of the vertebral bodies

Other cultures may be taken from infected skin lesions, sputum, urine or faeces, depending on their predicted relevance on clinical grounds.

The significance of the results of many of these tests is that they may form the basis for decisions in the differential diagnosis between infections, acute and chronic, and neoplastic diseases. In addition, the critical choice of appropriate chemotherapeutic agents will depend on some of them.

d) Radiological Examinations

i) Plain X-Ray

Plain X-rays and tomograms will demonstrate a variety of changes in the bones and soft tissues, pointing to their likely inflammatory basis.

ii) Computerized Axial Tomography

C.T. Scanning has been of inestimable value in demonstrating the relationships between pathological changes in the vertebrae and in the related soft tissue structures. Paravertebral and spinal epidural abscesses may be mapped accurately using this technique.

iii) Myelography

Myelography may be essential to identify the level of obstruction in the spinal canal caused by vertebral collapse or epidural abscess.

e) Needle Biopsy

The use of needles or small trephines inserted into vertebrae under X-ray control represents one of the most significant advances in management of patients with neoplastic or inflammatory lesions (Fig. 8.5). In parts of Asia, where infective lesions of bone are still common, the use of this method to obtain samples both for histological and bacteriological examination has improved the accuracy of diagnosis in many cases of non-tuberculous spinal infections which would have been classified previously as tuberculous (Chari, 1979).

f) Treatment

i) Bed Rest and Chemotherapy

Many patients will respond satisfactorily to conservative treatment. Spontaneous spinal fusion often follows healing of lesions in staphylococcal osteomyelitis.

Problems arising in cases of osteomyelitis due to staphylococcal infections vary with the virulence and sensitivity of the particular organisms. The use of chemotherapy continuously for more than six months may be necessary in patients who have developed multiple bone lesions complicating septicemia (Figs. 8.6a–d).

Figure 8.5. A lateral radiograph of the thoracic spine showing a lesion between the vertebrae of T11 and T12 from a woman aged 27 years who had presented with acute thoracic pain and upper abdominal pain some weeks after a gynaecological infection. Note the erosion of the vertebral end-plates in the anterior thirds of the adjacent vertebral margins together with the narrowing of the disc space. Needles used for vertebral biopsy are shown in place. Positive culture of a streptococcal organism was obtained

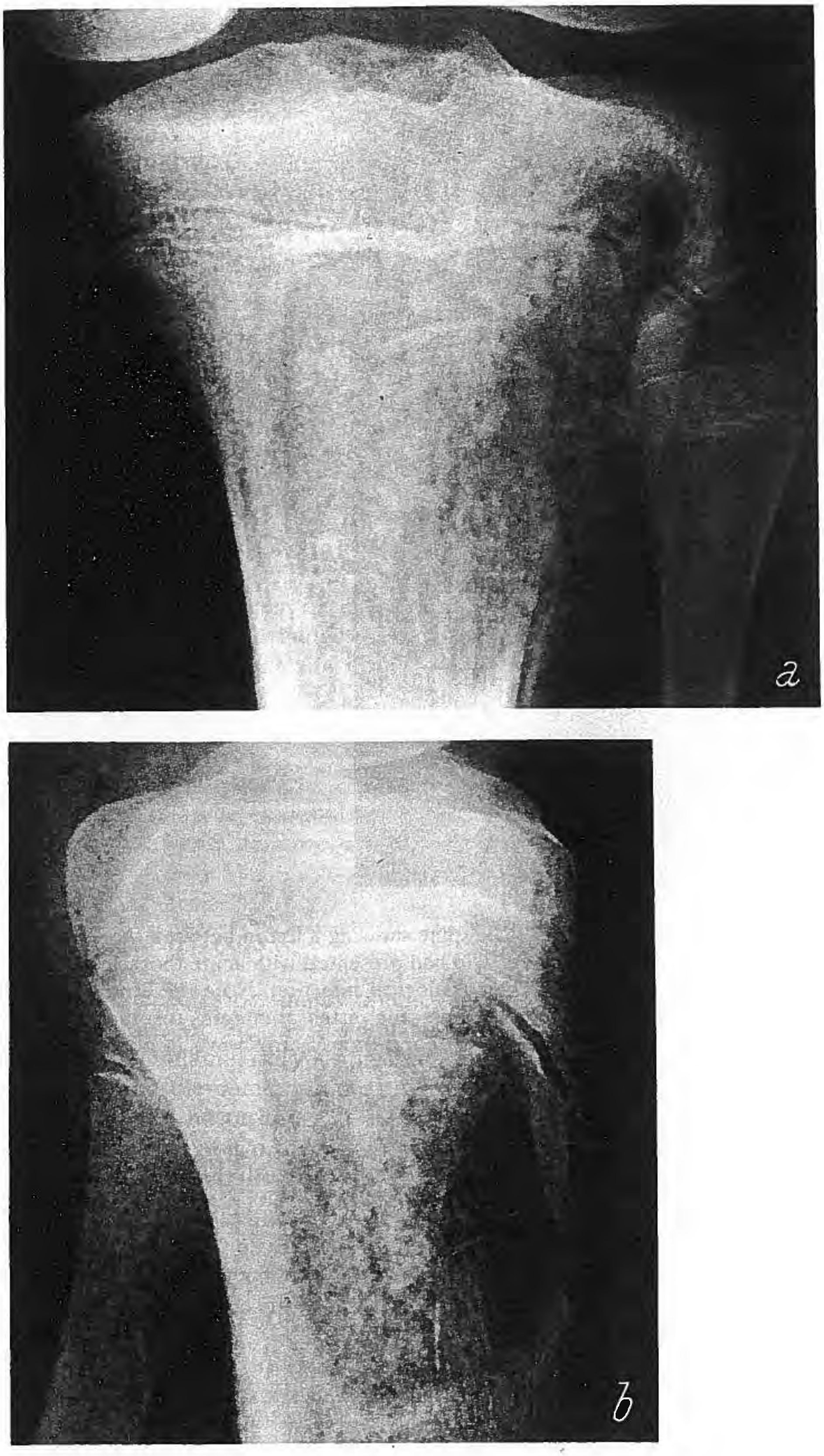
ii) Drainage of Abscesses

Emergency surgery is required for decompression of the spinal canal in cases developing tetraplegia or paraplegia due to the formation of epidural abscesses.

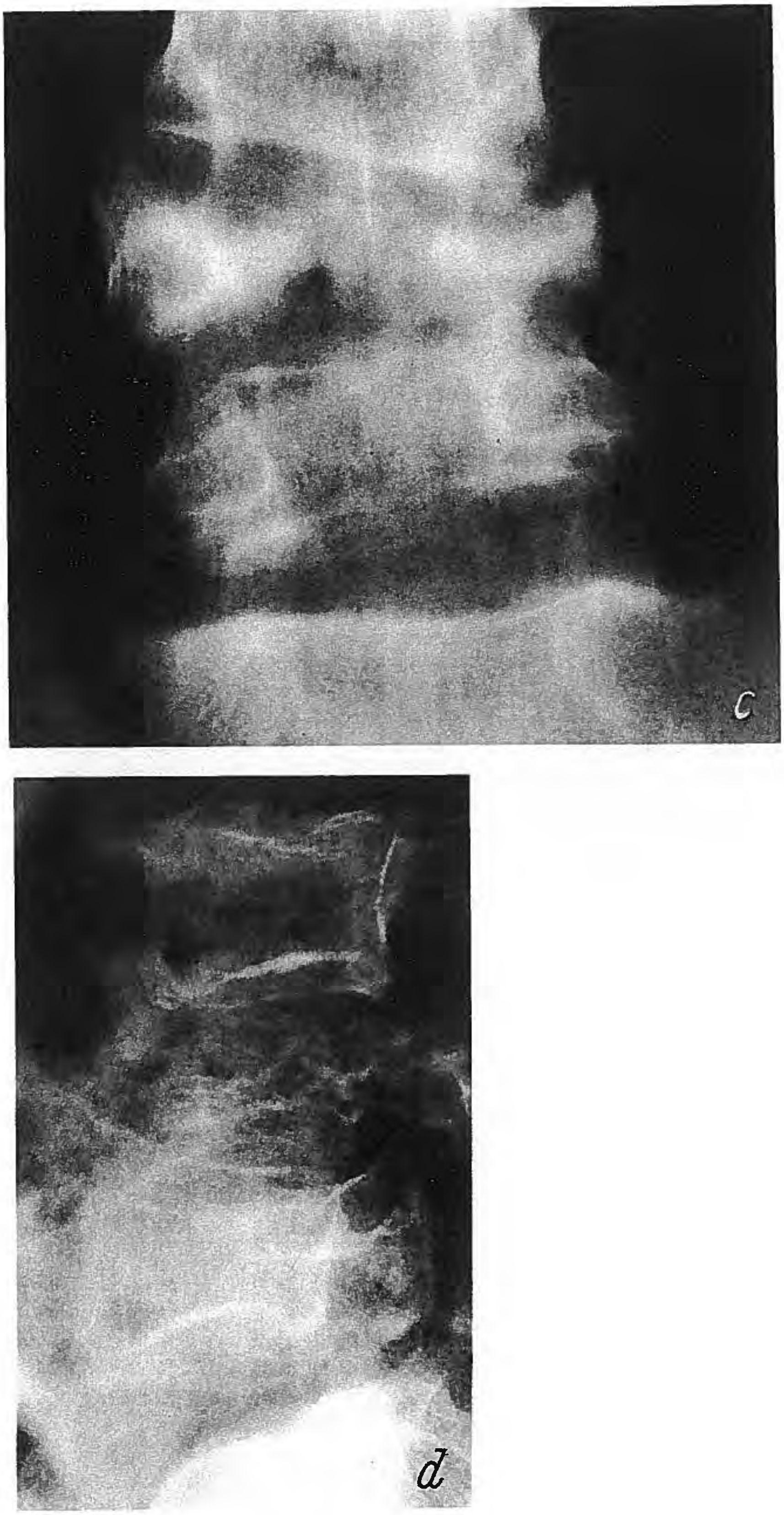
Occasionally drainage of psoas abscesses may be required, even in cases of non-tuberculous infections (Figs. 8.6c, d).

Surgical treatment of this type is recommended early in the management of vertebral osteomyelitis in drug addicts, because of the high resistance of organisms in these cases to chemotherapy alone (Hartman, 1978).

Even after extensive destruction of vertebral bodies due to staphylococcal infection, spontaneous spinal fusion usually occurs. Supplementary bone graft operations should not be required, providing sharp contrast with the requirements in the surgical management of Pott's disease.



Figures 8.6 a and **b.** Antero-posterior and lateral radiographs of the upper end of the tibia of a boy aged 14 years showing a large cavity in the upper metaphysis of the tibia resulting from acute haematogenous osteomyelitis. This enormous cavity had been drained and packed open until granulation covered its walls. Fragments of bone grafts can be seen in both views, these had been inserted when organisms had failed to grow in cultures taken from the cavity



Figures 8.6 c and **d.** Antero-posterior and lateral radiographs of the lower lumbar spine showing the 3rd, 4th and 5th lumbar vertebrae and the 1st sacral vertebra. Extensive destruction of the vertebral body of L4 is noted. This lesion developed in the spine twelve months after the boy had been treated for the acute lesion shown in Figs. 8.6 a and b in the upper end of his tibia. This vertebral lesion required extraperitoneal drainage of a large paravertebral abscess. The organism was a Penicillin-sensitive staphylococcus aureus

8.2. Tuberculous Disease of the Spine

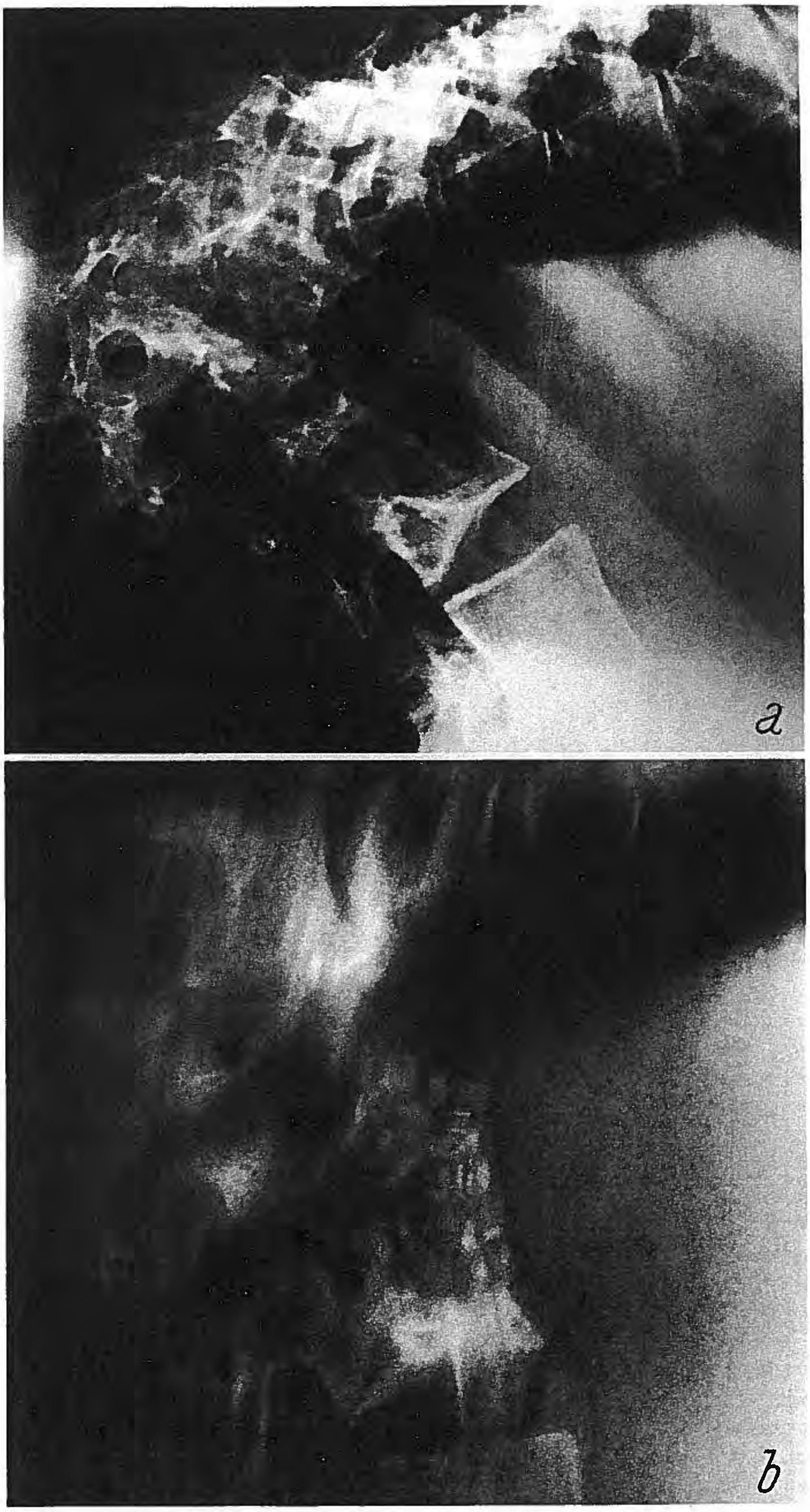
The surgical treatment of tuberculosis of the spine has attracted widespread interest in the past twenty years. During that time, the most authoritative accounts of the various surgical procedures which may be required in dealing with the spinal complications of this disease have come from the East, especially from Hong Kong (Hodgson, 1956).

Tuberculosis is now seen only rarely in Western communities, being found occasionally in migrants.

The illustrations in this chapter have been chosen simply to draw attention to some of the outstanding features of this disease as it affects the spine (Figs. 8.7–8.10).

Figure 8.7. A lateral radiograph of the lumbar spine of a man aged 54 who presented with severe low back pain. Note the loss of disc space with erosive changes in the adjacent vertebral bodies at the level of the disc between L2 and L3. The body of L4 is somewhat osteoporotic. In the antero-posterior view the classic deformity of the psoas shadows indicated the presence of bilateral psoas abscesses. This is an example of relatively localized tuberculous disease with minimal spinal deformity at the time of presentation

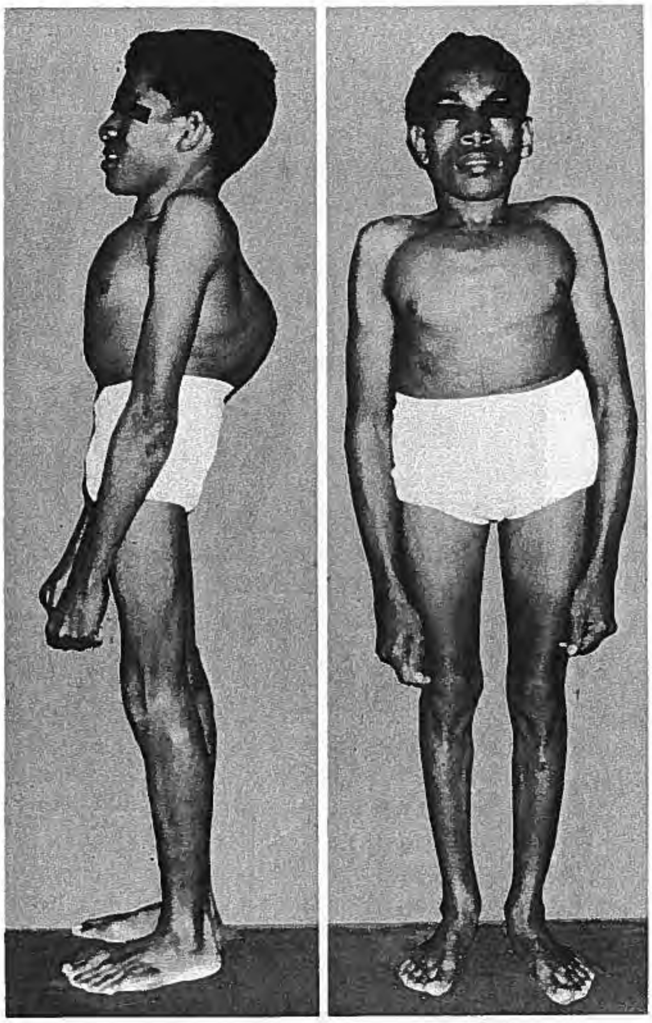
Figures 8.8. **a** A lateral radiograph of the thoraco-lumbar junction of the spine of a man aged 24 years who presented with complaints of spinal pain and increasing weakness of the lower extremities. **b** A lateral tomogram of the same area of this patient's spine following debridement and bone grafting of the area for active Pott's disease. No attempt was made to correct the deformity. The patient was managed post-operatively in a plaster bed and anti-tuberculous chemotherapy administered



Figures 8.8

Publication of these records may serve a useful purpose for those readers whose experience of this disease has been limited, reminding them of the magnitude of the problems which may occur in spinal tuberculosis.

Surgical treatment has been dominated by the use of interbody fusion operations, performed through anterior approaches at every level of the vertebral column, allowing debridement of carious debris and necrotic bone fragments before the insertion of strut grafts (Figs. 8.11–8.13).



Figures 8.9. Lateral and anterior photographs showing the gross deformity of the spine resulting from Pott's disease at the thoraco-lumbar junction. The X-rays of this patient are shown in Figs. 8.8a and b

Figures 8.10. **a** A lateral tomogram taken four months after operation showing the incorporation of grafts inserted for the treatment of tuberculous disease in the patient whose pre-operative films are illustrated in Figs. 8.3a and b. Note the fragment of rib graft adjacent to the spinal canal. **b** An antero-posterior tomogram of the same spine showing sound interbody fusion with no lateral deformity of the spine

Figure 8.11. A photograph of a Stryker rotor bed suitable for nursing patients following spinal surgery for infective or neoplastic lesions

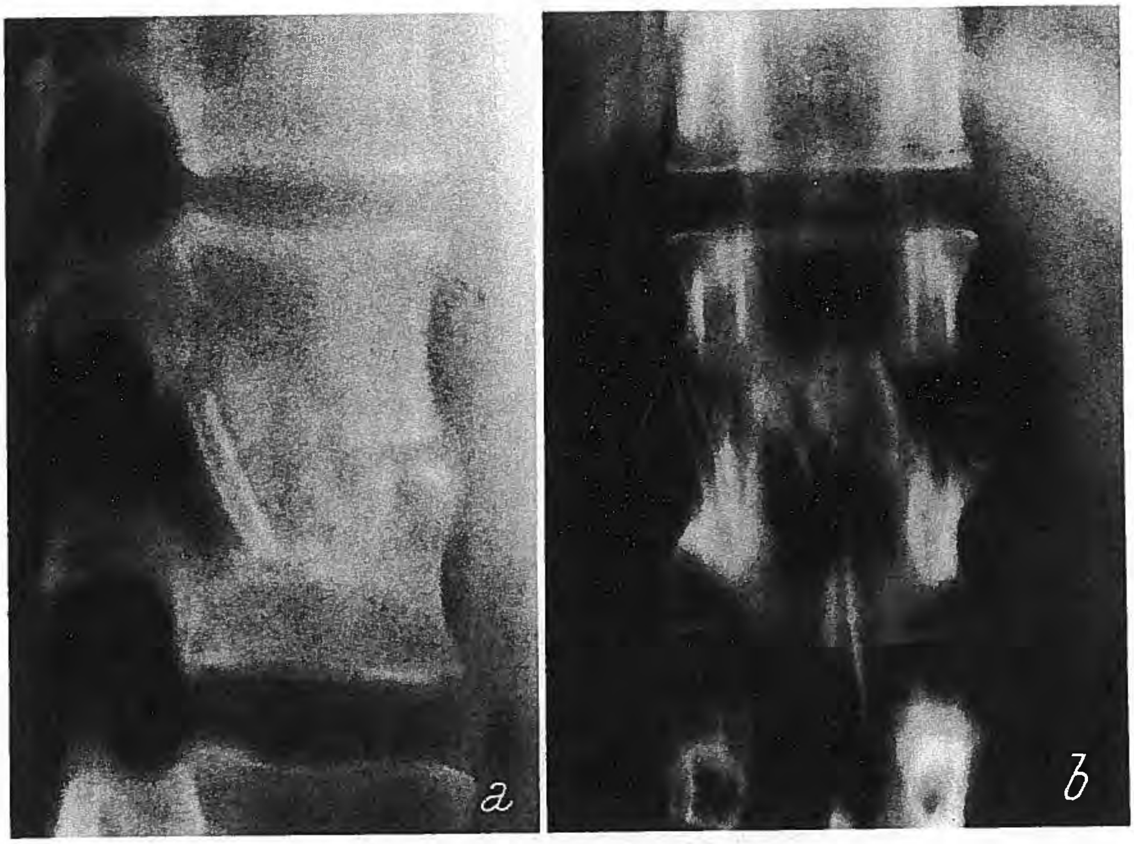


Figure 8.10

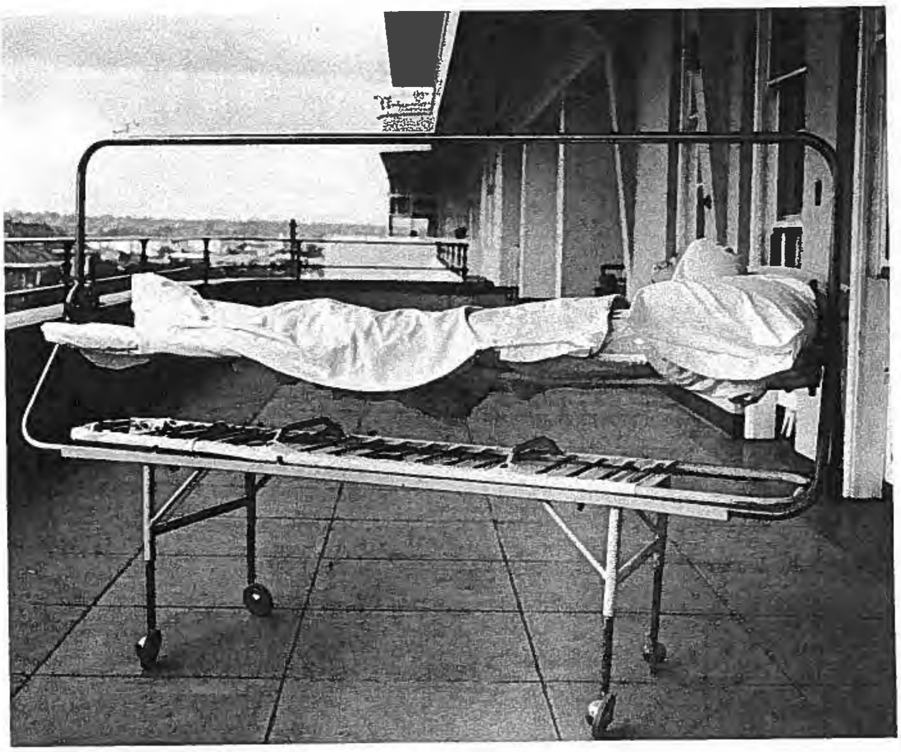
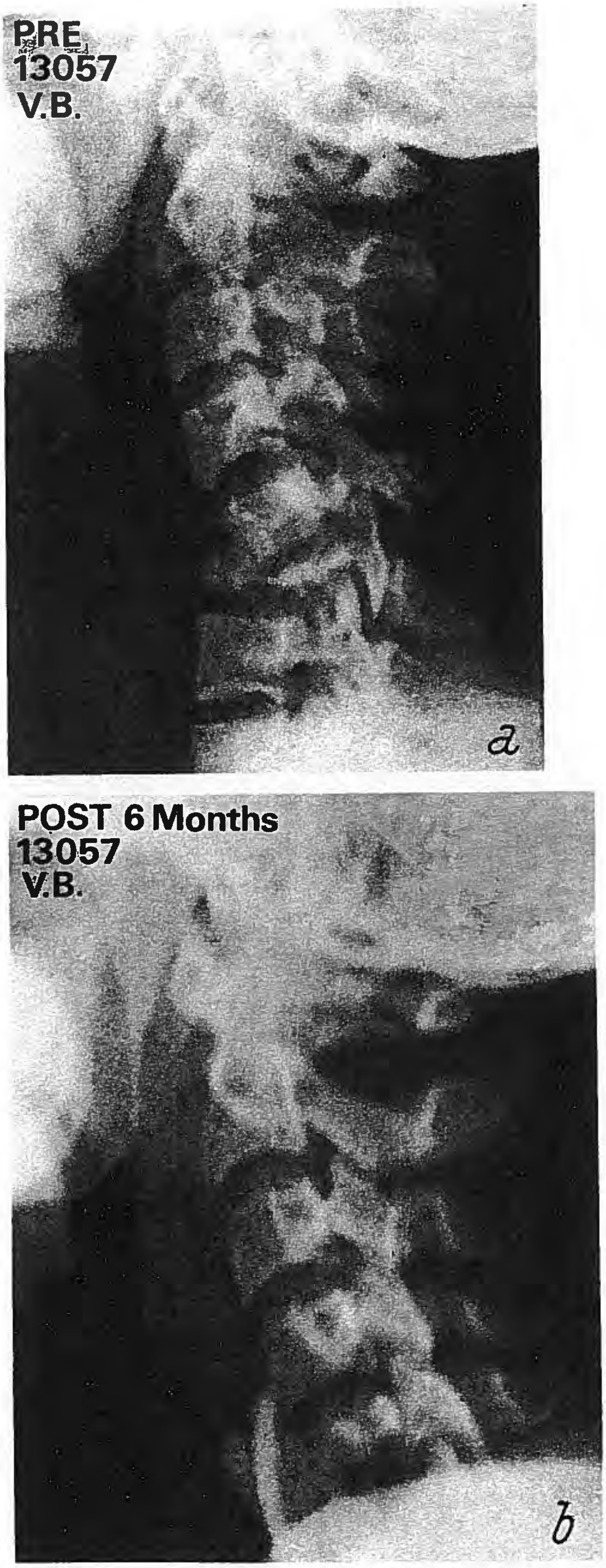
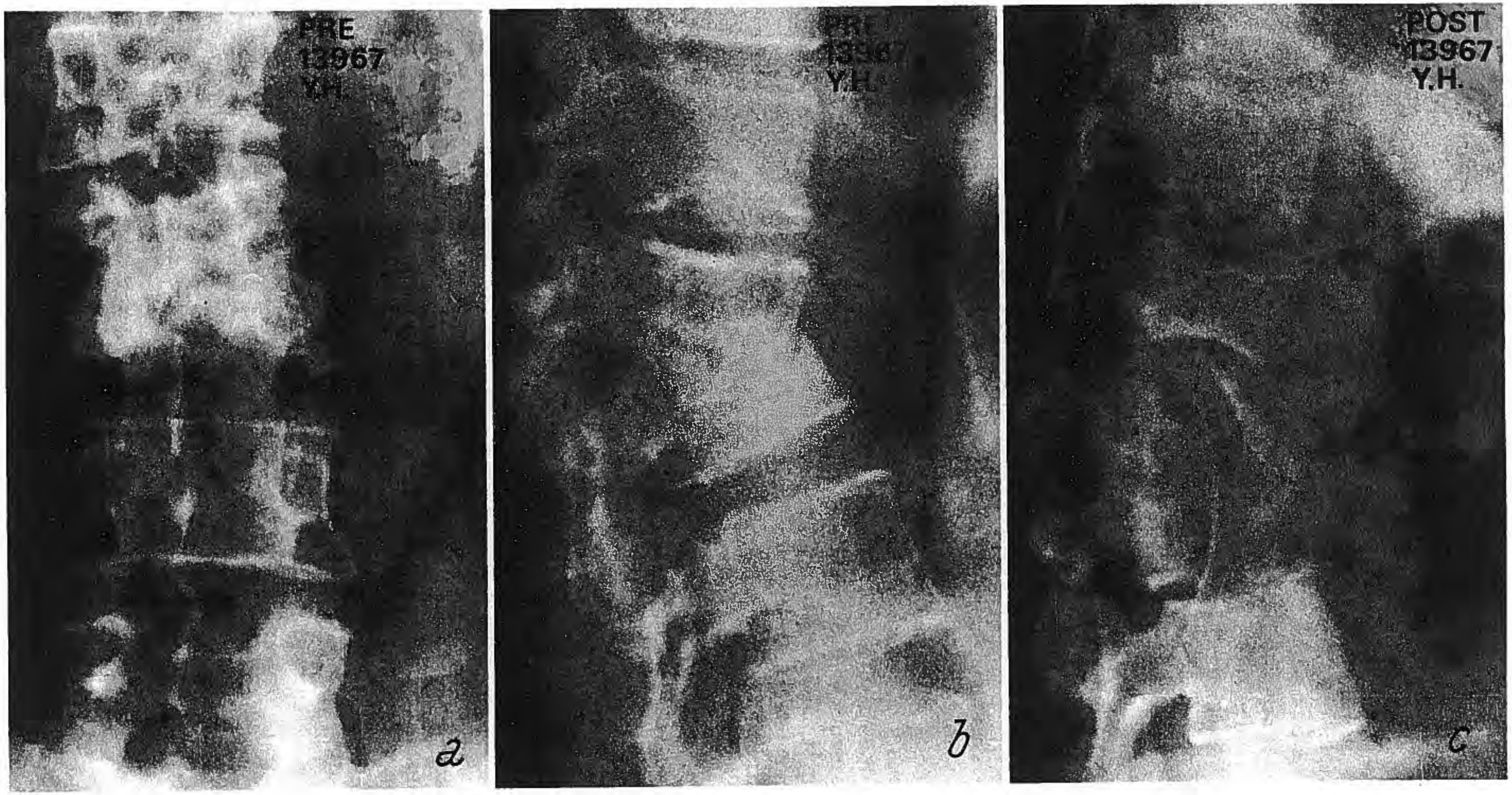


Figure 8.11



Figures 8.12. a A lateral radiograph of the cervical spine showing gross vertebral destruction at C6 with subluxation of the spine complicating tuberculous infection. **b** A lateral radiograph of the same spine six months after operative treatment for debridement and anterior interbody fusion. Note the correction of the deformity and the presence of a uniting interbody fusion



Figures 8.13. a An antero-posterior view of the lumbar spine of an adult patient with destructive changes in the vertebral bodies of L 2 and L 3 with a minor scoliosis. The psoas shadow is distorted on the right side of the picture. **b** A lateral radiograph of the same spine showing a kyphotic deformity developing at the site of the tuberculous lesion affecting the adjacent margins of the L 2 and L 3 vertebral bodies. **c** A lateral radiograph of the same spine taken following extensive debridement of the tuberculous lesion with the insertion of a large graft cut from the iliac crest. Post-operative management either in a plaster bed or on a rotor bed is essential for at least three months before the patient can be fitted with a plaster jacket or suitable brace. (The illustrations in Figs. 8.12 a and b and 8.13 a–c are provided by courtesy of Professor P. R. Chari, formerly of the Osmania Medical College, Hyderabad, India)

Correction of kyphotic deformities of the spine due to Pott's disease has been undertaken with considerable success in a limited number of special centres in the world.

A surgeon who has had no special experience in the management of post-infective kyphoses should avoid "trying his hand" on such cases. Should he be obliged to operate on a patient with a gross spinal kyphosis, with active tuberculous disease and clinical evidence of spinal cord dysfunction, he should treat the case by anterior decompression and anterior interbody fusion, making no attempt to correct the deformity. The patient should be nursed in a plaster bed for three months after surgery.

8.3. Post-Operative Infections

Some of the surgical aspects of the management of post-operative infections following spinal operations are discussed in Chapters 7 and 9.

Fortunately, serious infections are uncommon. Surgeons, therefore, have a natural tendency to hope that wound infections may subside with the use of chemotherapy alone. They may be reluctant to explore the wound early after the onset of infections.

Clinically, distinction should be drawn between superficial and deep wound infections. In patients with a thick layer of subcutaneous fat between skin and lumbo-dorsal fascia, fat necrosis and infections in the haematoma between the skin and the underlying paraspinal muscle layer will give rise to the appearance shown in Fig. 8.14. The patient's temperature will be only slightly elevated and local pain in the wound will not be severe. Although slow to heal, this type of infection is not serious. It will respond to limited local drainage, following removal of a few sutures, and the use of chemotherapy.

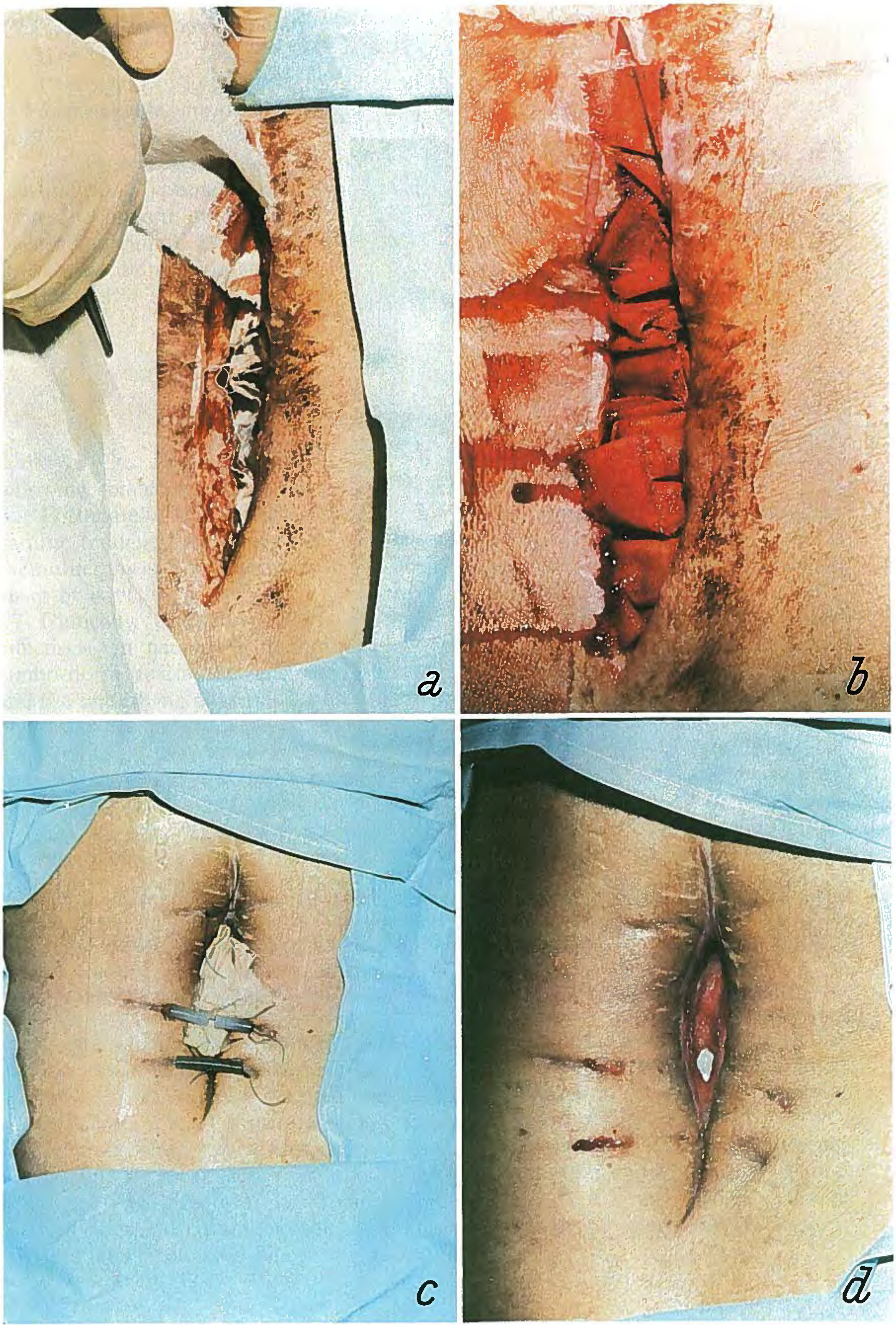
On the other hand, with deep infections, patients become febrile and ill, and they complain of extremely severe pain. Prompt surgical drainage should be carried out under anaesthesia. All sutures should be removed from the skin and deeper structures, so that the vertebral column can be re-explored. Infected blood clots and free pus should be aspirated, and material sent for further detailed bacteriological tests.

The whole wound should be washed out with a solution of hydrogen peroxide. Dry packing should then be inserted. Secondary suture of the wound can be performed when cultures from the granulating wound surfaces have become sterile.

If deep infections, either in the neck or elsewhere in the spine, are treated promptly in this way, the dreaded complications of vertebral osteomyelitis, epidural abscess formation, or even meningitis should not develop (Figs. 8.15a–d).

Patients who present with persistent severe spinal pain (with or without small discharging sinuses) some months after treatment for post-operative wound infections, will require very careful re-assessment. In this group, chronic osteomyelitis and chronic spinal epidural abscesses may be discovered resulting in crippling and prolonged illness (Fig. 8.16).

Figure 8.14. A photograph of the incision used for lumbar laminectomy in a young woman in whom the subcutaneous fat layer between skin and lumbo-dorsal fascia measured 9 cms. Serous fluid containing fat droplets leaks from the wound. The incision was re-opened in the mid-line but extensive dissection was not necessary, the problem being confined to the sub-cutaneous layers of tissue superficial to the lumbo-dorsal fascia, as is usual in this type of wound infection



Figures 8.15

Figure 8.16. A lateral tomogram of the mid-lumbar spine of a woman aged 58 years. Note the gross destruction of two adjacent vertebral bodies and the resultant marked kyphotic deformity. This patient developed an epidural abscess following infection of a laminectomy wound with secondary vertebral osteomyelitis

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Figures 8.15. Photographs illustrating progressive stages in the management of chronic osteomyelitis of the spine following posterior bone grafting for spondylolisthesis 15 years earlier. This patient had had a discharging sinus in his back with intractable back pain for many years. **a** The problem was treated by radical excision of the graft and packing of the cavity with calico. **b** The appearance of the wound three days after the operation for graft excision. **c** The appearance of the wound at the time of secondary suture when cultures from the granulating surfaces were sterile. **d** The appearance of the wound following removal of the tension sutures after secondary suture. Note the dural tissue in the base of the wound. The wound healed completely and epithelialized four weeks after this photograph was taken. The patient was treated with appropriate chemotherapeutic agents for more than one year

9

The Management of Failed Spinal Operations

9.1. Introduction

Waddell *et al.* (1980), painted a gloomy picture of the outcome for patients who have had multiple back operations. Little wonder that patients with persisting serious spinal problems are often given dire warnings about further operations, not only from non-medical sources but even from some specialist surgeons. There are certainly daunting problems in their management. These patients are often debilitated and demoralized. Family breakdown, financial stress, drug dependency and frank persecution by insurers, examining doctors and employers constitute some of their difficulties–leaving aside the question of the actual physical causes of their persisting disability.

This is one of the most challenging fields of spinal surgery and there is no place in it for a surgeon who is sceptical or suspicious of his patient or whose attitudes are in any way defeatist.

9.2. Investigation

The cornerstone of management is to investigate these problems with great care and with compassion, before recommending further surgery. The surgeon must establish a competent team of consultants to help him, though he should remember the aphorism which guided Harry S. Truman, the U.S. President: "The buck stops here"; a saying applicable to decision making in the context of divided responsibility. The team should include the following people:

general practitioner, psychologist, psychiatrist, social worker, physiatrist, physiotherapist, neurologist, radiologist–providing each has a declared interest in this type of work.

Before outlining a simple system for the analysis of failures after spinal operations, some general comments should be made on the subject of investigations.

Clinical neurological examination may be unrewarding in assessing the level or severity of nerve root or cauda equina lesions. Matsuda *et al.* (1977, 1979) have advocated the use of electro-neurophysiological techniques for the identification of compressive lesions of individual nerve roots of the cauda equina or for the study of single nerve root units in degenerative spondylolisthesis, and these may find wider usage in the future.

Radiological examinations which may be essential in helping to establish diagnoses and to plan further surgery in particular cases include:

a) Motion studies of the spine: instability may require spinal fusion.
b) Oblique views of the facet joints and intervertebral foramina: unrecognized foraminal stenosis may require decompression.
c) Antero-posterior and lateral tomograms in any case of failure following spinal fusion or canal exploration: irregular laminal remnants or re-formed bone in scar tissue may require revision of canal decompression.
d) Repeat myelography: to demonstrate space-occupying lesions or arachnoiditis.
e) Discography: to plan the extent of spinal fusion.
f) *Computerized tomography*–especially if reconstructed scans in three planes can be obtained: this offers a wide range of diagnostic information but *does not necessarily supersede the use of (a)–(e).*

The analysis of individual cases of failed spinal operations may be facilitated by using the following classification:

1. Outright Failure

This group comprises patients who show no improvement or who become worse after the first operation.

2. Temporary Relief

These patients may be free of symptoms for months or years after operation.

3. Failures in Spondylolisthesis

These patients are considered separately because of special features of the pathological anatomy in this condition. (See p. 146.)

4. Infection

9.3. *Outright Failure*

Failure is usually related to wrong diagnosis. Some pain and discomfort are to be expected after any spinal operation. Pain protracted over weeks may follow some operations in which adherent root sleeves have been tediously separated from disc tissue, yet a successful outcome can be predicted. Such special circumstances excluded, patients in this group can usually be identified soon after operation. They complain of pain which is more severe than is normally expected. Those with infections will have elevated temperatures and altered blood counts.

The questions to be determined are simply these:

Is the failure due to an *unrecognized condition?*
Is it due to *wrong diagnosis of the spinal lesion?*
Or finally, has it followed some *technical failure?*

a) Unrecognized Conditions

Investigations should begin as soon as possible, but several months may elapse before the diagnosis can be established. For example, a carcinoma involving the apex of the lung may be the cause of neck pain and brachial neuralgia persisting after anterior cervical fusion. Operation for lumbar spondylolisthesis may fail because the true cause of pain is a secondary prostatic carcinoma of the vertebra.

Rarely, infection after a spinal operation may be caused by tuberculosis or gonorrhoea.

Primary tumours in the spinal canal are relatively rare. They are usually diagnosed before operation by clinical examination and by myelography. However, in cases of failure, the possibility that such lesions may be the cause of continuing symptoms should be considered.

b) Error in Diagnosis of the Spinal Condition

Three questions must be answered:

1. What was the primary diagnosis?
2. What were the operative findings?
3. What was the nature of the operation?

Stenoses of the spinal canal or of a nerve root canal must be excluded as underlying causes of failure. The possibility that the symptoms are those of "claudication" of the cauda equina must be borne in mind. Under such circumstances, myelography is essential to clarify the diagnosis.

c) Technical Errors

i) In Operations for Disc Prolapse

Persistence of severe pain is unusual if the diagnosis of disc prolapse has been confirmed at operation. If a considerable amount of fragmented and dessicated disc material has been removed, it is likely that a further fragment has been displaced beneath the root sleeve after operation, or that a migrating sequestrated fragment has not been removed.

If a pre-operative diagnosis of disc prolapse was made but no disc prolapse was found at the time of operation, it is likely that the intervertebral space at the wrong level has been explored (Fig. 9.1).

Most failures occur when no disc prolapse has been found and perhaps the diagnosis of internal disc disruption should have been established by discography before operation (see pp. 44–56).

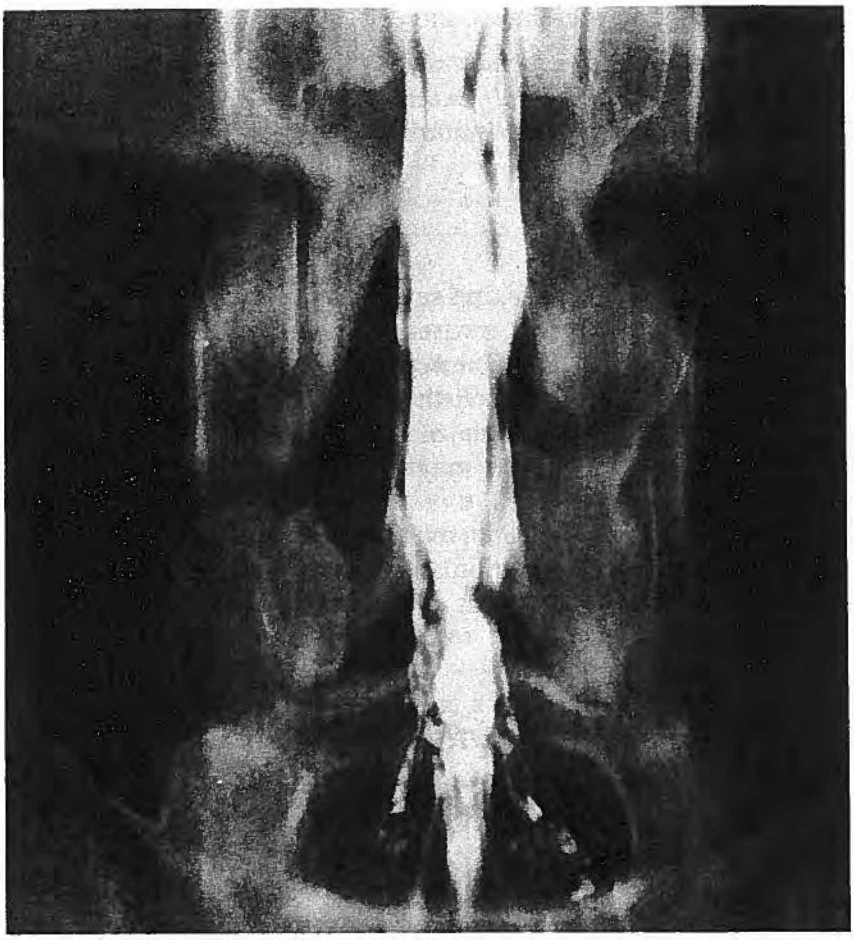


Figure 9.1. An antero-posterior tomograph of the lower lumbar spine in a patient aged 37 years, said to have undergone laminectomy for removal of a left-sided lumbo-sacral disc prolapse. Part of the upper margin of the lamina of the 4th lumbar vertebra has been removed, so that space between the 3rd and 4th vertebrae was probably explored. The outline of the myodil shows that there is bilateral stenosis of root canals at the L4/5 level. This patient's symptoms were relieved by further decompression of the spinal canal, involving removal of the central segment of the arch of the 4th lumbar lamina, combined with bilateral nerve root canal decompression at that level

ii) In Operations for Internal Disc Disruption

If this diagnosis has been established by discography and disc excision and interbody fusion have been done, early failure may indicate that the wrong level has been fused. In the neck particularly, levels should be identified by radiographs taken during operation. The injection of methylene blue at the time of discography is an unreliable method of identifying the level of an affected disc. Even in the lumbar spine, levels may be wrongly identified, especially if there are anomalies such as sacralization.

9.4. Temporary Relief

In this group initial relief of pain after operation may last for weeks or months before the recurrence of disabling pain. The largest number of cases falls into this category.

a) Failure After Operation for Disc Prolapse

Recurrence is usually caused by recurrent prolapse at the level operated on, especially if a large volume of disc material was removed at the original operation, or by a fresh prolapse at another level.

Recurrent but contralateral sciatica occurs after asymmetrical settling of the vertebrae when several grams of disc material have been removed at the initial operation. Radiographs show collapse of one side of the intervertebral space. Recurrence of pain is caused by a fresh prolapse of disc material or by stenosis of the nerve root canal following deformation due to the reduction in height of the intervertebral disc space.

The commonest cause of late recurrence of symptoms after initial successful excision of a disc prolapse is stenosis of the spinal and nerve root canals secondary to degenerative changes (Figs. 9.2a–c). Ectopic ossification or calcification in the remnants of ligamentum flavum may be found at the site of re-exploration in such cases.

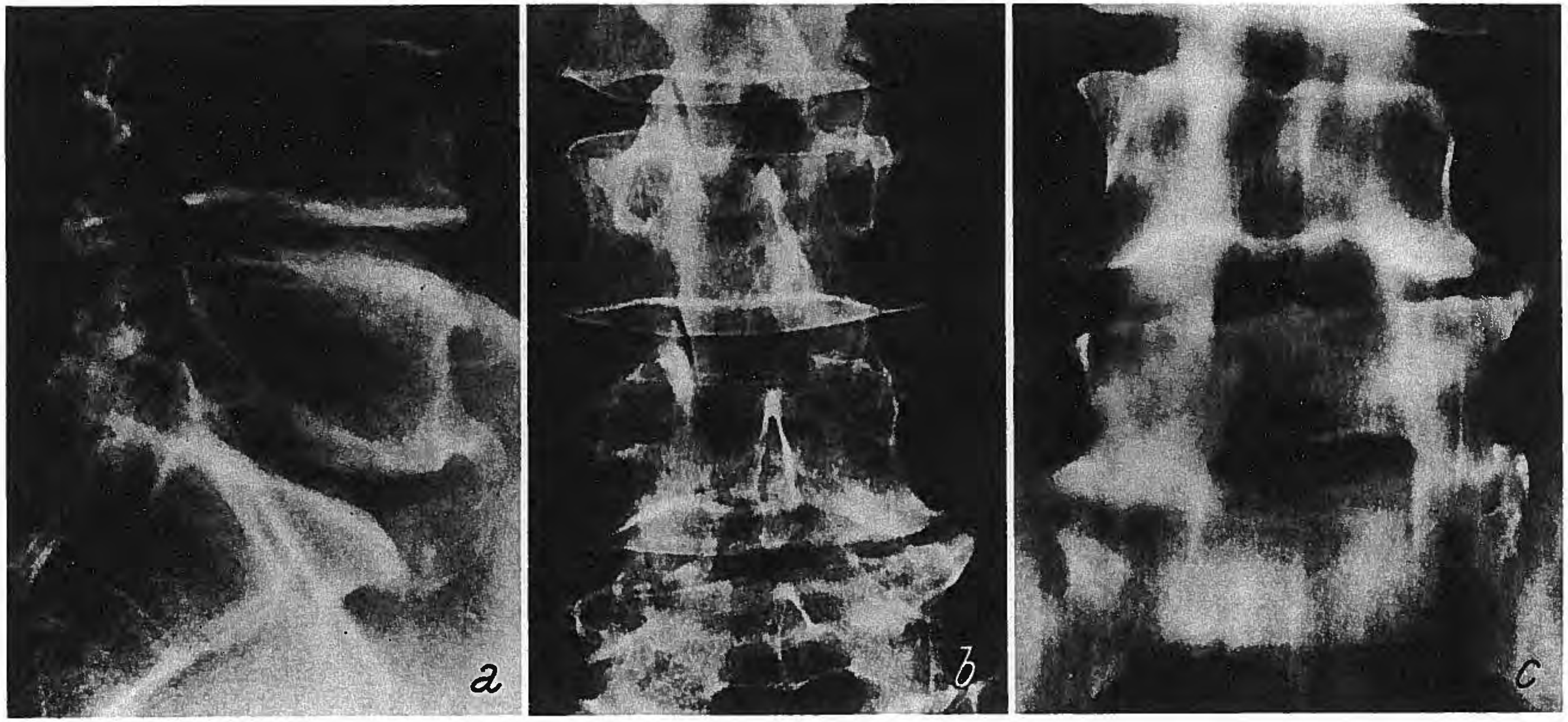
Another cause of late recurrence, often associated with secondary canal stenosis but contributing to the overall problem, is the presence of a meningocoele caused by damage to the dural sac at the time of the original operation.

b) Failure After Operation for Internal Disc Disruption

If interbody fusion has been performed for this lesion, early recurrence of severe symptoms within two or three months of operation may be due either to complications of the discography or to trouble arising at the site of grafting.

Chemical discitis may cause severe pain post-operatively if the discography has been followed within a short time by operation. Erosion of the vertebral end-plates and bodies in the area of the nucleus pulposus occurs on either side of the disc, leading to gross narrowing of the intervertebral space at the level of the normal disc above or below the "fused disc". Histological examination of specimens removed at operation shows inflammatory changes with plasma cell infiltration. Cultures are sterile. Injection of steroid into the disc usually controls the pain and promotes healing, though oral Cortisone administered over the course of ten days may also be effective (see Chapter 2, Figs. 2.17, 2.18a–c, 2.19a, b).

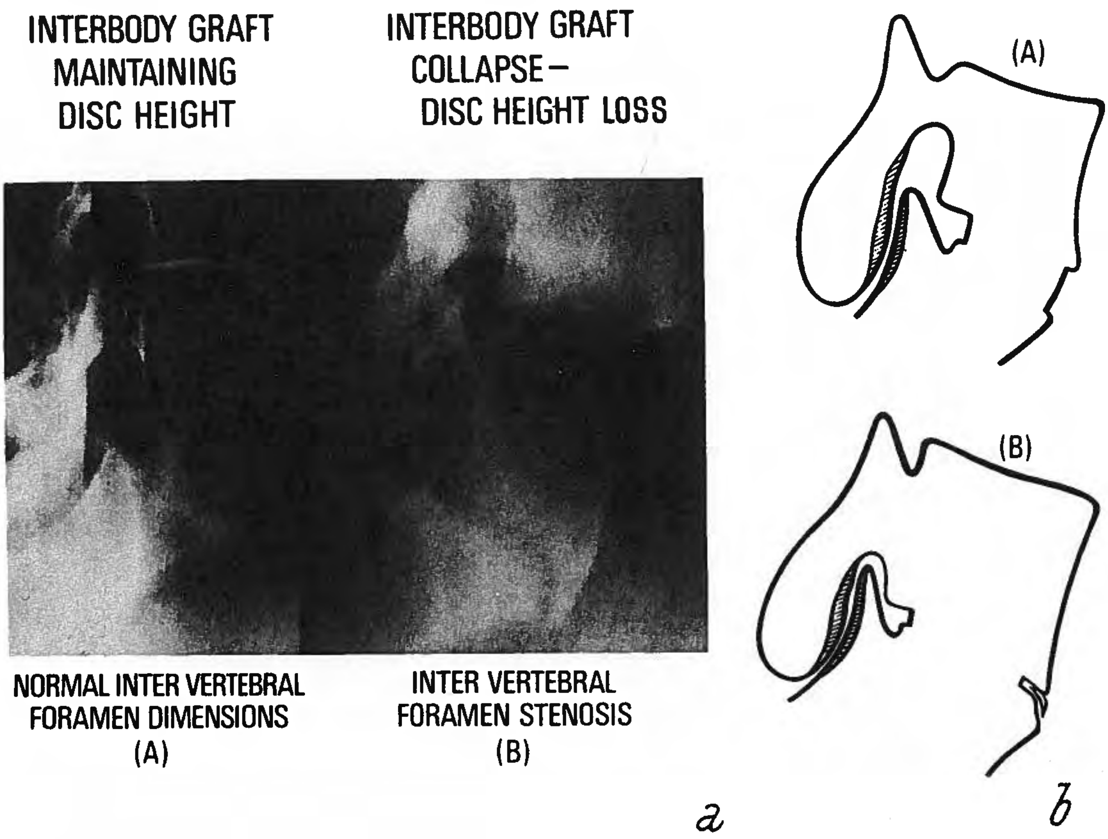
Non-union of grafts occurs in a few instances. These problems are discussed in detail on p. 83. The incidence of non-union of interbody grafts has been reduced in recent years following improvements in surgical technique reported by Crock (1976), by Crock (1982) and by Fujimaki, Crock and Bedbrook (1982). Grafts of cancellous bone were shown to have two disadvantages: they are prone to infiltration by disc remnants with subsequent non-union and graft resorption; secondly, even though union occurs, loss of intervertebral height may follow collapse of the cancellous graft and its settling into the vertebral bodies. Stenosis of the nerve



Figures 9.2 a–c. Degenerative changes 30 years after removal of an intervertebral disc prolapse at L4/5 level in a patient aged 61 years. Note the inter-laminar calcification in the antero-posterior view in Fig. 9.2b. Fig. 9.2c, a tomogram showing the extent of the decompression of the spinal canal and nerve root canals

root canal follows and may cause recurrence of pain in both lower limbs (Figs. 9.3 a, b).

Block or dowel grafts cut from the anterior half of the iliac crest provide grafts which are rapidly revascularized, usually maintain height and always resist infiltration by disc remnants (see Chapter 2, Fig. 2.45).

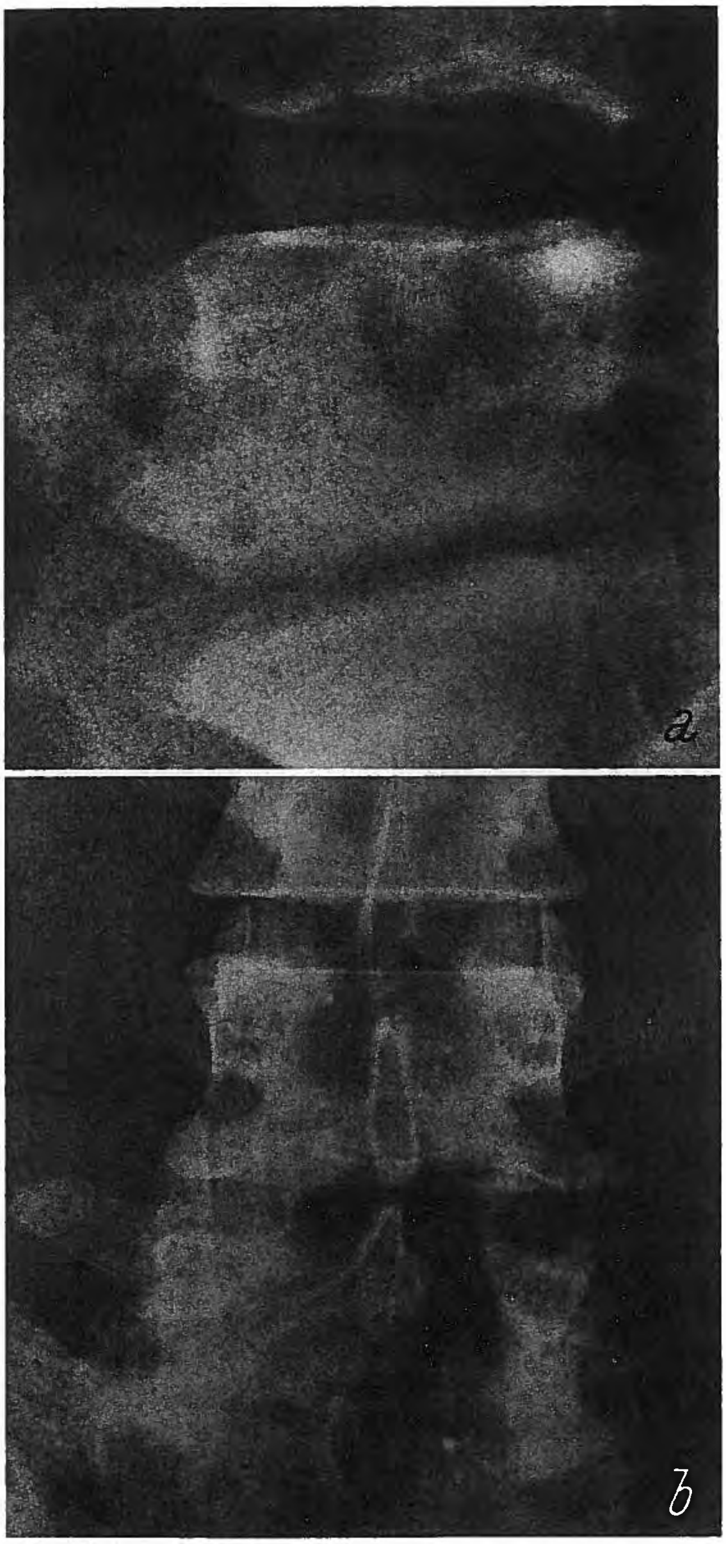


Figures 9.3 a and **b.** Lateral tomographs of the lumbo-sacral junction in man aged 46 years (A) is taken four months after operation, (B) is taken 18 months after operation. The graft has incorporated but secondary disc space collapse has occurred with resultant nerve root canal and intervertebral foraminal stenosis. The diagrams (A) and (B) alongside depict the genesis of the foraminal stenosis

Following successful interbody fusions, the ligamentum flavum related to the fused segment will atrophy, adhering then to the dura and nerve root sleeves. With vertebral column movements above the fused segment, stretching of the dural root sleeves may occur and cause pain. Relief follows total laminectomy and excision of the ligamentum flavum over the area of the fused spinal segment or segments, leaving intact the facet joints between the fused and mobile segments of the column. In the cervical spine, the relevant root canals should also be decompressed, using a very fine forward-angled rongeur.

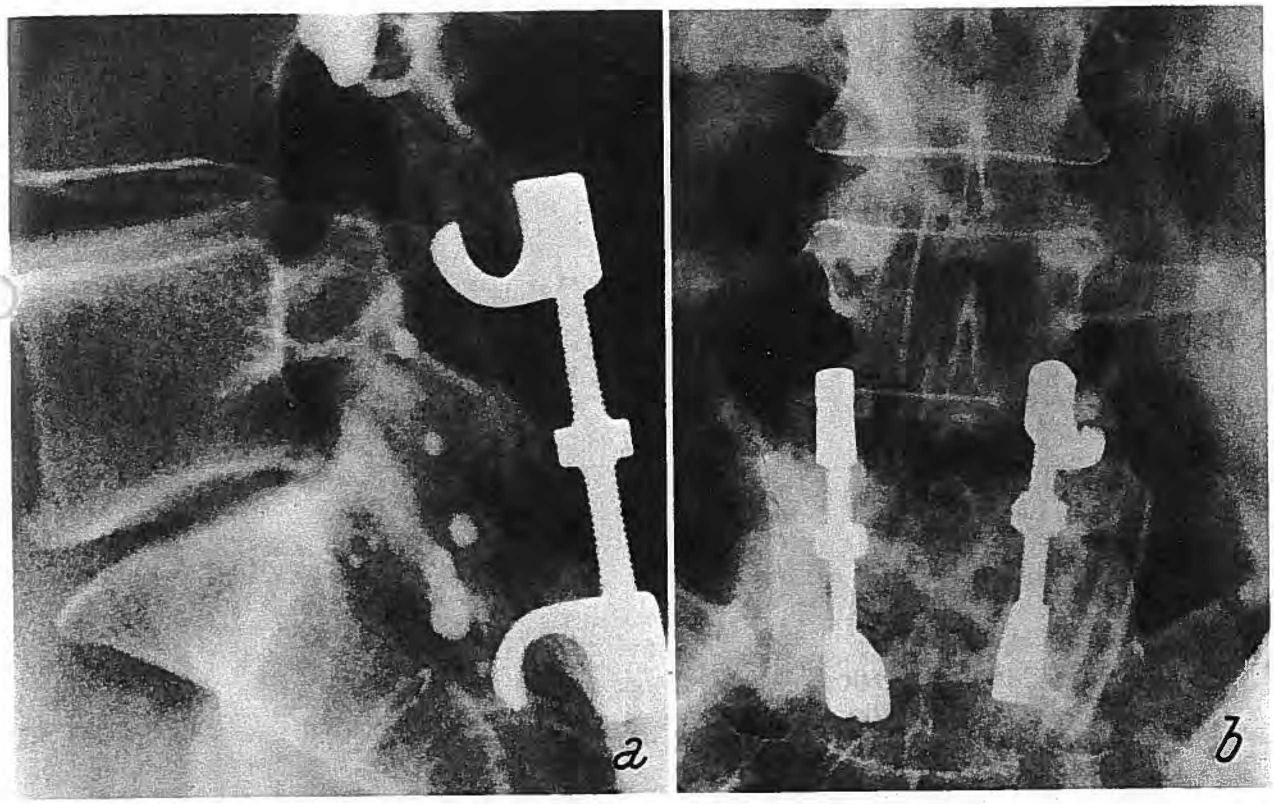
c) Failure After Operation for Isolated Disc Resorption

This condition has been discussed in detail in Chapter 1. Acquired disc resorption may follow partial disc excision or intradiscal injections of Chymopapain. In such



Figures 9.4

cases symptoms usually recur or persist after a second exploration of the disc space with hemi-laminectomy and removal of more disc material (Figs. 9.4a, b). The appropriate surgical treatment of bilateral nerve root canal decompression is discussed in detail on pp. 23–27. If the true significance of the pathology of isolated disc resorption is not appreciated, the patient may be subjected to further major surgery, involving adjacent normal segments of the spine (Figs. 9.5a, b).



Figures 9.5. a A lateral radiograph of the lower lumbar spine. Isolated disc resorption is noted at the lumbo-sacral junction with a degree of retrolisthesis of L5 on S1 and a positive Knuttson sign. The L4/5 disc space is normal. Knodt's rods have been inserted beneath the lamina of L4 above and into the sacrum below. **b** An antero-posterior radiograph of the same spine. Note the bilateral Knodt rods and the segments of graft, some of which extend upwards to lie against the left side of the spinous process of L3. The pathology in this case was present only at the L5/S1 level. *In this patient, two other normal spinal segments have been operated upon unnecessarily.* Supplementary treatment in this case involved removal of the Knodt rods, excision of the unwanted bone at L3/4 and L4/5, and bilateral nerve root canal decompression at L5/S1 level

Figures 9.4. a A lateral radiograph of the lower lumbar spine of a woman aged 37 years with persistent pain in the back and lower limbs. Note the narrowing of the lumbo-sacral intervertebral disc space, with minimal osteophyte formation and marked sclerosis of the adjacent vertebral body. **b** The antero-posterior radiograph shows the amount of residual laminal bone after two previous operations. This patient's problem was due to acquired disc space narrowing following intervertebral disc surgery, with resultant bilateral nerve root canal stenosis. The second operation has been inadequate, the remnants of the central portion of the 5th lumbar lamina should have been removed, and bilateral nerve root canal decompression performed as described in Chapter 1, pp. 23–27

9.5. Surgical Techniques for Re-Exploring the Spinal Canal

a) Preparation

These procedures are often time-consuming and associated with considerable blood loss. Blood transfusion facilities must be available. Adequate supplies of bone wax, gelfoam or equivalent haemostatic agents should be ready for use.

b) Radiology

Radiographs of the patient's spine should be displayed on a viewing box in the theatre. The most valuable information for the operation of re-exploring the spinal canal is usually provided in antero-posterior views, including tomograms which show the anatomy of the roof of the spinal canal or its remnants most clearly (Fig. 9.6).

c) Positioning

Positioning on the operating table is important and use of the prone position on a suitable frame is recommended.

d) Instruments

Opening of the dural sac may be indicated if arachnoiditis of the cauda equina is recognized during operation. Dural tears may occur accidentally in the course of dissection, especially at the junction of previously operated and non-operated areas. If the dural sac and nerve root sheaths are tethered to the floor of the spinal canal by dense adhesions, it may be necessary to open the dural sac to gain access for removal of prolapsed disc fragments. On rare occasions meningocoeles may be encountered unexpectedly. An adequate array of instruments, including a fine sucker, long handled fine toothed forceps, long handled fine needle holder and long fine "atraumatic sutures" on fine needles (4.0 or 6.0 sizes) should therefore be readily available so that any of these problems may be dealt with promptly during the operation.

e) Exposure

A mid-line incision should be used. Bony landmarks at the extremities of the incision should be palpated with the aim of exposing intact spinous processes and laminae above and below the area to be re-explored.

f) Orientation

The soft tissues relating to the spinous processes should be stripped on one side, then the other. While it may seem too simple to describe these manoeuvres, in fact, this part of the operation assumes great importance. The paraspinal muscles should be

Figure 9.6. An antero-posterior tomogram of the lower lumbar spine of a man aged 52 years who complained of recurrent back and leg pain following two previous spinal operations, including spinal canal decompression and postero-lateral inter-transverse-alar fusion. Note the reformation of the laminal remnant near the top of the picture on the right side at the upper extremity of the previous exploration

separated carefully from the lateral aspects of the spinous processes and the posterior surfaces of the laminae, leaving the periosteum intact and avoiding any disturbance of the capsules of the facet joints. At the upper end of the incision the intact lamina and its inferior facets should be clearly defined, as should the posterior surface of the sacrum below, to the level of its superior laminal edge. Self-retaining retractors should then be inserted before any effort is made to expose the actual area to be re-explored, beyond joining the zones of the sacral exposure and the upper spinous process by a mid-line incision a few centimetres deep into the scar tissue.

The surgeon must re-assess the patient's X-rays at this stage, to be certain of the location of laminal remnants in the dense scar tissue which has usually formed between the paraspinal muscles and the roof of the spinal canal following previous surgery.

Using a sharp scalpel, an oblique incision is made into this scar tissue, starting in the mid-line at the upper extremity of the wound on one side, the direction and depth of the cut being gauged by the orientation of the cleared lamina and its inferior facet joint, laterally and inferiorly to the level of the next joint. The extent of muscle damage resulting from the previous surgical procedure or procedures will be variable. Where it has been slight, there will be a clearly defined fatty layer between the anterior surface of the paraspinal muscles and the bony canal. Through this soft tissue the surgeon can easily palpate the facet joint with the tip of his index finger, thereby determining the plane of dissection. In cases where very dense scar tissue has invaded the paraspinal muscles at the site to be re-explored–a likely finding after multiple explorations–identification of the lateral edge of the pars interarticularis of the lamina and its inferior facet joint is difficult. The site of the pars interarticularis below the normal facet joint at the upper end of the incision can be identified either by removing the extra-synovial fat pad from this facet joint or by locating the main stem of the posterior branch of the lumbar artery which is a constant lateral relation of the pars interarticularis. Using either or both of these guidelines, one can determine the direction of the incision which will lead safely to the exposure of the outer edge of the lamina and its related facet joint. Depending on the findings in particular cases, one may proceed to expose the entire area to be re-explored on one side between the sacrum below and the normal spinous process and lamina above, then repeat the procedure on the opposite side. Where there have been multiple previous operations, it is often wiser to make limited exposures, one level at a time, on the right and left sides alternately, moving the self-retaining retractors progressively as required.

If a meningocoele is present, it will be identified early. Cerebrospinal fluid will fill the wound when the scalpel is used to cut obliquely into the scarred tissue after preliminary exposure of the normal bony segments of the canal, as described above. The inexperienced surgeon will be shaken by the appearance of C.S.F. so early in the operation. The meningocoele should be identified as such and thereafter ignored until the formal exposure of the roof of the spinal canal or its remnants has been completed.

Once the lateral bony margins of the laminae and the facet joints have been exposed on both sides, the self-retaining retractors are positioned definitively.

g) Timing of Retractor Application

The time of their application should be noted because re-exploration operations may last more than two hours. *The retractors should be removed at intervals of 45–60 minutes for 5 minutes,* to restore circulation in the paraspinal muscles. During these rest periods the wound may be irrigated with Ringer's solution.

At this stage of the procedure, a bulky mass of scar tissue of variable depth remains in the mid-line between the lumbar spinous process above and the back of the sacrum below. Its relationship to the underlying dura will vary depending on the amount of laminal bone remaining or reformed after the previous operation or operations. The surgeon should now strip all soft tissues from the outer surface of each lamina or laminal remnant, *referring once again to the patient's X-rays.*

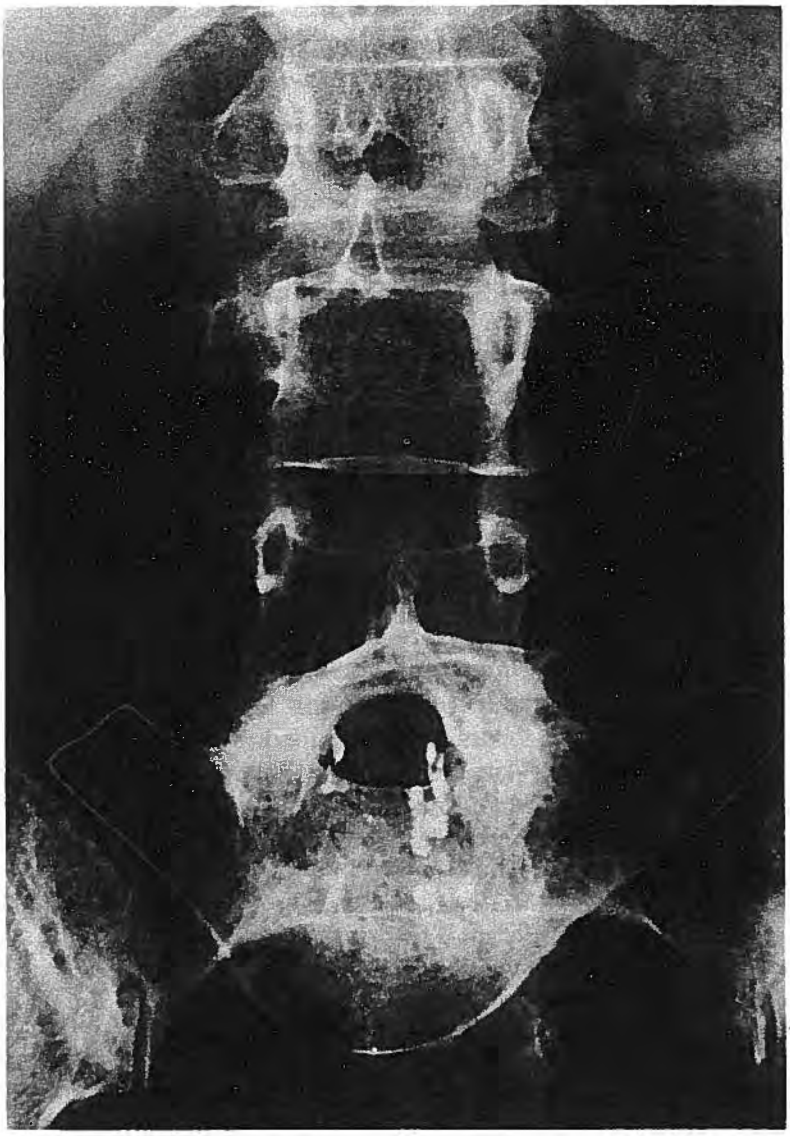


Figure 9.7. An antero-posterior radiograph of the lumbar spine of a woman aged 53, with spondyloptosis of L5. Note the classical radiological sign of "Napoleon's Hat". At operation, identification of vertebral levels can be difficult in such cases. Despite two operations aimed at decompressing the lumbar canal and nerve roots related to the spondyloptosis, the lamina of L5 remains intact. However, the laminae of L2 and L3 have been removed, along with some of their related facets

Identification of laminal levels can be very difficult, particularly in cases with anomalies at the lumbo-sacral junction or in spondylolisthesis with the higher grades of slip of the vertebral body (Fig. 9.7). It may be necessary to take control X-rays in the operating theatre in such cases. This done, at each level between the sacrum and the normal lamina and spinous process above, the bulky mid-line scar tissue can be excised or thinned down to the level of the bony canal, using either a large rongeur with sharp cutting edges or a sharp scalpel.

h) Re-Opening the Spinal Canal

If the upper end of the sacral lamina is in the field of operation, the canal can be re-entered easily in the mid-line, even if the dural sac is covered with densely adherent scar tissue. This can be done by thinning the lamina in the mid-line and then stripping the scar tissue carefully away from its upper edge with a pointed probe (such as the Watson-Cheyne probe). Alternatively, when the bone is very thin, a small gouge directed proximally from a few millimetres distal to the free edge of the lamina can be used. A small plug of laminal bone is turned out, allowing the insertion of a blunt-ended probe into the canal. The dura is pushed away and a 2 or 3 mm sized cup of a 45° forward-angled rongeur then inserted to open the roof of the sacral canal, a few millimetres distal to its upper free edge, from the mid-line outward on both sides to the level of the medial margins of each S1 pedicle. Dural tearing may occur at this stage. It is avoided by careful handling of the fragments of sacral bone created by the use of the angled rongeur. These fragments should not be pulled on forcibly. They are best left attached to the scar tissue, to be dissected free from it by sharp dissection after the canal has been exposed to the level of each S1 pedicle.

Should it be decided to commence the dissection for entry into the spinal canal at the upper end of the operation field, it may be easily done by removing the normal ligamentum flavum from the spinal segment immediately adjacent to the area to be re-explored. The central portion of the lamina on the inferior side of this vertebral interspace is then removed, using the same techniques described in dealing with the removal of the sacral laminal bone at its site of attachment to the scar tissue overlying the dura. Further dissection distally follows, using the landmarks of facet joints, medial pedicular margins and pars interarticularis, obtaining exposure one side at a time, with the careful technique outlined above.

Scar formation between the dura and nerve root sleeves and the paraspinal muscles is prevented by normal ligamentum flavum. This fact should be remembered when re-exploring a spinal interspace, which may have been opened previously on one side only, as it may be put to good use, allowing safe entry into the spinal canal without risk of injuring the dural sac.

Regrettably, notes made at the time of the original surgery are rarely available to a surgeon when he is re-exploring a patient's spine. The identification of a segment of normal ligamentum flavum often assumes great importance. Although the outer surface of this ligamentum may be covered with dense white scar tissue arising from the deep surface of the paraspinal muscles, its presence can be determined most easily by removing the extra-synovial fat pad from the adjacent facet joint, and then defining its characteristic yellow colour, where it attaches to the medial edge of the superior facet at the interspace. Once its presence has been confirmed, the white scar tissue can be cut away, defining its full extent, before incising this ligamentum flavum to gain access to the spinal canal.

In the course of the dissection just described, root canal stenosis or foraminal stenosis can be identified and relieved easily (see pp. 23–27). Once the lateral margins of the dural sac and the regional nerve root sleeves have been exposed on both sides over the whole area being re-explored, the surgeon is then in a position to assess the dural contents by digital palpation. If they are normal, the question of separating all the scar tissue from the dura should be addressed. It is not necessary to remove it entirely, but if scar tissue is left attached, it should be thin and should not contain any remnants of bony spicules. Bone left in scar tissue is likely to grow and it may lead to further canal stenosis after a few years, especially if a hemi-lamina is left nearby (Fig. 9.6).

With the canal thoroughly decompressed and any problems of root canal or foraminal stenosis already resolved, the regional intervertebral discs should be inspected, using digital palpation and probing with the Watson-Cheyne instrument. A nerve root may be bound to a recurrent disc prolapse by dense scar tissue. The use of an operating loop may be necessary to enable the separation of the root sleeve from prolapsed disc tissue, minimizing the risk of nerve injury. If recurrent disc prolapse is found, curettage of the intervertebral disc space may be indicated. The risk of penetration of the abdominal cavity may be high in these circumstances so that realization of this hazard should be uppermost in the surgeon's mind (see Chapter 3, Fig. 3.21).

i) Dural and Epidural Problems

i) Meningocoeles

These lesions are uncommon. They are often only recognized at operation and may be found early in the course of a re-exploration operation. When the spinal canal has been opened as described above, a meningocoele sac may then be dealt with quickly. It will usually have a single ostium which can be closed with a fine atraumatic suture after the bulk of the wall of the cystic cavity surrounding it has been separated from the dural sac and excised.

Dural tears should be avoided with attention to the details of dissecting technique outlined above. They may occur inevitably in some patients in whom the dura is abnormally thin. In such patients multiple tears sometimes occur and closure of the dural defects becomes impracticable. *The closure of the wound at the completion of the operation then becomes critical.* Several layers of sutures should be used in the muscle and fascial layers rendering the wound water-tight. Appropriate chemotherapy should be administered post-operatively until the surgical wound has healed, Penicillins and Sulphonamides being used together when applicable.

Small dural tears should be identified and closed with fine "atraumatic sutures", the area of the tear being kept dry with a fine low-pressure sucker and protective patty. Care should be taken to avoid trapping nerve root filaments in the sutures.

The management of the dura in cases of arachnoiditis of the cauda equina is discussed on p. 175.

The technique of transdural disc fragment excision is found on p. 119.

ii) Unrecognized Epidural Infection

Rarely during re-exploration of the lumbar canal, previously unrecognized epidural or vertebral body infections may be found. The history of a superficial wound infection, followed by *persistent spinal pain out of proportion to what might have been expected post-operatively,* should raise the possibility of this diagnosis. The planned operation of canal decompression should proceed, and intravenous chemotherapy should be commenced during the operation. Special care should be taken to avoid dural injury though the dura in such cases is often thickened. The epidural abscess should be sucked out and its extent defined. If necessary, pus in the intervertebral disc space should be aspirated and sent for immediate bacteriological examination.

The decision for primary or secondary wound closure should be resolved on the assessment of the extent and severity of the infection. It is better to pack the wound open with dry gauze where a large abscess cavity has been discovered, particularly if the vertebral bodies are infected. Secondary closure of the wound may be performed if cultures taken from the granulating surfaces become sterile (Chapter 8, Figs. 8.15a–d). Such wounds, even if they are extensive, will heal by secondary intention in 6–8 weeks. Daily wound care can be managed at home by visiting nurses after the first few post-operative weeks have been spent in hospital.

j) Re-Exploration of the Spine Following Spinal Fusion Operations

The principal indications for these operations are for the treatment of the following complications:

a) Non-union.
b) Graft overgrowth.
c) Development of secondary stenosis.
d) Disc or facet joint lesions above or below fused spinal segments.
e) Fusion at the wrong level.
f) Infection.
g) Spondylosis acquisita.
h) Ligamentum flavum atrophy.

i) Non-Union of Spinal Grafts

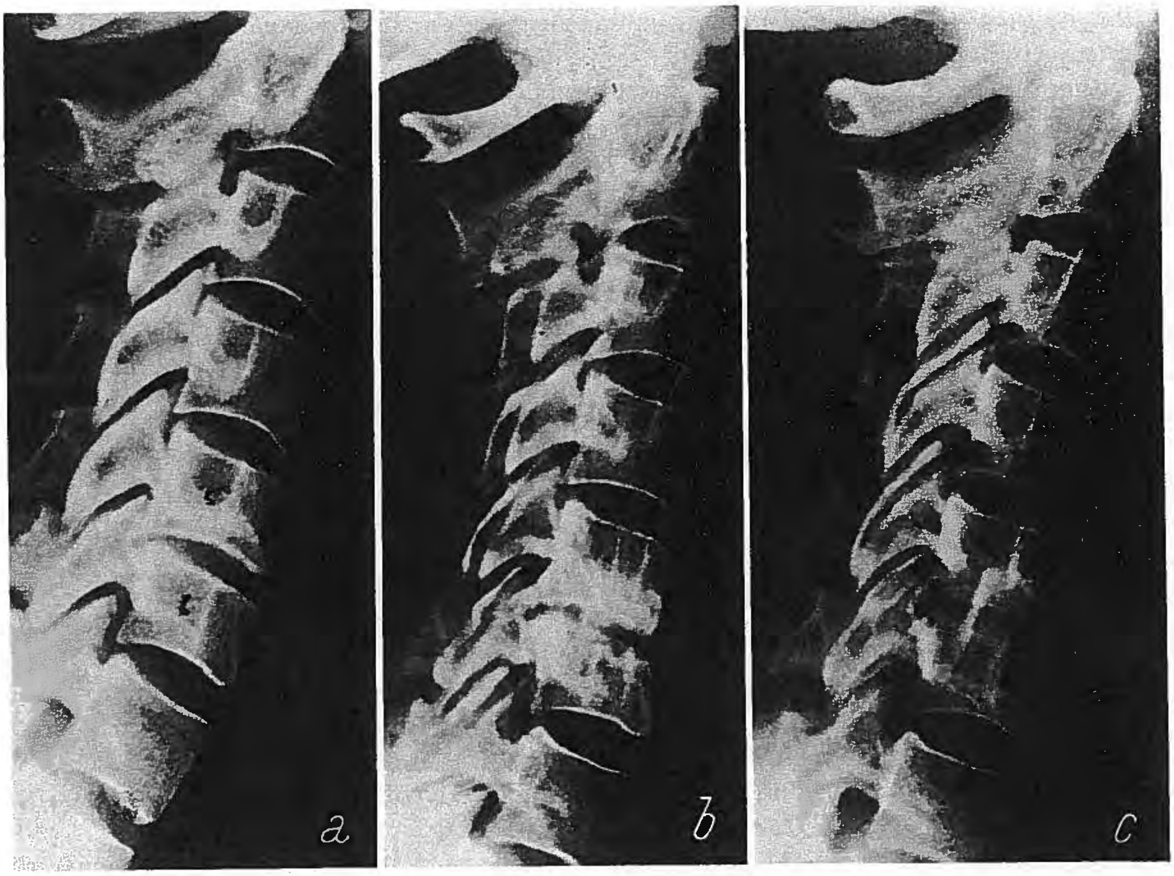
The multiplicity of methods of spinal fusion underlines the fact that it is difficult to produce union of the grafts with the vertebral column. The success rate of the lengthy spinal fusions used with Harrington's or Luecke's rods in scoliotics has not been matched when applied to the treatment of degenerative disorders or spondylolisthesis in the lumbar spine.

Non-union of the various spinal grafts used in the lumbar area can be diagnosed usually with plain X-rays, motion X-rays or tomograms. Discography may have a special place in the assessment of persisting pain after posterior spinal fusion with pseudarthrosis, as advocated by MacNab (1977, p. 214). Myelography may also be useful to demonstrate acquired canal stenosis.

Attempts at re-grafting in failed posterior fusions frequently fail. This problem may be managed most effectively in the majority of cases by a supplementary anterior interbody fusion.

Conversely, where an anterior interbody graft has failed, supplementary posterior inter-transverse grafting will often succeed, fusion of the anterior graft occurring pari-passu with the union of the posterior graft.

Particular problems may be encountered when attempting to repeat an anterior lumbar interbody grafting operation when no other method is applicable. The first is the identification of the vertebral interspace which will be obscured by extensive scarring. Facilities must be available for obtaining good quality radiographs in the operating room. The second problem of adherence of the great vessels to the vertebral column is always anticipated–so that a proper range of instruments and sutures should be available to deal with injuries to the great veins or their branches



Figures 9.8. Lateral radiographs of the cervical spine of a man aged 39 years. **a** shows an isolated spondylotic degenerative change between the vertebral bodies of C5 and C6, the cause of intractable neck pain, occipital headache and brachial neuralgia. **b** is a lateral radiograph taken nine months after interbody fusion performed by the Cloward method, showing non-union of the graft with some kyphotic deformity. **c** A lateral radiograph taken six months after replacement of the graft using the technique described in Chapter 7, pp. 199–206

which may be inflicted on them inadvertently during dissection. Lumbar interbody fusion operations are usually performed through left-sided abdominal incisions. In the special circumstances of attempting to re-graft in the case of failure, it may be wiser to expose the lower lumbar vertebrae through a right-sided extra-peritoneal approach. *Without doubt, attempted re-fusion of a failed anterior lumbar interbody graft should only be undertaken by a surgeon with special training in the use of these techniques of spinal fusion.* Even equipped with the necessary training and with the help of skilled assistants, it may prove technically impossible to perform a re-fusion by this method. The patient should be informed in advance of the potential problems, including the possibility that the operation may need to be abandoned without completion of the re-grafting.

Non-union of cervical anterior interbody fusions is uncommon. Re-grafting is usually easy, though identification of the site of the pseudarthrosis can be difficult. Special care is needed when inserting the instruments to cut a new graft bed—to ensure proper siting of the dowel cavity between the vertebral bodies, both in the longitudinal and transverse planes. In these cases it is easy to expose the vertebral artery and its venae comitantes if the cutter has been inserted too far laterally. The outlines of the inner margins of the longus colli muscles are usually obscured by the scar tissue formed following the previous surgery–so that the safety factor normally provided by the identification of these landmarks is lost. Damage to the vertebral artery and subsequent efforts to control the ensuing haemorrhage from it may lead to quadriparesis (Figs. 9.8 a–c).

ii) Graft Overgrowth After Posterior Spinal Fusion

Attention was drawn to this particular complication by Crock in 1976. It may occur following the use of techniques for posterior spinal fusions involving the use of fragments of cortico-cancellous bone. While every effort should be made to place the bone chips accurately at the time of performing inter-transverse, postero-lateral or Hibb's type posterior fusions, the movement of some of the graft fragments beyond the desired area of fusion may occur and these bony fragments may continue to grow. An extreme example of this problem was seen in an elderly lady who had had multiple spinal operations performed for a lumbo-sacral disc lesion. A dense spicule of bone had extended to the level of the facet joints at L1/2 on one side where the point of this "unwanted graft" impinged upon the facet joint capsule causing chronic pain. Examples of this unwanted overgrowth of graft are shown in Figs. 9.9 a–d. Gratifying relief of intractable back pain can be obtained in these cases by simply excising the "unwanted bone", leaving the main body of the graft intact.

iii) Development of Secondary Stenosis Beneath the Graft

Hypertrophy of posterior fusions has been reported and may lead to secondary lumbar canal stenosis after many years. The complication is not common. Currently it is best assessed either by the use of myelography or by C.T. scanning.

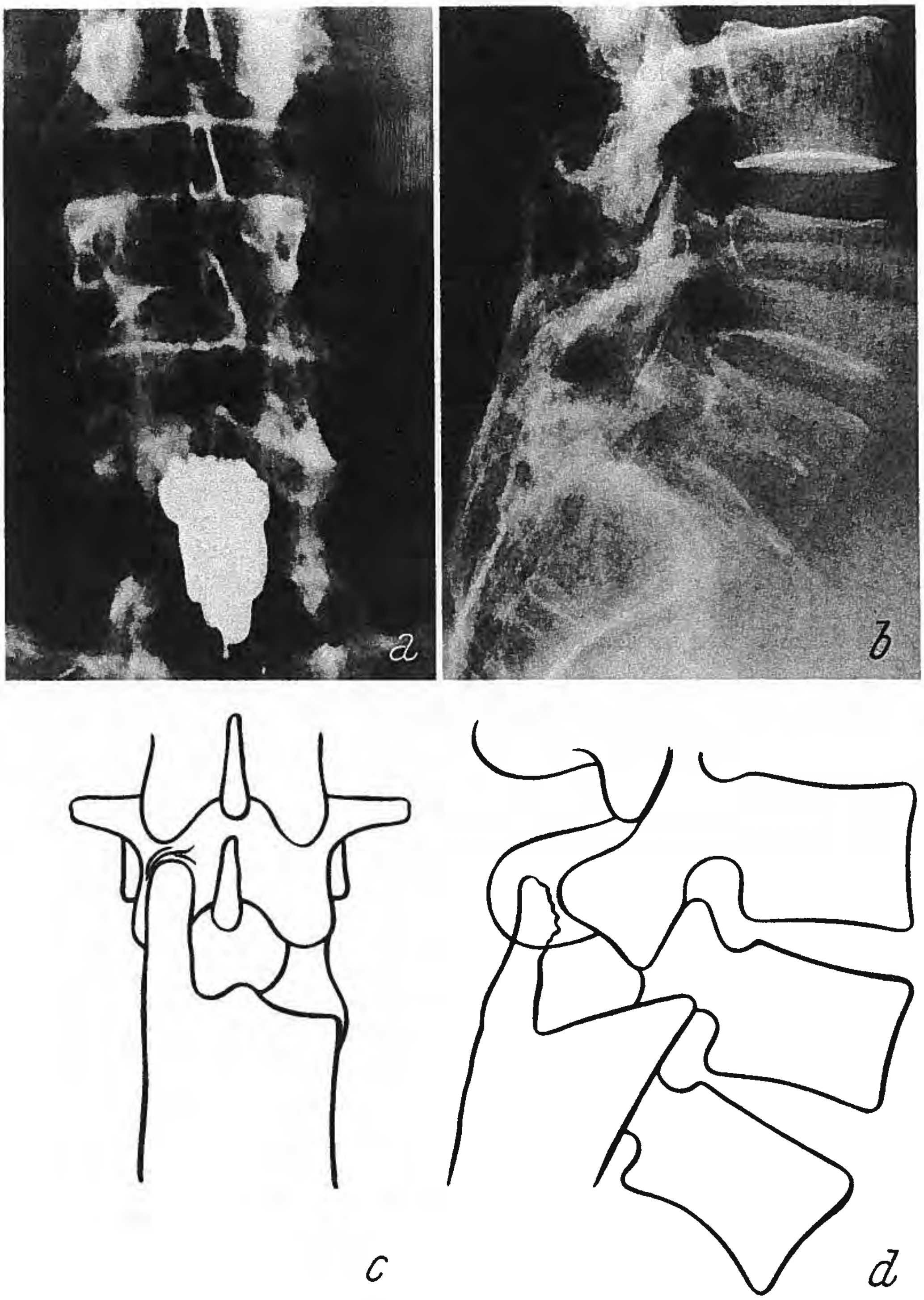
Relief of this form of stenosis can be difficult technically because the graft may measure many centimetres in depth. Usually it is possible to relieve the stenosis without interfering with the stability of the graft. This is done by removing the central segment of the graft and exposing the dural sac beneath it, being guided by the principles of re-exploration of the spine which have been outlined above.

iv) Disc or Facet Joint Lesions Above or Below the Fused Spinal Segment

Disc prolapse above a fused spinal segment occurs in a few cases. It usually occurs some years after the fusion and its identification is easy on clinical grounds. Myelography or C.T. scanning are useful investigations when this diagnosis is suspected.

Acute nucleus pulposus calcification may be seen in discs adjacent to a previously fused spinal segment (Chapter 4).

Secondary degenerative arthritic changes may affect the facet joints above and below fused spinal segments, leading to secondary root canal stenosis or even spinal canal stenosis. Limited root canal decompression operations are usually effective in relieving symptoms.



Figures 9.9. **a** and **b** Antero-posterior and lateral radiographs of a posterior spinal fusion for spondylolisthesis in a woman aged 48 years. The prolongation of a bar of grafted bone can be seen on the left side overlying the lamina of L3 with reactive bone formation near the adjacent facet. **c** and **d** Explanatory drawings of the radiographs. **c** shows solid fusion between the posterior elements of L4 and S2, with upward extension of the "unwanted graft"

v) Fusion at the Wrong Level

Surgeons dread this problem which may occur when anterior interbody fusion methods are used at any level in the vertebral column. Readers are referred again to the sections of this book dealing with the operative technique of anterior interbody fusion operations (Chapters 2 and 7).

vi) Infections

Fortunately, infection after spinal fusion is uncommon, though it is usually chronic and often difficult to control.

Early post-operative death from gas gangrene has been reported following inter-transverse-alar fusion.

Chronically infected posterior grafts can be treated successfully by open drainage and the use of long-term chemotherapy; that is, by the same methods which are usually effective in controlling chronic osteomyelitis in long bones.

Infection after anterior interbody grafting operations is rare but serious. Epidural abscess formation is likely and may lead to cervical cord compression or cauda equina compression. Urgent radical drainage is required, with special measures in the neck to prevent the development of secondary kyphotic deformities. Skull traction may be required for some weeks or some form of halo applied, fitted to a thoracic jacket.

If the infection is due to staphylococcal organisms, long-term chemotherapy for at least 6 months is recommended (Fig. 9.10).

vii) Spondylolysis acquisita

This is a well-recognized though uncommon complication of posterior spinal fusion, though as MacNab has pointed out (1977, p. 216) it does not complicate inter-transverse fusions in which the pars interarticularis of the proximal vertebral segment in the spinal fusion is supported by the graft.

Assuming that the disc at the level of the spondylolytic defect is intact, it may be satisfactory to perform a localized foraminal decompression, even on one side only.

viii) Ligamentum flavum Atrophy

Atrophy of the ligamentum flavum occurs following interbody fusion operations, both in the lumbar and cervical regions. In some cases, this may lead to dural root sleeve tethering, so that, with normal movements at the first mobile segment above the fusion, the nerve roots at the level of the fusion may be stretched because the ligamentum flavum adheres to them. In the lumbar region, total laminectomy with excision of the ligamentum flavum over the area of the fused segment of the spine, leaving intact the facet joints at the level of the first mobile segment above the fusion, has been found satisfactory.

Applied to the management of persisting problems of neck and arm pain following successful anterior cervical fusion, this operation of extensive laminectomy and foraminotomy with total excision of the ligamentum flavum has been found less effective probably because of inadequate foraminal decompressions in some cases.

Figure 9.10. A lateral tomogram of the lower lumbar spine of a man aged 45 years. This film was taken more than twelve months after interbody fusions had been performed at L4/5 and L5/S1 levels, following which staphylococcal infection of the spine had occurred, leading to the development of an epidural abscess and to infection of the laminae and spinous processes at both levels. The infection was due to a staphylococcus aureus sensitive to Cloxacillin. The patient was treated by surgical drainage of the paravertebral abscess through the left loin and subsequently by extensive laminectomy for removal of infected laminal bone and for further drainage of an epidural abscess. Long-term chemotherapy was required over the course of 18 months and fibrous union followed

9.6. Summary

The surgical techniques used in re-exploring the lumbar spine have been described in considerable detail in this chapter. In concluding, attention is focussed on a number of important points:

1. Pay particular attention to the muscles of the back which will be further damaged by the re-exploration operation.

Release self-retaining retractors every 45 minutes to allow the muscle blood supply to flow for 5 minutes before proceeding with the surgery.

2. Do not leave jagged remnants of laminal bone in the roof of the spinal canal. Preserve the pars interarticularis, leaving smooth laminal margins adjacent to the dural sac. Coat these bony surfaces with bone wax at the conclusion of the operation.

Do not leave bony spicules in scar tissue covering the dura.

3. Pay particular attention to haemostasis during the operation. Avoid electro-coagulation of vessels in the spinal canal as far as possible, relying rather on the use of haemostatic agents such as gelfoam, packed lightly in the paradural gutters at the end of the operation.

4. Use closed suction drainage post-operatively, except in cases where leakage of cerebrospinal fluid may be anticipated.

5. Before embarking on re-explorations of the spinal canal, *the surgeon must be familiar with techniques for opening and closing the dural sac or nerve root sheaths.* He or she must be aware of the potential danger of cauda equina injury and avoid the use of a strong sucker without the protection of a cotton patty on the sucker tip.

In treating cauda equina arachnoiditis (p. 175) or in circumstances where multiple rents have occurred in abnormally thin dura in the course of the operation, closure of the dura may not be indicated. Special care must then be exercised in closing the wounds and the patient should be given chemotherapy prophylactically.

9.7. Post-Operative Care

Pain control is often particularly difficult in these patients so that special management with continuous intravenous infusions of Pethidine or Omnopon may be required for a few days. Anticoagulant therapy is advised, particularly after lengthy operations.

Mobilization should start soon after operation and in due course a cautious rehabilitation programme should commence. Warm pool therapy is often useful, though if this is not available, then walking progressive distances is to be recommended. Any vigorous muscular exercise is to be avoided.

Light surgical corsets are often helpful for short-term use.

10

Basic Principles in the Management of Spinal Injuries

10.1. Introduction

Descriptions of spinal injuries with neural damage have been found in the earliest of medical writings. Between 1900 and 1935 the incidence of such injuries increased slowly. Since the Second World War further steady increase has led to an incidence of 35 cases per million of population per year in Western countries. Non-traumatic causes of paraplegia account on average for another 15–20 cases per million of population per year.

Motor vehicle trauma accounts for up to 50% of the cases, while injuries resulting from sporting accidents account for about 25% of them.

Spinal injuries are usually classified into three groups:

1. Those without radiological evidence of vertebral fractures.
2. Those with vertebral fractures but without neurological lesions.
3. Those with vertebral fractures and neurological damage including peripheral nerve injuries with or without cord injury.

Life expectancy following spinal injuries has increased until at present, in developed countries, the initial death rate is only 1–2% and life expectancy is normal in the absence of complications.

10.2. Historical

Controversy in the methods of treatment of spinal cord injuries with paraplegia has been a noted feature of their management for more than two hundred years, being first discussed by Gorter in 1742, Sommering in 1793 and Heister in 1750. They were perhaps the first authors to cast doubt on the efficacy of operative procedures in the management of patients with lumbo-dorsal fractures, and particularly those with paraplegia. It was not, however, until 1814 that Henry Klein, a London surgeon, first undertook a laminectomy to reduce a fracture-dislocation of the vertebral column. The controversy concerning the propriety of laminectomy in spinal cord trauma developed into a verbal battle between the giants, Sir Astley Cooper and Sir Charles Bell in 1824. Cooper supported the use of operative procedures while Bell, a leading anatomist and neurologist, wrote a special treatise denouncing Cooper for his support of such ill-timed operative interference.

Even as early as 1845, Bamfield made a number of categorical statements:

1. The operative procedure of laminectomy is difficult.
2. The diagnosis is rarely clear as to whether paralysis has been caused by concussion, extravasation or compression, by puncture, laceration or complete division of the cord, or finally, by general extrusion of osseous tissue from the fractured vertebrae pressing upon the spinal cord.
3. Bamfield further indicated his inability to understand how laminectomy was of assistance when any compression of the cord came from the posterior half of the vertebral body and not from the laminae.
4. He felt that inflammation of the "spinal membranes", as he called the dura and arachnoid, would certainly give rise to further fibrous compression.

Undoubtedly, some of the earliest pathological changes recorded by these authors were due to infection complicating injudicious operative procedures. It was peculiar, however, that in the nineteenth century the surgical method which appeared to be used least was traction with hyperextension as described by Hippocrates, and described again in 1847 by Malgaigne in his treatise on fractures and dislocations. It is noteworthy that he is amongst the first to describe a passive reduction of fracture-dislocation by the use of a postural pillow.

Beckett Howorth, in his treatise on injuries of the spinal column (1964) concluded that the surgical method of traction, extension and de-rotation had great advantages in the overall management of spinal injuries. He showed that attempts to reduce the dislocation by these methods had great effect on the result, both physiologically, posturally and functionally.

It was not until Guttmann started his comprehensive services in 1944, for patients with spinal cord injuries, that the modern care of paraplegia and tetraplegia commenced. Some years earlier, Munro of Boston had shown that management could be materially improved, and thus he sowed the seed for more adequate care of these patients in North America. At about the same time, Botterell in Canada started his service in Toronto, for patients with spinal cord injuries. The service at Stoke-Mandeville was stimulated by the opening of the second front in Europe during the Second World War, and it was shown from there that results in the treatment of these patients could be improved spectacularly.

10.3. Pathogenesis of the Injury

For more than twenty years the present author (G.M.B.) has collected pathological material and examined it in conjunction with Professor Byron Kakulas, so that at the present time, up to 200 cases have been studied and reported in detail (Vinken and Bruyn, Clinical Neurology, Vol. 25, 1976). All spinal fractures and fracture-dislocations are associated with excessive force, usually multi-directional, involving flexion-extension, rotation, compression and stretching. Isolated sharp injuries occurring in association with road trauma are rare. The bone and soft tissues of the vertebral column are usually extensively bruised, crushed and devitalized, with associated spinal cord disruption in many cases. It is unusual to find small discrete areas of damage at post mortem in patients who have died from this type of trauma.

Microscopic damage extends far beyond the macroscopic, accurate delineation of the injury being impossible in the early stages after accident. Avascular necrosis of bone and colliquative necrosis of the cord are concomitant findings. Clinical and pathological estimation of the quantum of damage is impossible until collateral circulation has been established.

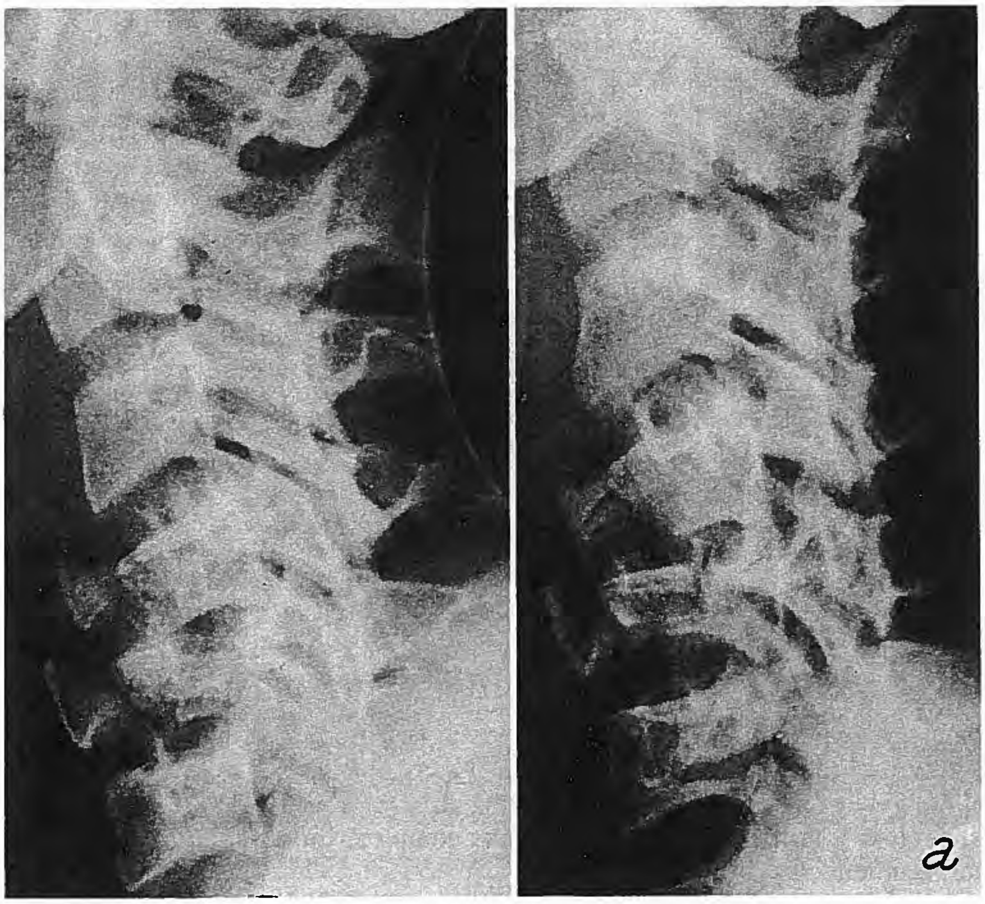


Figure 10.1a. Compression flexion injury of cervical spine associated with haemorrhagic necrosis of spinal cord

The fracture patterns seen on X-ray are either of compressive type or of a flexion type (Figs. 10.1a–c), or a combination of both. The degree of displacement of the fragments varies but there is always some degree of crushing with consequent avascularity of cancellous bone. Replacement and regeneration of this avascular bone is a slow process, and complete reformation of the vertebral body is rare after fracture. In 98% of cases it occurs by paravertebral callus formation. Stability is achieved, with or without reduction of the fracture-dislocation, in the first two or three weeks after injury. Clinical stability of the fracture can be expected when all but one of the ligamentous structures, anterior or posterior to the spinal canal, have

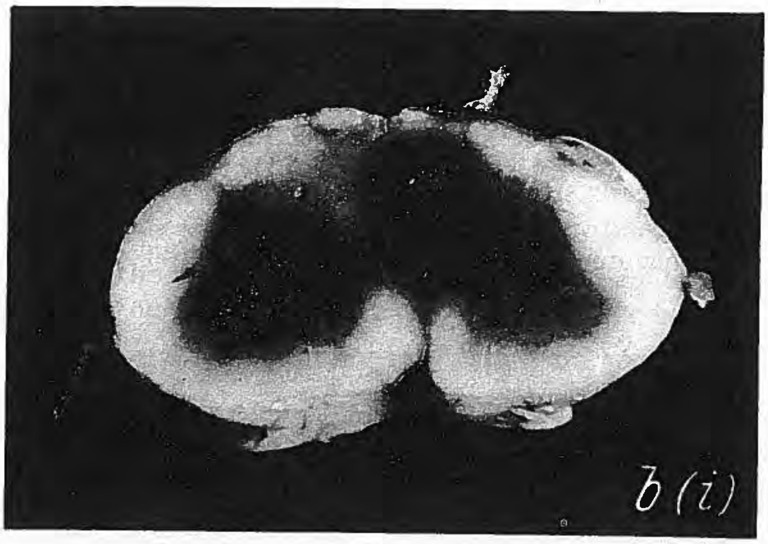


Figure 10.1b (i). Central haemorrhagic necrosis of spinal cord

Figure 10.1b (ii). Necrosis of spinal cord six weeks after injury

been damaged. The terms "stable" and "unstable" should be reserved for the later stages of management rather than in the early stages of assessment. Holdsworth in 1963 indicated the importance of the posterior ligamentous structures in estimating such stability. While he emphasized the importance of the posterior ligamentous complex, it is clear that the anterior ligamentous complex, the disc, and the anterior longitudinal ligament, are also important.

Neural damage may include neuropraxia, axonotmesis, neurontmesis of the spinal rootlets, as well as damage to the spinal cord, varying in degree from patient to patient.

Even in fracture-dislocations which appear to be of comparable severity, neural damage can be quite variable. Various patterns of cord damage emerge, including central necrosis, anterior or posterior necrosis of the cord, complete crushing of the cord, or minor petechial haemorrhages in it.

With the passage of time, the natural history of injury is towards healing, the bony debris being removed and replaced by new bone, while damaged neural tissue is replaced by an intense gliosis in which abortive attempts at nerve regeneration may occur.

The pathology of spinal injuries in the cervico-dorsal spine has features somewhat different from those in the dorsal and lumbo-dorsal column. For example, of the cervico-dorsal injuries with tetraplegia admitted to hospital, over 70% will be incomplete, while root sparing in lumbo-dorsal injuries will be seen in 50%.

Anatomically, the capacity of the neural canal compared with the size of the spinal cord finds its most significant relationship in the lower cervical area where the cervical enlargement usually occupies more than the standard 50% of the canal, and particularly in the older age groups, where with cervical spondylosis the canal may well be almost wholly occupied by the cervical enlargement of the cord. Thus, the

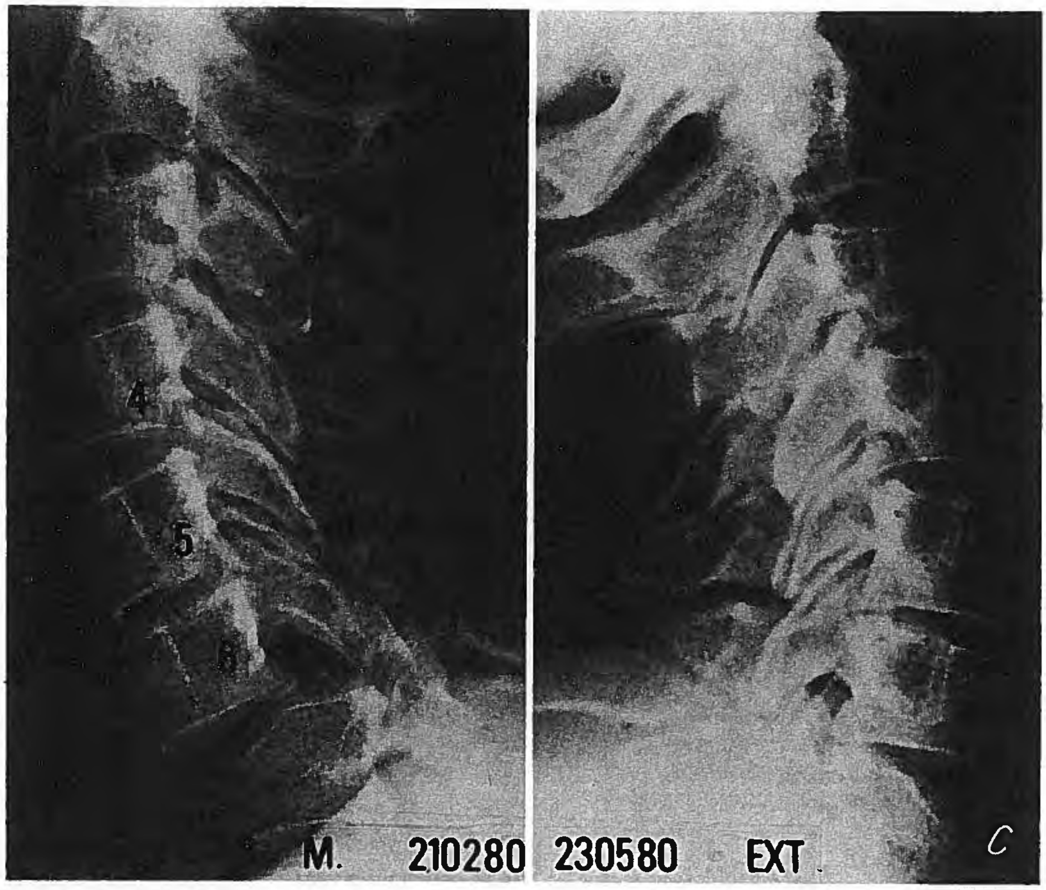
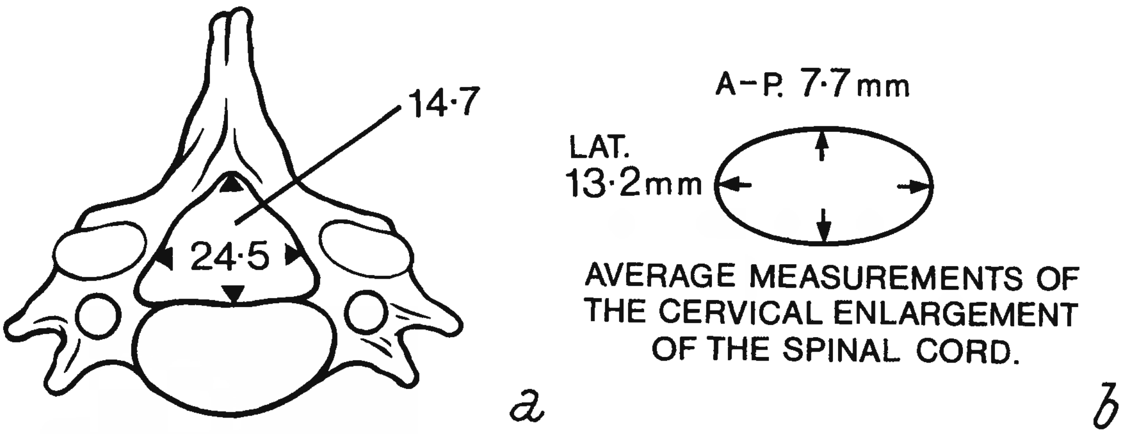


Figure 10.1c. Flexion injury of cervical column with bilateral facet fracture dislocation

anatomical features of the cervical spinal column pre-accident may have a profound effect on the pattern of injury. The spinal cord varies considerably in size from subject to subject. Elliot in 1963, was able to quote variations in the diameter of the cord and the canal, with average measurements showing that the cord occupies only about 50% of the capacity of the canal. In the cervical cord, the cervical enlargement measures, on average, 13.2 mm in width, 7.7 mm in the antero-posterior diameter, while the canal measurements at the same level are 24.5 mm in width and 14.7 mm in the antero-posterior diameter (Figs. 10.2a, b). Caudo-cephalic movements of approximately 1–2 cms occur during flexion and extension of the cervical spine.

Having considered briefly the major anatomical factors which may have a bearing on the outcome of spinal injury, let us examine the common resultant pathological findings.



Figures 10.2. A drawing showing average measurements (in millimetres) of the bony cervical canal at the level of the cervical enlargement of the cord

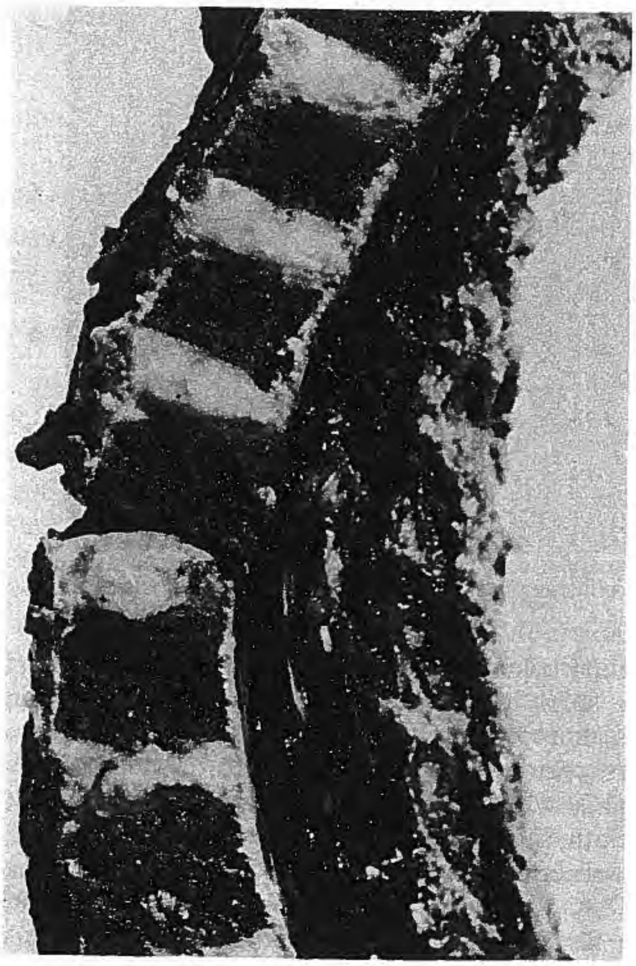


Figure 10.3. Severe extension injury of cervical column. Vertebral end-plate rupture. Gross patchy extra-dural haemorrhage not causing compression

1. Extradural haemorrhage surrounding the spinal cord is seen in all injuries, though it varies in extent from case to case (Fig. 10.3).

In contrast to intracranial extradural haemorrhage, extradural haemorrhage in the spinal column does not give rise to compression of the spinal cord unless the epidural space has been obliterated following previous trauma or operation. Blood which accumulates in the extradural space after spinal injury tends to migrate freely in the canal for several segments above and below the major area of damage. It is unusual to see extradural haemorrhage in the spinal canal as an isolated finding, except in post mortem specimens in patients in whom sudden death has occurred, when there has been insufficient time for the spinal cord to show manifestations of concomitant damage. The clinical significance of extradural-spinal haemorrhage is variable, much of the blood being absorbed, though dural scarring and adherence to the bony canal also occurs. This pathological change in the dura is usually irregular in distribution and may be the cause of discomfort and pain in some patients following spinal injury without associated neurological damage.

2. The completely crushed cord is seen in either flexion or extension injuries, usually in the cervical and rarely in the lumbar enlargement of the cord. Extension injuries in the lumbar column are uncommon (1%) whereas in the cervical column they account for about 26% of the injuries. In 80% of such cervical cases, completely damaged, crushed spinal cords occur where there is no neural continuity (Fig. 10.1b ii).

3. Gross necrosis of the cord may occur following compression injuries or flexion-rotation injuries of the cervical column. Similar injuries of the lumbar column are uncommon and usually occur in association with incomplete cauda equina lesions. However, the conus medullaris may manifest a central necrosis. In all of these cases there is peripherally intact cord tissue with the majority of the damage to central cord tissue usually in the pattern supplied by a central branch from the anterior median longitudinal arterial trunk of the spinal cord, Crock and Yoshizawa, 1977 (Fig. 10.1b i).

4. Anterior necrosis occurs in flexion-rotation injuries usually of the unilateral type and usually in the cervical column. Such necrosis does not follow the pattern of the arterial supply and it commonly involves, in this instance, both grey matter and white matter, leaving the posterior columns intact. The aetiology of such a pattern of cord injury may be due both to anterior compression momentarily and to venous haemorrhage in the cord due to rupture of the ligamentum denticulatum. These injuries are usually associated with gross extradural haemorrhage.

5. Cauda equina injuries occur in the lumbar column and in the lumbo-dorsal column where the conus medullaris finishes at a variable level–from T11 to L2. It must be remembered that the rootlets of the cauda equina can be avulsed from the conus medullaris or severely stretched with flexion-rotation strains. At the same time, a vertical rent can occur in the dura, through which nerve roots may prolapse. Thus at a later stage of examination, the nerve roots appear to have lost their usual vertical alignment and appear to be knotted. Typical Wallerian degeneration occurs at a later stage still; plaques of calcified material can be observed among the rapidly forming gliotic scar tissues.

To summarize, injuries of the spinal cord may occur after severe trauma, where various combinations of flexion, extension, rotation, compression and longitudinal stresses are exerted on a tissue which has a very low coefficient of elasticity and does not tolerate injury well. The spinal cord normally acts as a very soft spring and while it has some resilience during the normal processes of spinal movement and even occasionally in situations of abnormal stress such as may occur during an extension injury of the cervical column without neural damage, nevertheless spinal cord tissue will not stand severe trauma.

Pathologically, the following fractures will usually be stable (Figs. 10.1, 10.2):

1. The crush fracture or dispersion fracture, both of the lumbar and the cervical column; because the ligamentous complexes remain intact.
2. Extension injuries of both the lumbar and cervical column are usually stable because the posterior ligamentous complex is intact along with the posterior longitudinal ligament.

On the other hand, the clinically and pathologically unstable fractures are those in the following groups:

1. Fractures manifested mainly by the flexion-rotation injury where all of the posterior ligaments are ruptured or damaged, including the interspinous, the capsular ligaments and the ligamentum flavum, while one of the anterior group, e.g. the anterior longitudinal ligament, usually remains intact and thus will, on reduction, maintain spinal stability. However, pathologically this injury must be considered to be unstable.

2. Vertebral body fractures, with one vertebral body displaced in front of another, are associated with gross disruption of spinal ligaments. Pathologically, when all of the displaced fractures and fracture-dislocations have been adequately reduced, there will be rapid healing in the ligamentous structures and slow but sure healing in the osseous tissues, so that stability will occur either:

i) by ligamentous healing over a period of six to eight weeks, or
ii) by paravertebral callus in the ruptured ligamentous structures where some osteogenic tissue is found.

In a survey of spinal injuries, over 90% were shown to heal by local means, often with fusion of only two segments, or three at the most, leaving the rest of the vertebral column mobile. However, even when the maximum injury occurs at one mobile spinal segment, e.g. between T12 and L1, it is important to remember that the mobile segment between T11 and T12, and L1 and L2, may have sustained soft tissue damage (i.e. to disc and longitudinal ligaments), which will not be manifested for some years and which can explain the late onset of pain in a paraplegic who otherwise has remained well since accident. *Late pathological manifestations are common and must not be forgotten.*

Finally, it must be remembered that injuries may be multiple in the spinal column so that segments may be "jumped". Only by recalling that such patterns of injury may occur can diagnosis be complete.

In the cervical column the common bony injuries include:

1. Extension injuries with rupture of the anterior longitudinal ligament and/or disc.
2. Compression fractures with intact ligamentous structures.
3. Flexion-rotation injuries, either a unilateral fracture-dislocation or a bilateral fracture-dislocation.

In the lumbar column, the following patterns of injury may occur:

1. Severe flexion-rotation injuries, either unilateral or bilateral facetal fracture-dislocations giving greater than one-half vertebral body displacement in the sagittal plane.
2. Compression injuries or dispersion injuries of the vertebral column.
3. Rarely, extension injuries.

The pattern of vertebral injury will depend on which segment of the column absorbs the damage. The physical stresses are absorbed either by a single vertebra, by a two-vertebrale complex, or even occasionally by a three-vertebrale complex. Experimentally, different patterns will emerge when force is directed to either one, two or three segments of the vertebral column and whether the force is dissipated in either the static bony structure or the more mobile discal segment between two vertebral bodies.

10.4. Recognition of the Injury

Despite technical advances in studying neural impulses which may help to monitor neural disruption, *techniques of diagnosis of all spinal injuries, including spinal cord dysfunction, remain predominantly clinical.* Physical examination continues to require great acumen on the part of clinicians, both in the elucidation of signs and in the interpretation of their significance. In acute spinal fractures with or without spinal cord interruption, physical examination either by a doctor or by a person trained in first-aid, should give, in the conscious patient, an immediate basic diagnosis of the level and extent of neural damage–both sensory and motor. With the arrival of more skilled personnel at the scene of the accident, accurate physical diagnosis in three-dimensional terms of the spinal column and cord can be made. In the case of spinal cord injury, early admission to a comprehensive spinal unit is mandatory to reduce secondary problems as well as to obtain maximal recovery from neural sparing.

It is relevant to state dogmatically that all cases of paraplegia or tetraplegia must be treated as acute emergencies. Following spinal cord injury there are some specific signs which are of great diagnostic significance:

1. A definite "sensory level".
2. Bradycardia and low blood pressure–indicating neurogenic shock.
3. The presence or absence of perineal "neurological sparing".
4. Early intense priapism in the male indicates severe cord damage.
5. Complete areflexia in the lower limbs or upper limbs, significant in the unconscious patient.
6. Associated injuries are common so that a thorough general examination of the patient is essential.

Tenderness over a spinal segment always indicates a spinal fracture until proven otherwise, while restriction of movement is also to be carefully observed and is always a significant factor. The neurological state at the end of six to eight hours after the episode of trauma will help to elucidate prognosis in the paraplegic and enable the examiner to continue to build up a three-dimensional picture of the injuries. Early special examinations such as X-rays and blood investigations should be deferred until a clinical diagnosis has been made.

a) Clinical Examination

No other investigation is as important in those patients suspected of having a spinal injury. Too often the surgeon comes to rely heavily on special examinations and not enough on his clinical acumen. The first medical examiner has a great responsibility to conduct a thorough and complete examination; accurate diagnosis is usually possible and is vital before definitive treatment is carried out. Features that need to be stressed in establishing a diagnosis in these patients are:

i) History

1. The police, ambulance officers and original medical examiners can all be helpful in getting accurate historical information.

ii) General Assessment

2. Resuscitation does not mean just intravenous therapy and oxygen, but should include airway control and lower limb support by bandaging or abdominal compression. Occasionally, laparoscopy, if intra-abdominal blood loss is suspected.
3. The surgeon needs to have patience. Time spent in examination should be of no consequence once life has been preserved by the use of urgent resuscitative methods.
4. No special examinations should be ordered until a thorough physical assessment of the patient has been made, allowing a clear cut diagnosis in nearly all cases. A review of our acute cases has confirmed the accuracy of diagnosis which can be established purely on careful clinical assessment.
5. Many patients are alcoholic and fractious. Firm handling is essential to get the maximum amount of information. *All patients must be turned and all clothing removed.* The lessons of leprosy apply: *All* surface areas must be examined meticulously by the time-honoured methods of inspection, palpation, auscultation, including inspection of the oropharyngeal and rectal cavities.
6. Cranial trauma is a common accompaniment, so that the conscious state needs adequate assessment and if necessary immediate attention. Respiratory distress needs early assessment, particularly if associated with chest injuries. Abdominal diagnosis in the flaccid paraplegic can depend simply on the early detection of peristalsis which is rarely affected in the early stages unless there is an associated abdominal injury.
7. Less than 1% of acute cases will need urgent surgery within a few hours of admission. Drama must give way to meticulous examination before definitive treatment can commence.

iii) Examination of the Spine

Too often the examination of the spine is left to the examination of an X-ray. Careful, clinical examination by palpation of all vertebral segments and movement of the mobile segments within the limits of pain will give information as to the level and extent of damage. Palpation of the interspinous ligaments will determine the level of severe dislocation, for there is usually a gap admitting more than one horizontally applied digit. Even a subluxation is palpable.

iv) C.N.S. Examination

A paraplegic, or tetraplegic, complete on examination after five to six hours will probably remain so. In tetraplegia, however, all authorities agree that care should be exercised in predicting prognosis until six to eight weeks have elapsed, for up to 15% of so-called complete tetraplegics may be incomplete. At post mortem, complete disruption of the cord and meninges in the cervical area is uncommon.

The important points in neural examination include:

1. Develop a routine of examination, for example:

a) Examination of all reflexes including evidence of spinal reflexes seen in disruption. These will depend on time after accident, early flaccidity and absence of any complications. Special reflexes such as the bulbocavernosus, or the anal reflex, may be absent, while priapism and the dartos response must be searched for. Early return of such reflexes usually means the loss of spinal shock and spinal cord isolation. The bulbocavernosus response may be slow to return in the presence of urinary infection. Its absence in the otherwise complete paraplegic must be treated with caution and provided there are no complications, it may be evidence of an intact cord.

b) Motor examination of all muscle groups, using Medical Research Council standards, including observations of spasm and pain is vital. In some cases individual muscles may be flaccid, while others may be spastic. There may be an associated irregular loss of reflexes and thus a three-dimensional clinico-pathological picture of the cord damage will be built up.

c) Detailed sensory charting and marking of the sensory chart on the patient's body is essential. *Every dermatome must be examined.* A finite level of sensory loss is an indication of complete transection of the spinal cord. Absence of a finite sensory level with a variable amount of hyperaesthesia indicates that cord injury is incomplete. *Sacral sparing is a vital clinical finding:*

i) it may mean that excellent recovery overall is likely to occur;
ii) it will mean that excellent visceral function can be expected;
iii) it may be the only evidence of incomplete spinal cord injury to be found during the original clinical examination.

d) A detailed examination of the cranial nerves is always necessary.

2. Remember always that sensory neurones, axons and sensory nerves withstand trauma better than the motor elements and that motor sparing frequently takes a long time to be finite.

3. Clinical examination, both in patients with spinal cord injury and in those with spinal column injury alone, needs to be repeated after six to eight hours, to provide confirmation of observations and record changes, either of regression or resolution. Accurate recording is the only way to follow up the continuing changes of pathology now well documented in many centres.

4. Recording each examination on a chart is essential, also the regular recording of skin sensory loss.

5. The surgeon can only really help continuing signs of compression. He cannot as yet regularly help acute incomplete cases whose chances of recovery can easily be made worse by meddlesome surgery. What, therefore, are the probable signs of compression? In the acute stages of spinal trauma they include:

a) Massive dislocation with incomplete lesions.
b) No bony displacement with acute neural changes.
c) Those cases seen with an upper motor neurone onset.

In later stages it includes:

a) A plateauing of improvement of the central nervous system changes, in the absence of complications such as urinary tract infection.
b) Deterioration, usually seen in compression of slow onset which includes spasm and paresis.

It is important for the surgeon at this stage to know the common pathological changes seen in both acute osseous trauma and acute spinal cord trauma. The latter includes complete disruption, central cord necrosis, varying degrees of necrosis, neural disruption of varying degrees, and lastly, gross extradural haemorrhage seen in all cases but rarely of clinical significance (see pp. 272, 273).

Correlation of the clinico-pathological features leads to more accurate diagnosis and so to better care. All lesions in the vertebral column are three-dimensional, either major or minor, and bear no relationship to the X-ray appearances as seen for the elucidation of the bony fracture types. Head injuries are commonly associated with spinal column injuries. All patients admitted to hospital with head injuries should be X-rayed to exclude cervical injury and vice versa.

Unconscious patients should be carefully examined peripherally, the following signs being suspicious:

a) absence of all reflexes;
b) total flaccidity in the lightly unconscious state;
c) urinary retention in similar states;
d) a decerebrate state with uneven development of spasm.

Spinal injury should always be suspected in unconscious patients following head injury. There is *no* substitute for repeated physical examination in such cases.

Having completed a full physical examination including both a spinal examination and neurological examination, the examiner, before any other diagnostic measures are applied, should be able to say that this is a fracture or fracture-dislocation at the level "x" or "y" with complete, incomplete, or no spinal paralysis below the appropriate level. This neurological segment has been designated as the last intact one as defined by Michaelis and Guttmann.

Asymmetry of spinal cord injuries is usual. Longitudinal signs, sensory changes with variations in type and intensity will help in determining the three-dimensional character.

Spinal shock, consisting of total areflexia, flaccidity, total sensory loss and bladder atonia frequently delays final assembling of the pathological evidence for a few days.

Confirmatory diagnostic methods will include X-rays, lumbar puncture, the use of contrast methods, and occasionally others, e.g. peritoneal lavage.

b) Radiological

Radiological evidence is essential to confirm the clinical diagnosis. It must be remembered that injuries so demonstrated have no quantitative relationship to the neural lesion present. Requests must be precise as to the level or levels of examination required in multiple level injuries and the types of special views needed should be clearly designated. When routine antero-posterior, lateral and oblique films have been studied, the surgeon may require special views and special methods. Sagittal and coronal tomography in 1–2 mm cuts are invaluable; I believe they have helped considerably in our diagnostic facility. However, computer assisted tomography, although investigated and used for research purposes, has not so far been proven to be useful routinely, except in some upper cervical spine injuries.

c) Special Problems

Each area of the spinal column has its own diagnostic problems (see Fig. 10.4).

In the cervical spine poor radiology of C6 to T1 and C1/2 is the best known, and can be easily overcome by using the special swimmer's and open mouth views. Preservation of sensation infra-clavicularly does not mean that the upper limbs are preserved as the presence of the intact infra-clavicular nerve comes from C3 and C4. Asymmetry of upper limb signs in tetraplegics is to be expected. Some lack of motor and sensory correlation can be explained on the basis of pre- and post-fixation of the brachial plexus.

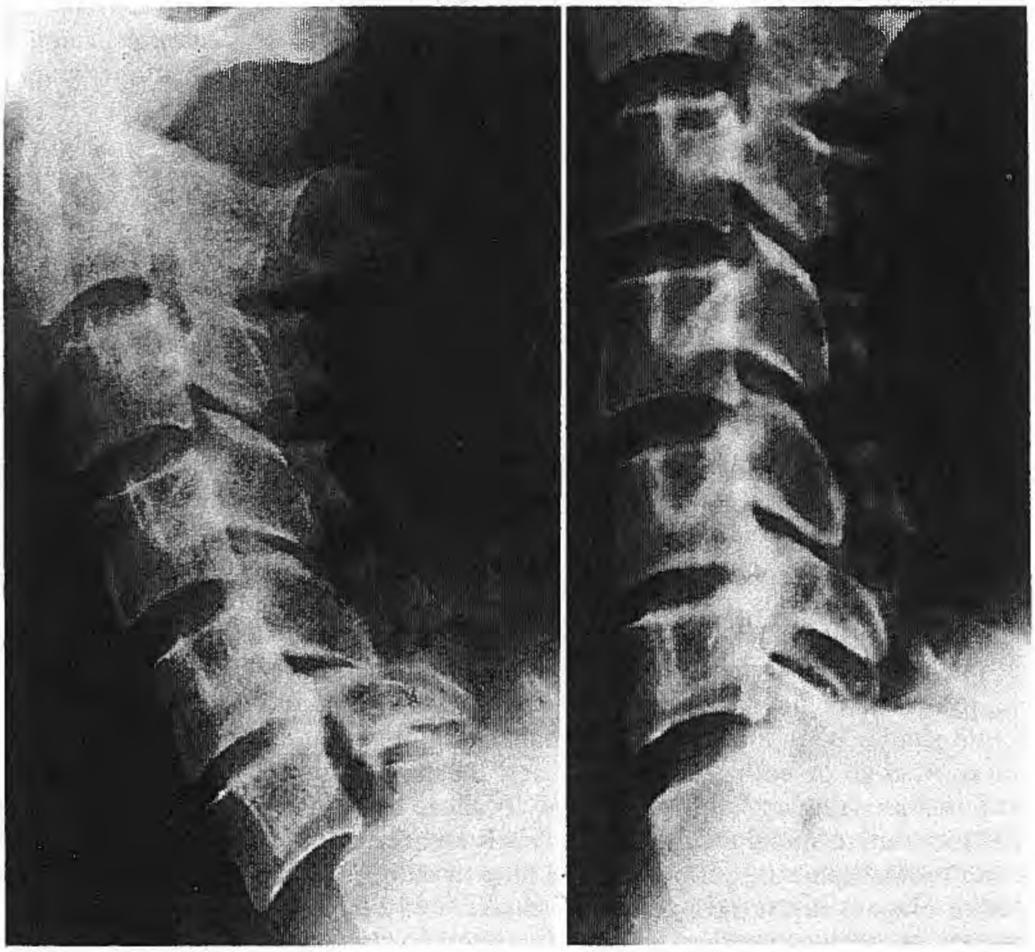


Figure 10.4. Fracture-dislocation of C6 on C7. Poor radiography failed to demonstrate the fracture-dislocation in the film on the right

Figure 10.5. Fracture-dislocation of T12/L1. Posturing has assisted in obtaining better radiographs

In the thoracic column, poor examination by palpation and failure to examine the dorsal surface of the trunk is usually the cause of difficulty, while failing to remember that fractures of the sternum are often associated with thoracic fractures is another area of concern. Radiology needs to be exact. Tomography is useful.

In the lumbo-dorsal column (Fig. 10.5), errors result from failure to examine the dorsal area of the spine and failure to realize that if two fingers can be placed between adjacent spinous processes at the painful area, fracture-dislocation is certain. Good radiology depends on accurate pre-clinical diagnosis and then extra oblique and tomographic views can be ordered, if necessary. Mixed upper motor neurone, lower motor neurone lesions with sensory sparing, and a variety of neural lesions with similar bony injury create a challenging area that can be resolved by an accurate knowledge of both the anatomy and the pathology of injury to this area. Sacral injuries are frequently missed, largely because of failure to examine this area as part of the routine spinal examination. This is an area of the spine where accurate clinical and radiographical examination will help to reduce the iatrogenic problems of disorders of bladder and bowel function.

The use of lumbar puncture and myelography has been debated for years. The use of lumbar puncture with pressure studies has not been useful as a diagnostic aid, in our hands, because of the variability of the pathology, extradural haemorrhage, and intraneural necrosis which becomes defined in the first days. Likewise, myelography as an acute diagnostic tool has not usually been valuable. The introduction of irritant contrast material into the spinal theca carries certain risks. Scher in Cape Town sums up well when he states, "Myelography in acute spinal cord injury is technically difficult and has not regularly led to positive help as well as being hazardous for the patient". Opinions differ, but until more positive evidence is available, this is the generally held opinion. Air contrast techniques, with C.T. scanning, can assist in the definition of the pathology, but has not given much more information than is obtainable by using standard X-ray techniques. Again, the surgeon is regularly seeking evidence of continuing compression by "space-occupying lesions" or bony masses. These are very rare; even discs may be space-occupying, but rarely, if ever, cause compression when cases are first seen after severe injury.

No surgical procedure has yet been proven to be useful in spinal cord lesions, either anterior decompression or posterior release. The very pathology itself, being three-dimensional over three to four segments, does not lead to such surgery being useful. Myelography must, however, be used in some cases where neural findings are deteriorating (despite their poor prognosis) and in some cases where paraplegia is of late onset. Cord lesions amenable to relief by surgical means are uncommon.

Other procedures, such as discography, have little place, particularly if the clinical examination is well done by an examiner who understands the pathology of spinal injuries.

d) Associated Injuries

The diagnosis of associated injuries is important and must always be sought. Neural, vascular, bony and soft tissue injuries are common. Only by careful repeated examination can these injuries be discovered. Ruptures of the diaphragm at the lumbo-dorsal area must always be excluded, while fractures of the pelvis may account in large measure for profound shock. Peritoneal lavage has ben advised as a subsidiary diagnostic measure.

The methods found to be of greatest use in the diagnosis of peripheral injuries associated with spinal column lesions are:

1. Careful palpation of all limb bones.
2. Careful passive movements of joints.
3. Detection of severe bruising.
4. Auscultation of the abdomen and chest and major blood vessels. Abdominal palpation and testing for shifting dullness.
5. Good sensory charts in incomplete lesions to determine peripheral nerve injuries.
6. Careful radiography of suspicious areas always including the chest and frequently the abdomen in various positions.

The effects of first-aid and time in diagnosis have not been sufficiently emphasized and need to be. Once again, stress must be placed on the importance of re-examination a short time after admission and early careful recording by the first clinical examiner. Good first-aid will reduce shock. Any suspicion of greater shock than is usual should be an indication for another search for associated injuries. The consequences of poor diagnosis are immense in terms of complications, treatment and final disability. Nothing is of greater importance in reducing final disability in medicine generally than early adequate diagnosis.

Finally, having made a diagnosis, the examiner must carefully consider a differential diagnosis. Diagnoses which have been confused with spinal injury and paralysis include:

1. Hysteria.
2. Secondary malignancy.
3. Old fractures of the spine.
4. Previous spinal cord injury with a new non-paralytic episode.
5. Very occasionally, minor accidents of spinal dysfunction with purpura and/or vascular catastrophies.

Hysteria is the most serious. Signs which assist are:

a) Normal reflexes immediately, which remain unaltered.
b) Changing patterns of non-anatomical sensory disturbances.
c) Normal visceral function.
d) Abnormal behaviour.

However, it should be remembered that hysteria can exist in genuine cases of cord damage.

Secondary malignancy can become manifested by injury, but usually the patient's antecedent history will help to clear up misunderstandings.

Old fractures and previous spinal cord injury will be excluded if a careful history is obtained in *all* cases as well as adequate X-rays. They do constitute a group to be remembered, particularly if the patient is unconscious.

Diagnosis and differential diagnosis of spinal fractures with and without cord transection are, I believe, clinically solvable matters. In summary, the most useful methods of diagnosis are based on:

a) Knowledge of the pathological changes which may follow spinal cord injury.
b) Careful, repeated examination by all clinical methods.
c) Proper recording of results by standard methods.
d) Adequate radiological examination of the vertebral column, including computerized tomography if available.

11

The Management of Spinal Injuries With and Without Neural Damage

11.1. Introduction

Management of spinal fractures and fracture-dislocations starts immediately after the accident; at the roadside, in the mine or on the farm. Good first-aid will result in a decrease in morbidity and disability and a decrease in the number of complete paraplegics being admitted to paraplegic units.

First-aid measures for the management of spinal injuries have been clearly set out in manuals by the St. John Ambulance Association and other bodies. The guiding principle must be gentleness with adequate lifting and turning of the patient in one piece. Life-saving procedures such as overcoming airway obstruction and reducing blood loss are first priorities, followed by the establishment of an adequate diagnosis of the nature of the injuries.

In many parts of the world flying squads are now available for emergency calls and these coordinated teams have improved the standard and efficiency of first-aid care, especially for victims of spinal injury.

In any unconscious patient the airway must be maintained so that anoxia is prevented, while a diagnosis of spinal injury should always be suspected. Serious associated injuries will occur in about 40% of paraplegics, e.g. lower limb fractures. Splinting of limb injuries at the site of the accident is essential.

With the arrival of a flying squad, additional care can be given, such as:

a) The use of prepared splints and cervical collars.
b) The use of intravenous therapy.
c) The use of airways or endotracheal tubes.

Overall, however, the aim of first-aid management in these cases is to secure satisfactory posture for the patient in a comfortable, normal supine or lateral position, preventing further potentially damaging spinal movement during transport to hospital. Patients with suspected cervical spinal injuries should be treated with traction, while those with suspected injuries to the lumbar vertebral column should be transported with adequate lateral splinting.

11.2. Transport

During the early stages of the first-aid management of the patient with spinal injuries, arrangements should be made to transport them to the nearest major emergency centre, or preferably, to a comprehensive spinal unit. If the patient is to be transported by air, then facilities for the use of some form of rotor stretcher are usually available. The standard stretchers available in most ambulances are satisfactory, providing firm support can be assured for the lumbar and cervical spinal curves.

It is dangerous to transport patients with severe respiratory insufficiency, with severe head injuries and anoxia, or with associated major injuries and profound shock in unpressurized aircraft.

On admission to hospital, the following routines should be established as soon as possible:

1. Disciplined nursing with a turning technique to maintain all normal curves of the spine and to maintain extension postures in the lower limbs.
2. Strict monitoring of blood pressure, pulse and respiratory rates. Recording of urinary output is essential, following intermittent catheterization or the use of a temporary indwelling catheter.
3. Management of the associated injuries with the use of temporary plasters or splints.
4. Occasionally, skeletal traction may need to be applied urgently.

During the early stages of the patient's management in the original medical centre, diagnosis of the spinal injury should be confirmed on an emergency basis, following careful physical examination and the use of appropriate radiographic examinations as discussed in Chapter 10.

11.3. Prevention of Secondary and Tertiary Complications

In all cases with spinal injuries, complications can be prevented by strict attention to simple details in the early stages of management. Complications include:

1. Deterioration of the spinal fracture.
2. Early introduction of urinary tract infection.
3. Pressure sores.
4. Limb oedema, contractures and muscle spasm, aggravated by poor posture.

The appearance of these complications may create tertiary states which can aggravate the patient's condition throughout his or her life. Central to the management of these patients is the maintenance of cleanliness and the prevention of infection, especially in relation to the care of the bladder.

11.4. Early Care in the Resuscitation Unit and/or Spinal Cord Injury Centre

Advance notice of the patient's admission to a spinal injuries centre should be given so that a consultant can be available for consultation at the time of admission. Further care may be required as follows:

1. Replacing blood loss.
2. The use of intercostal tubes for the treatment of haemopneumothorax.
3. Positive pressure ventilation or occasionally tracheostomy.
4. Continuation of the postural care of the spinal fractures.
5. *All* minor injuries, at this stage, should be carefully diagnosed and managed.
6. All associated injuries should be checked.

The basic plans for the management of the patient in the six or eight weeks following his admission to the spinal injuries centre are laid down in the acute emergency area. Careful thought is needed before a programme of balanced care can be planned. Clinically, all systems need to be fully investigated, with particular reference to changes that have occurred in the time between the original examination at the site of accident and the findings on admission to the spinal injuries centre. Radiological examination must now be precise and accurate, and requests to the radiographer should be precisely set down, detailing the levels of the vertebral column to be examined and the special views required. Particular attention is to be paid to the difficult areas in the upper and lower cervical vertebral column so that the risks of missing lesions at C1/2 or at the C6 to T1 levels are minimized. *Flexion and extension films should only be carried out by consultants or medical officers with experience and should only be used as an extension of diagnosis in those cases where it is felt necessary,* for example, where the original X-rays failed to reveal a fracture-dislocation which is suspected to be present. Special examinations may be used on occasions. They include:

1. Computerized tomography. This is especially useful following injuries in the upper cervical spine. However, it has not yet replaced standard radiological techniques in the general investigation of spinal injuries.

2. Routine tomography is of great value in defining the pathological anatomy of any fracture. This should be performed in both coronal and sagittal planes.

3. Myelography. This investigation has little use in the early management of patients with spinal fractures and neural damage. It is useful in the rare cases of spinal stenosis which may occur late after injury.

11.5. General Considerations

Once again, emphasis should be placed on the general care of patients under treatment in a spinal cord injury unit. The basic principles of management have been laid down: adequate posture, adequate visceral care, adequate cleanliness, careful procedural activity and early attention to the reduction of fracture-dislocations of the spine. Spinal surgery can be safely delayed until the admission of the patient to a major neurosurgical-orthopaedic service, or particularly to a comprehensive spinal injuries unit. There are well documented reasons for this advice:

Figure 11.1 a. Postural reduction of lumbo-dorsal fracture-dislocation, the supine position

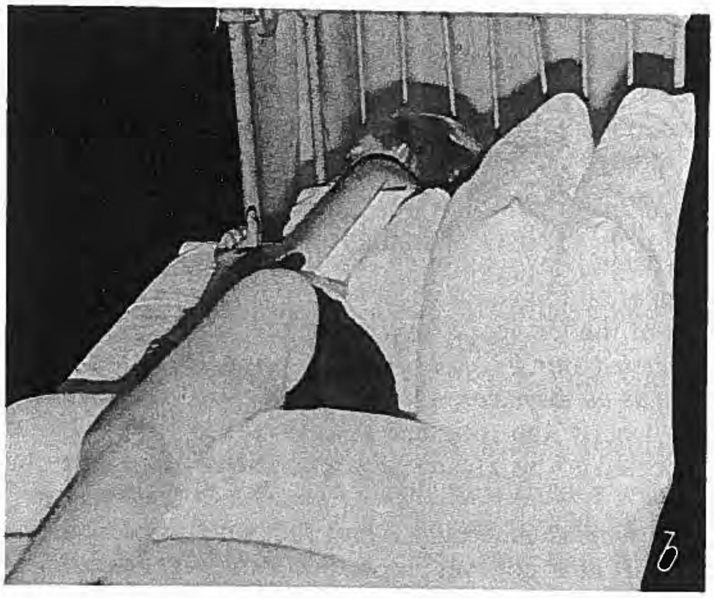


Figure 11.1 b. Postural reduction of lumbo-dorsal fracture-dislocation, the lateral position, showing placement of the pillows

Figure 11.1 c. Postural maintenance after reduction of cervical fracture-dislocation, the supine cervical position

1. Poor surgery is likely to increase the neurological damage; the "occasional surgeon" should avoid becoming involved in the care of such problems.
2. There is no proof that early surgery is of value in aiding neurological recovery.
3. Urgent surgery is rarely required. Distinctions between indications and contra-indications can be more clearly drawn 48 hours after admission.

It should be remembered that early social care of the patient and relatives is important.

11.6. The Role of Special Procedures in Specific Areas of Spinal Injury

a) Postural Reduction of the Fracture (Figs. 11.1a–c)

Watson-Jones, Nicoll and others agree that most fractures and fracture-dislocations can be reduced by postural methods using either a pillow technique as described by Guttmann, or by using a two-table technique for plastering as described by Watson-Jones during the Second World War. In cases with severe fracture-dislocations treated by postural reduction and nursed in hyperextension, a dead space is left in the vertebral bodies. This fills with haematoma and secondary deformity follows inevitably. It is doubtful whether one should persist with the use of plaster casts as a general technique in such cases. Nicoll has advocated early muscle activity in the erector spinae and abdominal muscle groups to encourage a better functional recovery of vertebral column movements.

b) Traction, Including Flexion and Extension, Effecting Reduction of the Fracture-Dislocation (Fig. 11.2)

This method has proven of great value both historically and in contemporary use. Ambrose Paré in 1575 described the method of pelvic-thoracic traction which is well illustrated in Howorth's book "Injuries of the Spine" (1964). Most surgeons attempt to reduce severe lumbo-dorsal and cervico-dorsal fractures and fracture-dislocations with bilateral facet dislocations by postural methods without general anaesthesia. After admission, skeletal traction in cervical injuries with careful traction first in flexion and then in extension over a 24-hour period will result in reduction (Bedbrook, 1981). In lumbo-dorsal injuries, good postural methods can be supplemented by traction. These methods are safe and effective and should always be used initially in the management of these patients.

c) Manipulative Reduction (Figs. 11.3a, b)

Manipulative reduction of cervico-dorsal injuries and lumbo-dorsal injuries may be tried slowly, usually without anaesthesia, or rapidly under anaesthesia. In the case of the cervico-dorsal injuries, some type of skeletal traction should be applied. Without anaesthesia, the head should be shaved and prepared, noting the sagittal line and the

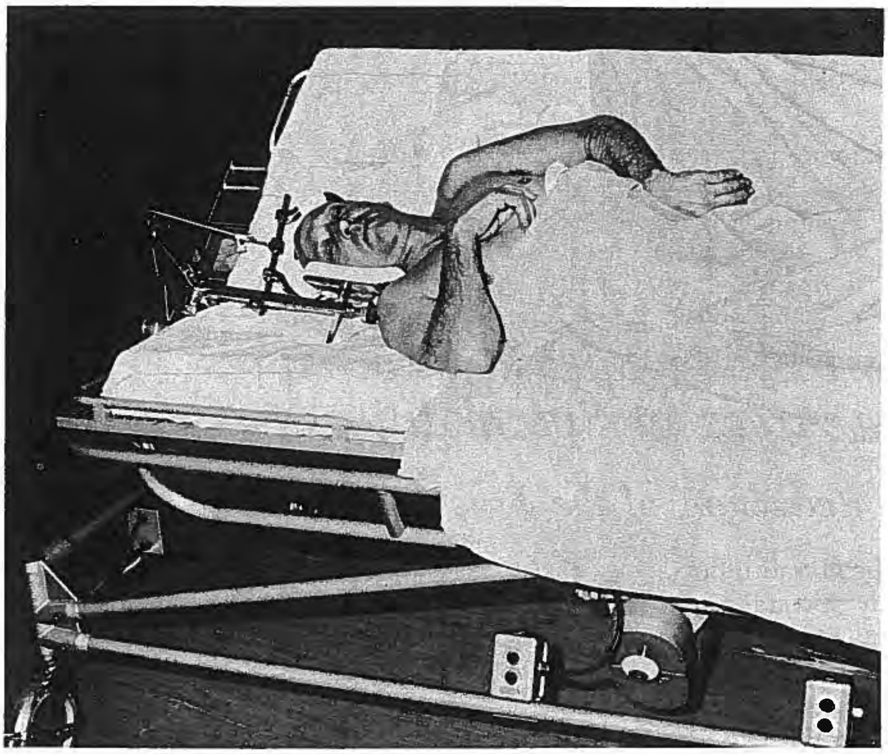


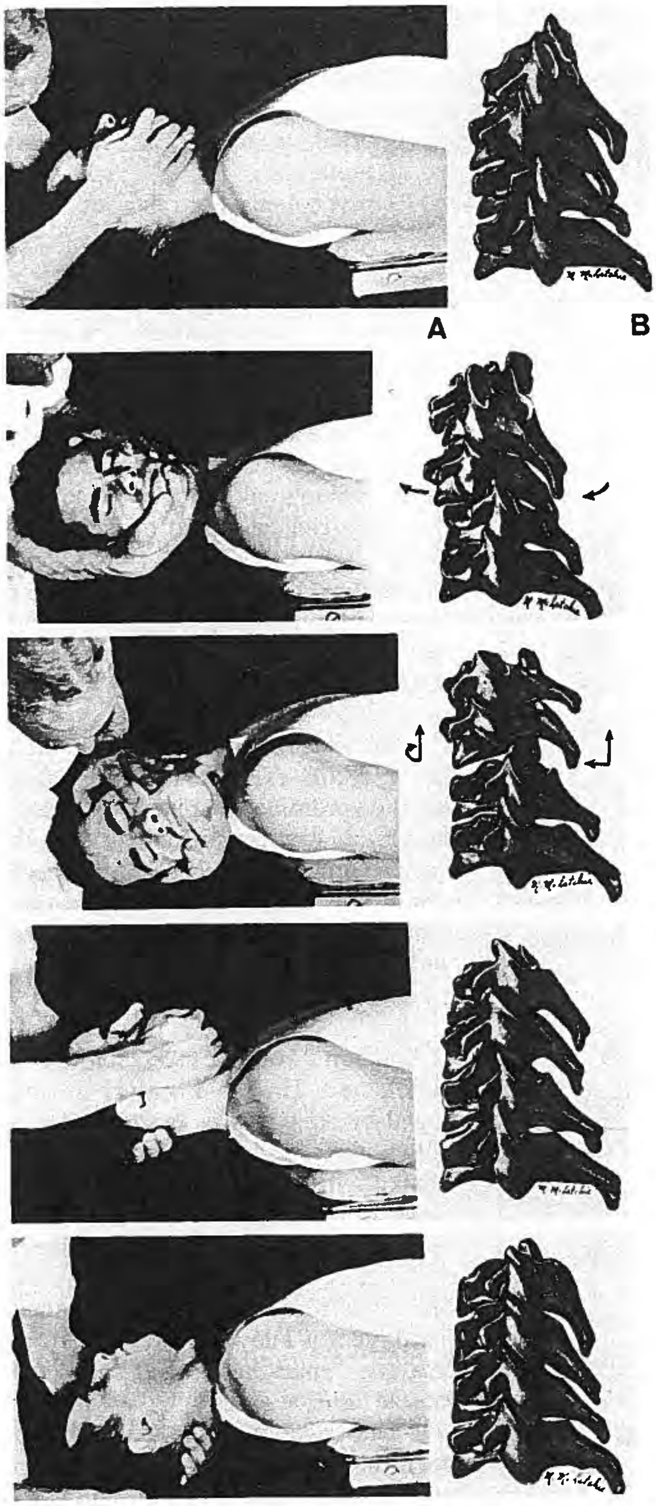
Figure 11.2. The Stoke Mandeville Edgerton bed used in this instance with traction for a cervical injury

inter-aural line, both of which are marked on the scalp with Bonney's Blue. The points at which the calipers will enter the skull are then marked carefully, holding the open calipers over the skull. Flexion of the cervical spine can be obtained by placing the calipers behind the transverse plane, while extension can be produced if they are set anterior to this plane. Local anaesthetic is then infiltrated into the selected points and the skull exposed with half inch incisions, the underlying pericranium being reflected. A 7/16th inch drill is then used to drill the outer table of the skull on both sides; this is fitted with a protective device to prevent penetration of the inner table. When both sides have been carefully drilled, the calipers are then inserted firmly. Weights of up to 80 kg can be applied if necessary.

In cervico-dorsal fractures, traction should be applied first in flexion of 35° to unlock the fracture. If the fracture-dislocation is unilateral, the traction should be applied more to one side than to the other to unlock the dislocation. After the dislocation has been unlocked then the head can be brought slowly into extension, thus reducing the fracture-dislocation. In using a manipulative measure, Walton's manoeuvres for the reduction of unilateral fracture-dislocations of the cervical spine can be performed under general anaesthesia, as illustrated in the diagrams in Fig. 11.3a.

Occasionally, cervical dislocations will reduce spontaneously after induction of anaesthesia, during intubation, when a soft click is heard in the spine.

In the lumbo-dorsal column a similar technique can be used for the reduction of locked facets or locked fracture-dislocations. With the patient adequately anaesthetized and relaxed, pelvic traction and thoracic counter-traction in some



Stage I

A Position for reduction at the start. Walton manipulative reduction
B Rotary dislocation of the cervical spine

Stage II

Walton reduction. Rotation away from the side of the lesion

Stage III

Walton reduction. Retrolateral flexion

Stage IV

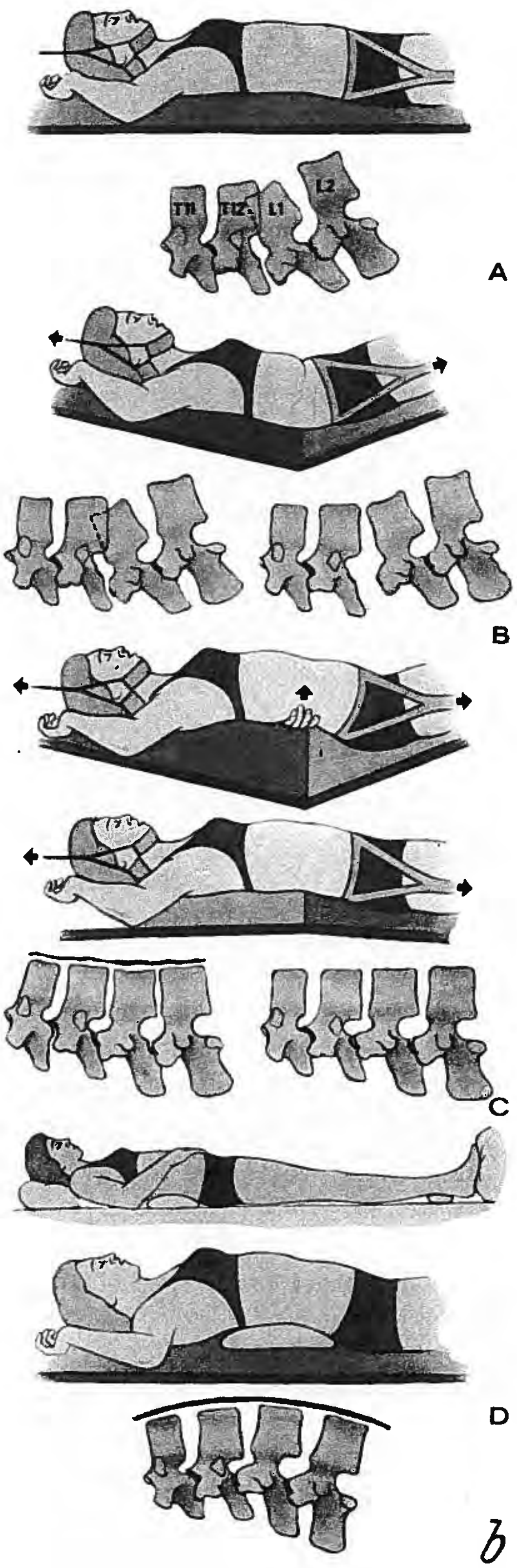
Walton reduction. Rotation back to neutral. Lateral flexion maintained

Stage V

Walton reduction. Extension in neutral. Complete reduction

a

Figure 11.3 a. The procedure used for manual manipulation of displaced fracture-dislocations of unilateral type



Indications

1. When postural reduction fails.
2. When open reduction is contra-indicated by:
   a) infection;
   b) multiple injuries;
   c) other complications such as pulmonary; or
   d) psychological or religious reasons.
3. Before open reduction.

Method

Reduction under general anaesthesia.

A The patient is placed supine with relaxation, ensuring that the fracture site is at the break in the table so that the spine can be flexed or extended.

B Traction is applied manually or via harness to the head or thorax and pelvis to distract the fracture in the flexed position by "breaking" table.

C With traction continuously applied the operator exerts a forward thrust to the prominent spinous process, thus lifting (patient supine) the lumbo-dorsal spine lordosis. The lumbar column below the fracture-dislocation can usually be felt to move forward and be locked by the anterior longitudinal ligament.

D Traction and extension are maintained. The table is reversed and a gall-bladder rest is raised under a pillow to give hyperextension, thus "fixing" the intact anterior longitudinal ligament. Traction is released but postural reduction is maintained.

The X-ray is checked. The above process is repeated if necessary, then the patient is allowed to recover from relaxant anaesthesia so that the muscle tone assists.

The patient is taken off the operating table by the sliding method onto a rigid surface to hold reduction. The rigid surface is removed in the ward when the patient is fully conscious.

Postural reduction is maintained.

Figure 11.3b. Closed reduction of fracture-dislocation of lumbo-dorsal spine with locked facets, with and without paraplegia [from: Bedbrook, G. M.: Spinal Injuries, pp. 222–241; in: Operative Surgery, Orthopaedics (Bentley, G., ed.). Butterworths. 1979] flexion will serve to unlock the fracture-dislocation which can then be hyperextended, reducing the dislocation by local manipulation. All of these procedures should be regarded as gentle techniques having a regular application in treatment, leading frequently to complete reduction of fracture-dislocations.

In the cervico-dorsal column such methods have almost superseded open techniques, while in the lumbo-dorsal column the results are not quite as good, though often satisfactory.

d) Open Reduction and Internal Fixation

The usual indications for such procedures are said to be: – to ensure stability, for ease of nursing, to control pain, for failure to reduce by other methods, or for reduction of the kyphos.

Operative procedures have been used in all areas of the vertebral column, but particularly in the lumbo-dorsal area. Early operative reduction is indicated, in the author's opinion, only in the following circumstances:

a) Following failure to reduce by postural or manipulative measures gross fracture-dislocations which have resulted from flexion and rotation forces.

b) In cases where, after reduction, difficulties in nursing management may produce recurrent deformity at the fracture site.

However, such procedures are rarely indicated. There are, in fact, no absolute indications for open reduction and fixation in either the cervico-dorsal or the lumbo-dorsal area, particularly within the first 48 hours after injury. Gross disruption of the vertebral column and early scoliosis may eventually need fixation. Patients should have operations only after the indications and the contra-indications, e.g. urinary infection, pressure sores etc., have been adequately assessed and where the surgeon can review carefully all aspects of care before deciding that surgery can be of assistance.

e) Laminectomy

This operation has been generally abandoned, except in occasional cases. Post-operative instability following laminectomy may require anterior spinal fusion, and there is mounting concern for its role in the production of arachnoiditis (Comarr, 1968). The history of this operation in the management of patients with spinal cord injury is black. Schneider (1951), Morgan and Wharton (1970) have reported series of patients with cervical injuries treated by laminectomy, in which cases with incomplete spinal cord damage ended with complete paralysis following operation. Comarr and Kaufman in their classical review of 850 cases in 1956 showed that results of neurological recovery were significantly better in patients who had not been subjected to exploratory laminectomy.

f) Use of Exoskeletons

Exoskeletons are used regularly in the management of patients with cervico-dorsal and lumbo-dorsal fractures. Many patients whose spinal injuries have been managed conservatively need an exoskeleton when allowed to get up, particularly if they complain of pain. Exoskeletons are regularly used in most patients at the end of six weeks. Many varieties of these devices are now available.

a) Plaster of Paris jackets are still widely used, applied by a number of methods including the two-table technique, traction on a scoliosis frame or simply by applying anterior and posterior shells which can be subsequently connected.
b) The use of polythene supports which are constructed around plaster moulds of the patient's trunk.
c) The use of functional splints such as cervical collars. Many varieties are now available commercially.
d) Special functional splints such as the SOMI Brace providing neck support based on four pillars attached to a thoracic jacket.
   Most of these exoskeletons will be much more comfortable with the patient in the erect position and should not be considered to be perfectly satisfactory in the supine position. They are made for functional activity. Careful fitting to maintain adequate posture with the use of such exoskeletons is essential.
e) Halo cast. Over the last decade since Halo pelvic apparatus has been described in the management of scoliosis there have been various ways of applying such exoskeletal appliances to fractures of the spine. Pelvic fixation is now rarely used; most have become variations of halo cast techniques whereby a skull halo is applied and fixed to a custom built body cast. These appliances have been used from any time between one and six weeks after injury for periods up to three months after accident. For tetraplegics this method has limited application as it runs all the risks of skin stress and sores. A trial made by this author (G. M. B.) led to an initial abandonment of the method as not adequate and not improving rehabilitation. For non-tetraplegics the method has advantages of early mobility, allowing early discharge from hospital, but there are disadvantages:
   (i) Considerable maintenance is required.
   (ii) Scalp infection along the pin tracks is likely to occur.
   (iii) Unstable fractures treated in this device may displace quietly and unobtrusively.
   (iv) Halo casts may be comfortable with the patient in the erect posture but uncomfortable in the supine position. Casts tend to ride upwards. These appliances require adjustment often two or three times daily.

These are the procedures which are available to the surgeon caring for patients with spinal injuries. The majority of cases are treated best by the use of posture, postural reduction, regular isometric exercise and occasionally non-operative manipulative reduction. Rarely indeed is early open surgery required. Physical rehabilitation using isometric and graded resisted muscle exercises is essential.

11.7. Management in Specific Areas

a) Cervico-Dorsal Fractures and Fracture-Dislocations in Early Stages

i) Acceleration/Deceleration Injury

This so-called "whiplash" injury of the neck usually results from motor vehicle accidents when the driver and passenger are seated in a stationary vehicle which is hit from behind. These injuries occur in considerable numbers in all major cities. This mechanism of neck injury may be associated with lower motor neurone paralysis in the upper cervical trunk, particularly if there has been a sudden lateral flexion injury of the spine. Plain X-rays of the spine taken at the time of the accident usually show no abnormality, though occasionally minor fractures may be noted. In many of these cases the maximal effects of injury are exerted on the cervical intervertebral discs (see Chapter 7) and on the anterior ligamentous structures of the neck. Associated peridural and epineural extradural haematomas may occur.

The majority of patients who have sustained this injury respond to careful conservative treatment for pain, including the use of a collar and the early introduction of isometric muscle activity. Many develop major psychological problems, and quite a few may require surgical treatment in the long term for disc excision and interbody fusion at the affected level (see Chapter 7).

ii) Fractures and Fracture-Dislocations from C3 to T1

(i) Hyper-Extension Injury: Incidence of 23% (Fig. 10.3, Chapter 10)

In these cases there is usually a history of a blow on the head and clinical examination may show abrasions on the forehead. On palpation of the spine there may be tenderness anteriorly along the anterior longitudinal ligament. Neurological examination may be normal, while in others there may be complete or incomplete tetraparesis.

Lateral X-rays in flexion and extension may reveal wide opening of the disc space at the affected level. With this mechanism of injury, damage to multiple discs occurs frequently.

The majority of these patients can be immobilized simply in bed with the neck in flexion (Fig. 11.1c); the length of bed rest will depend entirely on the severity of the injury and its association with spinal cord damage.

(ii) Axial Compression Injuries – Sometimes Associated With Flexion Injuries (Fig. 10.1a, Chapter 10)

Following this mechanism of injury, vertebral body fragments may be displaced anteriorly, posteriorly and laterally. Vertebral body fragments displaced posteriorly into the canal may damage the spinal cord. Injuries of this type may occur with little or no final displacement as seen on X-ray, though major neurological damage may have occurred.

Having determined that these injuries are stable by careful X-ray study, the majority need no further treatment other than collar support and isometric neck muscle exercises until the fracture subluxation has healed. In this group, flexion and extension X-rays are required at the time of the initial management to determine whether or not the spine is stable.

(iii) Flexion Rotation Injuries With Unilateral Facet Fracture-Dislocation: Incidence 25% of Injuries (Fig. 11.4)

Fracture-dislocation of the cervical spine with associated subluxation of a single facet, with or without cord injury is known as a Beatson Type I injury. Reduction of this type of injury is necessary. Some of the fractures will reduce spontaneously when the neck is postured in extension to restore the cervical

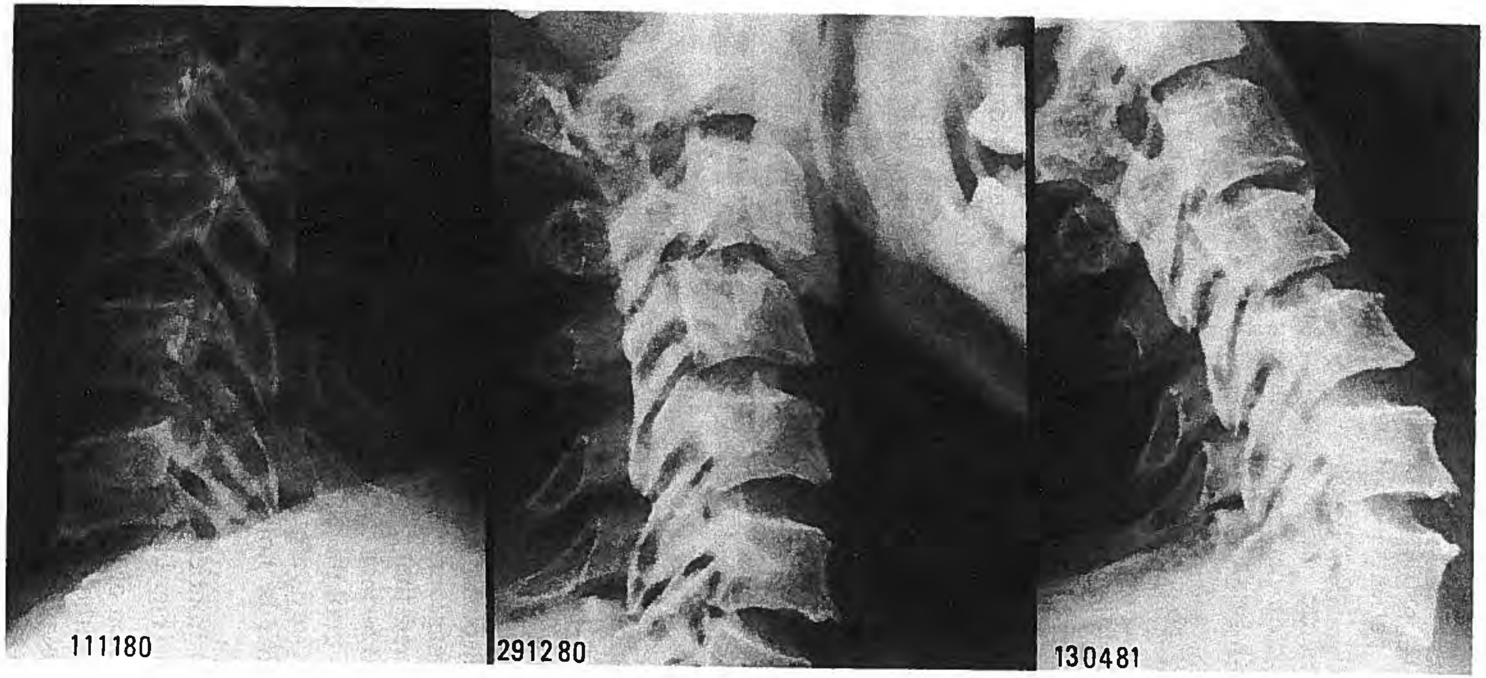


Figure 11.4. Unilateral C3/C4 fracture-dislocation associated with fracture of lamina of C2, emphasizing the multiplicity of injuries in the same cervical spine

lordotic curve. In cases with unilateral facet dislocation, reduction is usually necessary. However, if there is an associated fracture-dislocation then spontaneous reduction may occur, Key (1976).

In the acute management of these injuries, simple posturing, occasionally with cervical traction, may only be required to effect reduction. Occasionally, manipulative reduction with the use of the Walton method is required (Fig. 11.3a). Surgical treatment is rarely indicated but may be necessary if spinal instability persists after six or eight weeks of treatment. In addition, open reduction may be required where conservative reduction has failed and the patient refuses prolonged conservative treatment. However, failure to reduce this type of injury is not necessarily an indication for surgery, as the majority of cases of unilateral fracture-dislocations heal well in the unreduced position. The spinal cord is not really in jeopardy, this fact being well demonstrated in computerized tomography studies.

(iv) Gross Vertebral Fractures and Fracture-Dislocations of the Beatson Type II: Constituting 25% of Injuries With Tetraplegia (Fig. 10.1c, Chapter 10)

These fractures and fracture-dislocations always need reduction. Those associated with gross fractures of the apophyseal joints can usually be reduced without anaesthesia after skeletal traction has been applied. With careful increase in traction, first in flexion to unlock the facets, and then with extension, the fracture-dislocation will usually reduce within 24 hours. Dislocations not associated with gross fractures are rare. (Fractures were found in every case of 65 specimens examined at post mortem.) These gross dislocations and fracture-dislocations are best reduced by the manipulative measures which have already been discussed. Maintenance of the reduction can be achieved by the application of adequate skeletal traction using 4–6 kgs for a period of six to eight weeks. In the post-operative management, one should stress again the importance of adequate attention to the maintenance of cervical lordosis by posturing the head and neck. In these cases surgical treatment is rarely indicated in the early stages. Bony union will occur in 85% of cases; 10% will stabilize with fibrous unions and only 5–6% will be found unstable in the long term, requiring stabilization.

b) Lumbo-Dorsal Injuries (Fig. 11.5)

In lumbo-dorsal injuries 95–98% of cases will result from flexion-rotation strains, while compression forces will account for 2–3% of the injuries and extension forces for only 1%. In dealing with these cases, it is important that the surgeon should understand the mechanism of injury in each case. Injuries resulting from hyperextension forces can be nursed in flexion and therefore need to be nursed carefully in bed without a pillow under the lumbar spine. Stability results from adequate healing of the perivertebral soft tissues and ligaments. Crushing injuries of the vertebral column in this region may also be treated conservatively providing they are not associated with flexion-rotation injuries. Even in paraplegics, providing the sensory level is in the groin at L1 or L2, plaster fixation may be satisfactory with either of these types of injuries.

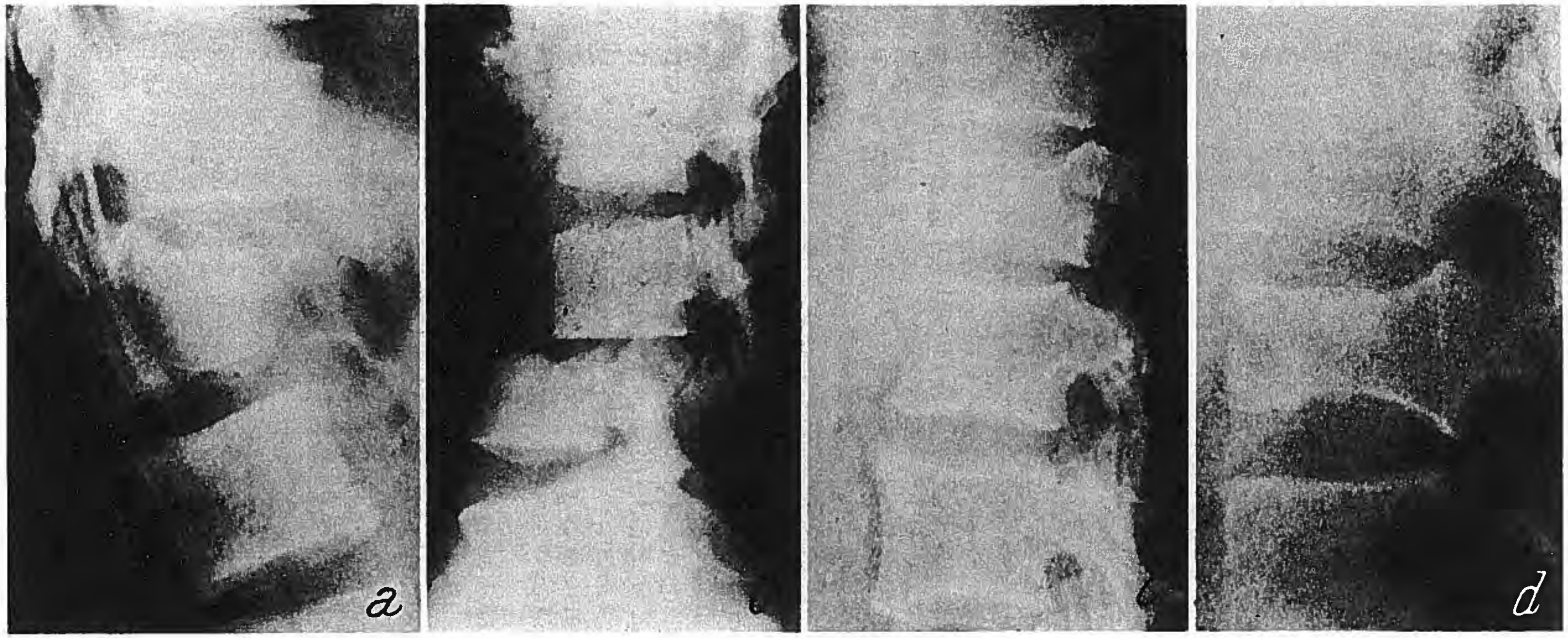


Figure 11.5. The lumbo-dorsal fractures and fracture dislocations. **a** Flexion-rotation. **b** Hyperextension. **c** and **d** Axial compression

The most difficult problems in management are seen in cases with flexion-rotation injury. Even in these cases, the majority can be managed adequately by postural methods. Postural reduction should always be attempted as soon as possible after the patient's admission to hospital. It is important to remember that 95% of these fractures and fracture-dislocations will heal by conservative measures, resulting in fusion of only two vertebral segments. By contrast, if surgical procedures are undertaken, at least four or five vertebral segments may fuse. This will inevitably give rise to a stiffer spine, the patient being left without full mobility. One of the reasons put forward by proponents of internal fixation is that earlier mobility of the patient is allowed. This, in fact, is not regularly so in units which institute early mobility in bed and still provide postural reduction. Most patients using a postural reduction technique can be fitted with an exoskeleton, usually of a polythene type, at the end of five to six weeks, with mobilization out of bed at that stage. Prior to that particular stage, most patients will be mobile in bed, undertaking many activities in physical therapy, exercising their erector spinae and abdominal muscles in the lumbo-dorsal area. If surgery is undertaken, it should be remembered that some surgical procedures inevitably denervate areas of the erector spinae muscles, unnecessarily causing further paralysis for the patient. After most lumbo-dorsal fractures and fracture-dislocations with paraplegia, the nerve supply to the erector spinae muscles remains intact at least two to three segments below the level of the injury (Bedbrook and Donovan, 1979). Thus the erector spinae and the latissimus dorsi muscles particularly may be damaged further during surgical exploration. There will, however, be a small group of patients where early–as opposed to emergency–surgery must be considered. The indications for surgical treatment are as follows:

a) For complete disruptive lesions of the vertebral column with scoliosis.
b) For those patients in whom adequate reduction of the fracture-dislocation cannot be achieved by conservative means.
c) For those who have locked facets. Even in this group the present author finds no absolute indication for open reduction.

Definite contra-indications to surgery exist if there are any infected areas on the skin, if early urinary tract infection occurs and if there are other injuries which need preferential surgical treatment. The surgeon should recognize the fact that an early surgical procedure on the spine could prove too much for his or her patient. When surgical procedures on the spine are undertaken, they should be performed by those who are best qualified and who regularly use surgical techniques for other indications in the spine, e.g. for scoliosis corrections. Internal fixation using plates has been generally abandoned. Currently, the Harrington distraction rod system is the one most widely used.

The application of plates through screws fixed to the pedicles has been described by Roy-Camille, though the method carries potential hazards if the screws are wrongly positioned in the pedicles.

11.8. Surgical Technique

Patients are placed in the prone position, avoiding too much flexion. The fracture-dislocation is exposed through a mid-line incision and the paravertebral muscles separated. Frequently the muscles will have been torn from their mid-line attachments so that further surgical separation should be limited. Reduction of the fracture may not occur until facetectomy has been performed in some cases. The question of fixation must be decided in each case, depending on the local findings after reduction.

Harrington distraction rods are placed two segments above and two segments below the lesion on both sides. Occasionally the distraction rods will produce distraction of the fracture-dislocation; however, as the anterior longitudinal ligament is intact in most cases, this is not a common problem. Over-distraction should be avoided as it may lead to non-union at the fracture site.

Some surgeons advise bone grafting, while others claim it is unnecessary. The present author feels that grafting of the area of the fracture-dislocation is essential. The laminae should be preserved, but if there is a fractured fragment found indenting the posterior surface of the dura it should be carefully removed.

11.9. Indications and Contra-Indications for Specific Surgical Procedures

a) Anterior Decompression of Acute Fractures of the Cervical Spine

There is really no absolute indication for anterior decompression of acute cervical fractures. Comparisons between groups of patients treated by surgery or by conservative methods indicate that the results achieved by conservative methods are as good and probably better than those achieved surgically.

There are a number of contra-indications to surgery:

a) Incomplete tetraplegia–operative intervention can aggravate the tetraplegia, rendering it complete (Morgan and Wharton, 1971, Sussman, 1978). A malpractice suit in this context was settled recently in the United States of America for 3.5 million dollars.
b) Urinary infection.
c) Any other associated major injury.

b) Open Reduction and Internal Fixation of Lumbo-Dorsal Fractures

Indications for surgery are:

a) Gross disruptive fracture-dislocations that cannot be maintained and reduced by postural methods.
b) Locked facets, rarely.

Contra-indications to the use of Harrington internal fixation procedure are:

a) Infection arising either from bed sores or from the urinary tract.
b) A patient with incomplete paralysis showing signs of improvement clinically, with adequate reduction achieved conservatively.
c) Associated minor injuries.

c) *Antero-Lateral Decompression*

This operation may have some place in the management of secondary canal stenosis occurring late after injury.

d) *Spinal Fusion*

Spontaneous union of spinal fractures can be expected in approximately 95% of lumbo-dorsal fractures and in 85% of cervico-dorsal injuries. Accordingly, there should be no indication for spinal fusion in the early stages of management.

In later stages, fusion is indicated for non-union or for pain proven to arise from a disc space higher or lower than the fracture or fracture-dislocation. The operation finds a valuable place in the management of progressive kyphoses following vertebral injuries in children or adolescents.

In a group of 750 cases with spinal injuries, 50 patients required spinal fusion for the following reasons:

a) Following failure of conservative management where traction had been removed too early.

b) Following extensive spinal injuries in young children between the ages of 12 and 13 years where vertebral epiphyseal growth had been disturbed.

c) For non-union following unsatisfactory reduction of fracture-dislocations.

d) For progressive spinal deformity following fractures of multiple vertebral bodies.

11.10. Management of Problem Cases

Cases presenting to the orthopaedic surgeon with a fracture or fracture-dislocation unreduced at the end of seven to ten days should be managed initially in exactly the same way as acute cases. In many of these, reduction can be achieved using postural methods or manipulative techniques combined with slow traction.

Most surgeons avoid the use of acute manipulative reduction of fractures or fracture-dislocations presenting 48 hours after injury.

Patients who present even later, up to two to three weeks from the initial injury, can usually be managed with adequate traction, and if reduction is not achieved in cases with fractures of the fracture-dislocation type, then a decision about the use of surgical methods must be taken. At this later stage the operative procedure does not carry the risks which may lead to disastrous results with its use in the acute phase of management, because the blood supply of the cord, by then, has been re-established. Facetectomy can be undertaken without fear of further damaging the blood supply of the spinal cord. However, facetectomy does not always result in reduction of the fracture and fracture-dislocation and then fusion in situ may be required.

In cases in which reduction has not been achieved at the three to six weeks period it is wiser to allow fusion to occur spontaneously in situ. Should symptoms arise from spinal stenosis in such cases, a supplementary decompression of the area can be undertaken, either through the spinal canal or by an anterior approach to the vertebral column. If there is obvious evidence of instability four to five weeks after injury then spinal fusion is required.

11.11. Summary

The risks following the use of surgical procedures early after spinal injury are summarized below:

1. The anterior longitudinal ligament–which is usually intact after fracture-dislocation of the spine–may be damaged, rendering the spinal segment unstable.
2. After anterior interbody fusion, the graft may slip forwards into the retro-oesophageal position because of poor fixation. [This problem may not occur if a dowel graft is inserted transversely across the disc space (Cornish, 1968).]
3. Posterior operations in the early stages can interfere with the blood supply of an already damaged spinal cord, as reported by Schneider (1951), Cheshire (1964) and Morgan (1971).
4. Operative interference in the early and even in the late stages following injury may be difficult, with the risk of further damage to an already damaged cord.
5. Early operative procedures aimed at producing spinal fusion are contra-indicated when it is known that spontaneous fusion can be expected in a high percentage of cases.
6. *Operative procedures in the early stages following spinal cord injury have a definite mortality rate.*

Surgical procedures should be restricted to the following general indications:

a) For gross dislocation with or without fractures, where conservative methods have failed.
b) For spinal injuries resulting from gunshot wounds in the acute stage.
c) For non-union of fractures.
d) For the stabilization of fracture-dislocations with proven instability six to eight weeks after the initial injury.
e) Following the failure of conservative management in any case.
f) *For neurological deterioration after incomplete paraplegia.* Regrettably even in this situation good results cannot always be guaranteed.

11.12. Conclusions

The surgeon's attitudes to his or her role in the overall management of spinal trauma should be strongly influenced by knowledge of the surgical pathology of spinal injuries.

There is no indication to operate on a patient with spinal injuries merely because the surgeon is "concerned" or because the patient deserves to be given the "benefit of the doubt".

After careful consideration of the mechanisms of injury and following evaluation of the resultant spinal lesions, doubts about indications for surgical treatment should not exist.

In most patients in whom paralysis does not complicate the spinal injury, the use of postural methods of reduction or reduction with manipulative procedures followed by physical rehabilitation in the manner described by Watson-Jones in 1952 will be found effective. In paraplegic patients the clinical methods discussed must be followed carefully, and only a few patients will need to be submitted to surgical treatment of the spine (less than 5%). The indications for surgery need to be precisely defined.

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The work is supplemented by a contribution on The Management of Spinal Injuries by his great friend Sir George Bedbrook—himself also an identical twin.

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