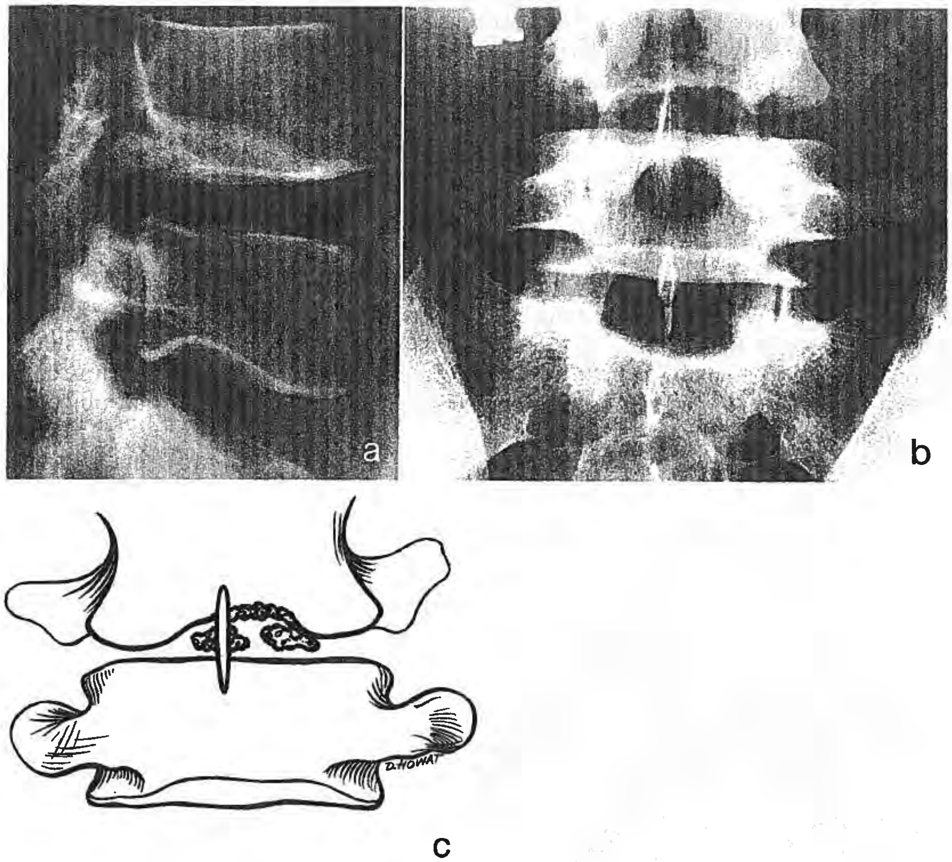
rounded, firm or fluctuant protrusions are found with stretched but intact annular fibres and, when incised at operation, only a small quantity of disc tissue may escape and be removed, leaving in the disc a defect which admits neither curettes nor disc rongeurs easily. The consistency of such discs is often described as rubbery. Some degenerative annular fibres are usually found with the extruded nuclear tissue in these cases.



Figures 3.2 a–c. Intra-spongeous disc herniation with fracture of the vertebral body margin and sequestration of disc fragments into the spinal canal. **a** Lateral radiograph. A large bony fragment separated from the posterior-inferior margin of the 4th lumbar vertebral body. It projects into the spinal canal. **b** Antero-posterior view. The L 4/5 disc space is narrowed and tilted. There is a defect in the central zone of the vertebral end-plate area of the 4th vertebral body. Below this, two bony fragments can be identified. These findings were confirmed at operation. **c** Drawing of the position of these fragments. (Courtesy of Mr. K. Mills)

Figure 3.1. A drawing depicting various types of disc prolapses which may be encountered in the lumbar region. *a* A sequestrated disc with fragments migrating distally from its origin at the L4/5 interspace. *b* "A shoulder" prolapse related to the S 1 nerve root at its take off point from the dural sac. *c* A central disc prolapse. *d* An axillary prolapse. *e* An extra-foraminal prolapse. *f* The common sub-rhizal prolapse. *g* An intra-foraminal prolapse

Extrusion of variable quantities of disc tissue (1.1–13.5 g) into the spinal canal may be seen when gross degenerative changes have occurred in the disc as a whole. The description of "sequestrated disc fragments" is then applied. The components of such fragments may include nuclear, annular and end-plate material.

Between these two extremes, a variety of pathological changes may be noted. Incomplete sequestration may be associated with marked peri-neural fibrosis, a finding related to physico-chemical changes in the disc (Nachemson, 1969). Calcified nuclear tissue may herniate, or calcification may occur in prolapsed tissue leading occasionally to erosion of the dural sac (Blikra, 1969).

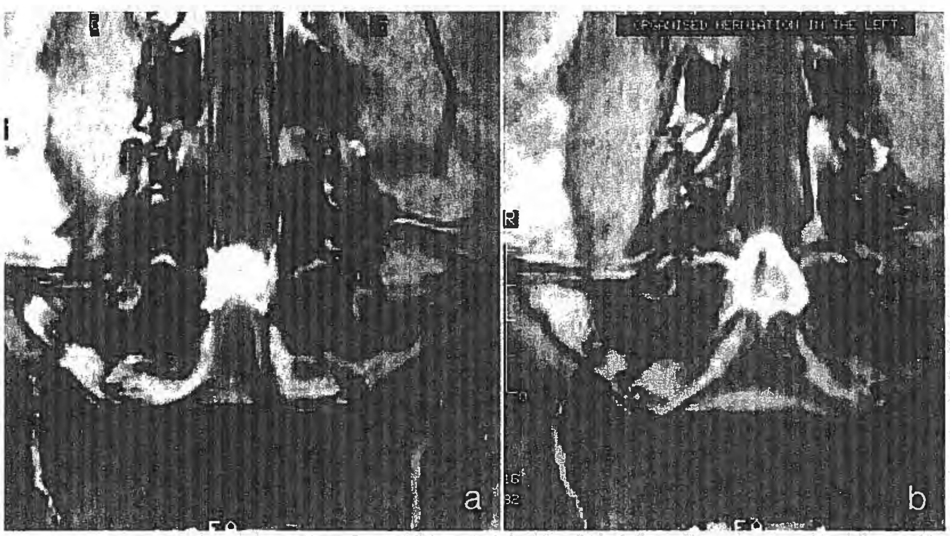
A sequestrated fragment may migrate to another level from the disc of its origin, leaving a clearly defined oval defect in the posterior annulus (Fig. 3.1). Sequestrated disc tissue may present posterior to the dural sac (Hooper, 1973).

Rarely, disc tissue may prolapse into the vertebral bodies and re-enter the spinal canal, pushing ahead of it a small fragment of vertebral end-plate bone and cartilage (Figs. 3.2 a–c).

In a sub-rhizal prolapse, the disc fragment lies anterior to the affected nerve root, and this usually causes severe pain with objective motor and sensory signs distally, in the part of the limb supplied by the compressed nerve root.

Prolapses situated between the dural sac and the nerve root sheath, axillary prolapses, or these lying on the outer side of the nerve root sheath, para-rhizal prolapses, may produce symptoms of severe sciatica without abnormal objective physical signs.

Centrally placed prolapses or a large migrating sequestrated fragment in the spinal canal may give rise to physical signs including bowel or bladder dysfunction and neurological signs or symptoms which vary from day to day in one leg or the



Figures 3.3 a, b. MR images with gadolinium enhancement showing marked oedema and venous engorgement at L4/5 with an organised left sided sub-rhizal disc prolapse

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other. In the lumbar region, cauda equina claudication with the onset of buttock or leg pains after walking short distances may also be found (Verbiest, 1955).

In considering this pathology, the clinician should always give some thought to the shape and size of the patient's spinal canal (Figs. 3.3 a, b).

3.3. Clinical Features

The classic features of lumbar scoliosis, depression of one or more reflexes in the affected limb, muscle weakness or wasting, gross limitation of straight leg raising and the finding of areas of impaired sensation over affected dermatomes are all well known.

Perhaps less well appreciated is the reported observation that the pattern of pain radiation into the leg does not differ appreciably in L4/5 and L5/S1 disc lesions. In fact, clinical signs caused by lumbar disc prolapses may be misleading. Brown and Pont (1963) observed in a review of 570 patients that the ankle jerk may be absent in cases of prolapse at L4/5 or at L3/4. They found that sensory changes in the foot were more accurate aids in diagnosis than were changes in the leg as a whole.

In eliciting the physical sign of limitation of straight leg raising as an index of sciatic nerve irritation, attempts to lift the leg quickly from the extended position, with the patient supine, frequently evoke such a painful response that the straight leg can be raised only a few degrees from the examination couch. On the other hand, if the knee and hip are cautiously flexed and the knee then extended slowly with the examiner's thumb in the popliteal fossa exerting some pressure on the terminal branches of the sciatic nerve, and these manoeuvres are combined with dorsi-flexion of the foot, even minor degrees of sciatic nerve irritation can be appreciated. This is commonly known as Lasègue's sign. A patient with convincing sciatica is unable to sit upright with both knees fully extended. In the presence of sciatic irritation he will automatically flex the hip and knee on the affected side when attempting to adopt this posture. This has been described as the "bath-tub sign" by Pennybacker (1959).

Changes in the clinical features referred to above are all important in assessing the progress or failure of recovery of sciatica due to disc prolapse. Of particular importance is the severity of pain, especially when it reaches a level which consistently disturbs sleep at night.

3.4. Investigations

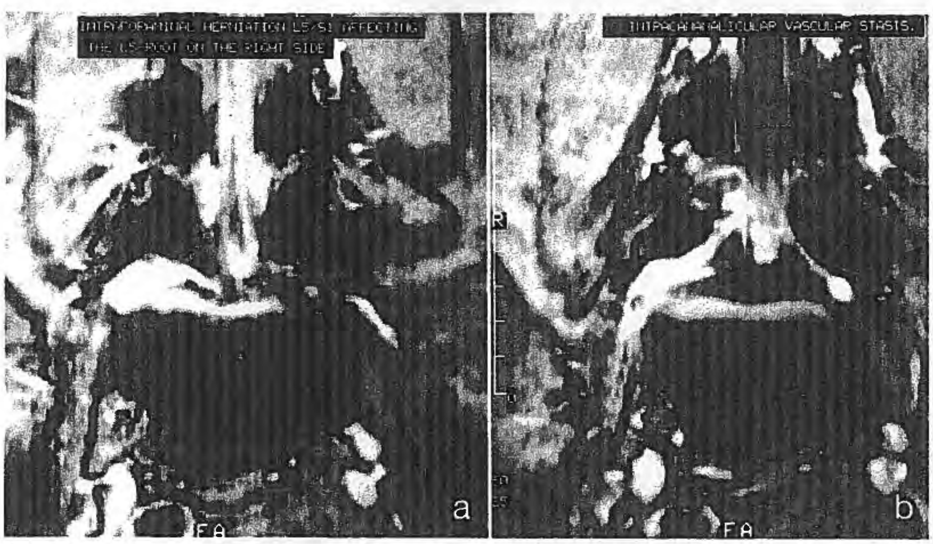
a) Plain X-Rays

These X-rays always provide essential information on the bony anatomy of the vertebral column particularly in regard to the arrangement of laminae and the site of the lumbo-sacral junction. They are also important for the exclusion of other lesions such as spondylosis which may cause confusion in diagnosis. Usually they do not provide any useful guide to the site of prolapse.

b) MRI

This is already established as the investigation of choice in the diagnosis of lumbar and thoracic disc prolapses. In the cervical spine it is often useful, but CT radiculography is more accurate in helping to localize smaller and laterally situated disc prolapses.

Figure 3.4. Coronal reconstruction of a lumbar MRI showing vascular stasis affecting the right sided lower lumbar nerve root due to a disc prolapse related to the take off point of this nerve root with surrounding oedema spreading centrally



Figures 3.5 a,b. Coronal reconstructions of MR images showing: **a** an intra-foraminal herniation at L5/S1 affecting the right sided L5 nerve root with **b** marked intra-canalicular vascular stasis

Used with gadolinium enhancement it gives accurate definitions of foraminal, extra-foraminal, intra-canalicular and sequestrated disc prolapses and shows the amazing extent of root oedema or vascular engorgement that occurs adjacent to many of these lesions (Figs. 3.3–3.11).

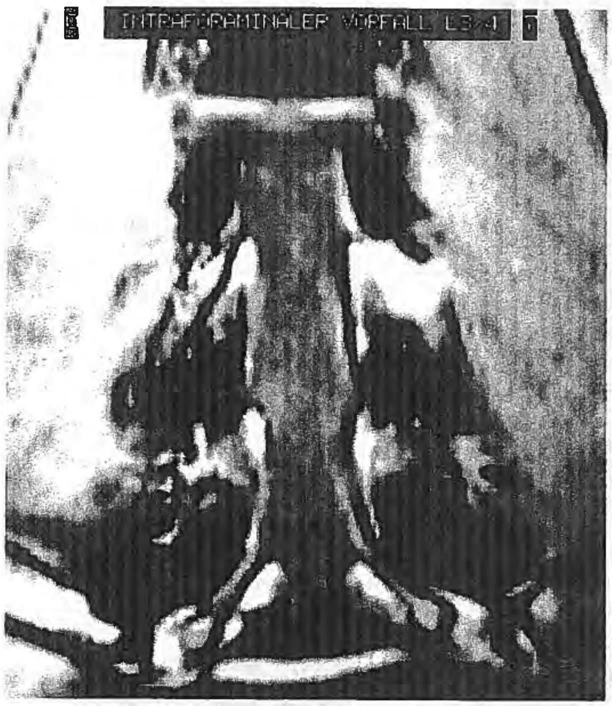
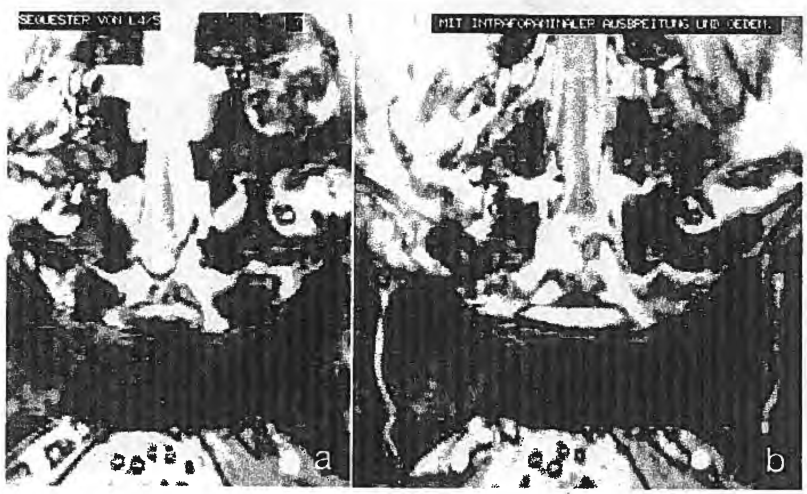


Figure 3.6. MRI – coronal reconstruction showing an intra-foraminal prolapse at L3/4



Figures 3.7 a,b. Coronal reconstructions of MR images showing: **a** sequestration of the L4/5 disc with **b** an intra-foraminal sequestration and surrounding oedema

Figures 3.8a,b. a An axial MR image with gadolinium enhancement in the case of an organised sequestrated intra-canalicular hernia. Note the surrounding oedema and in particular the oedema in the pedicle of L5 due to venous obstruction in the intervertebral foramen. **b** A large intra-foraminal hernia with surrounding oedema

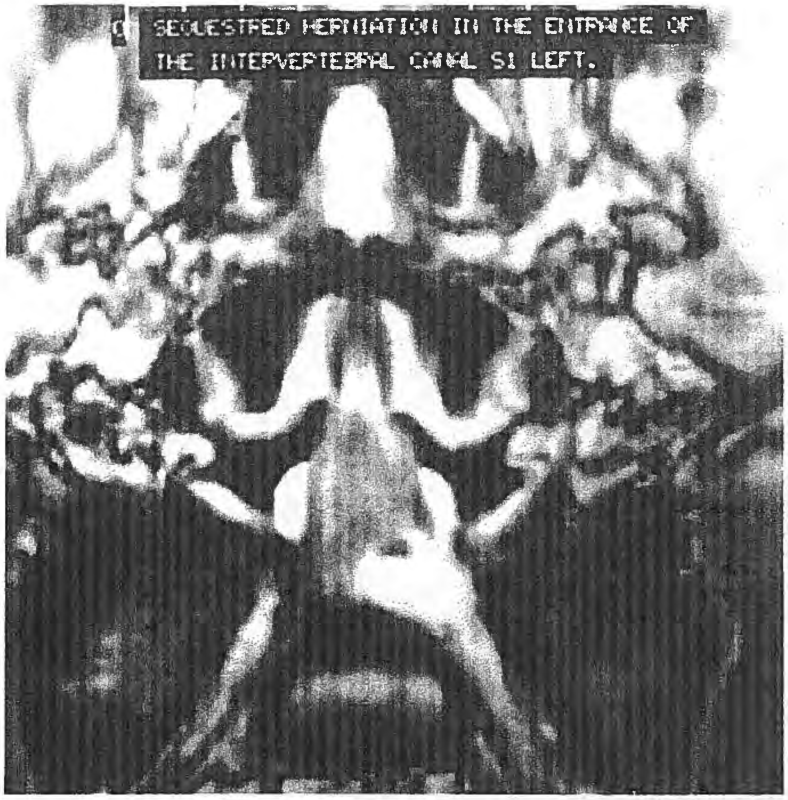


Figure 3.9. A coronal reconstruction showing a sequestrated herniation extending along the nerve root canal of S1 on the left side

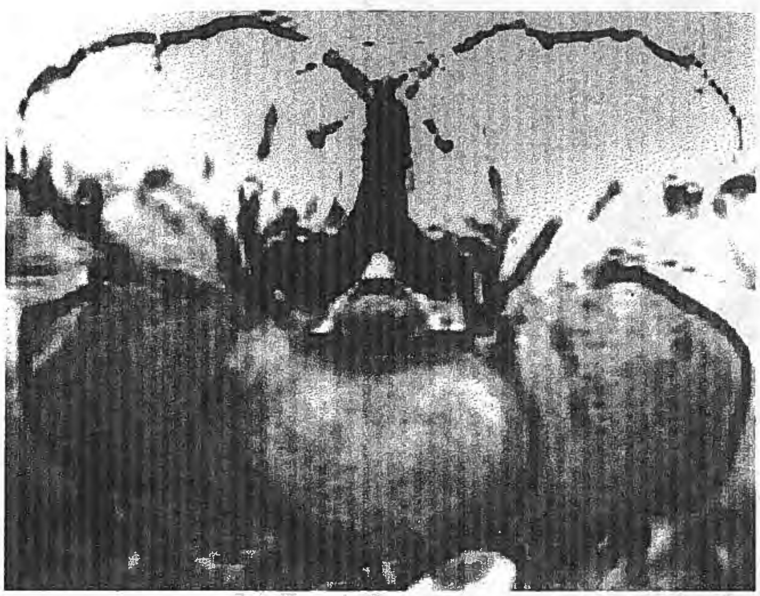


Figure 3.10. An axial MR image showing an extra-foraminal prolapse in the lumbar region

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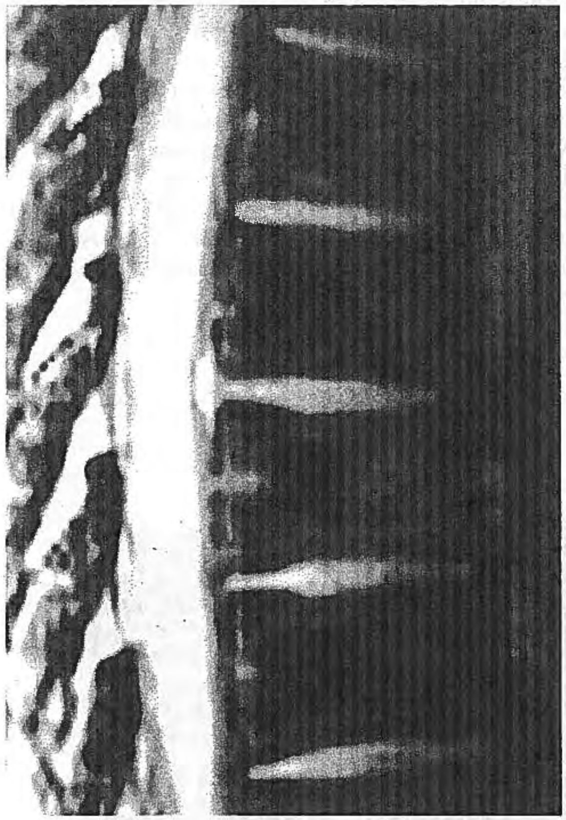
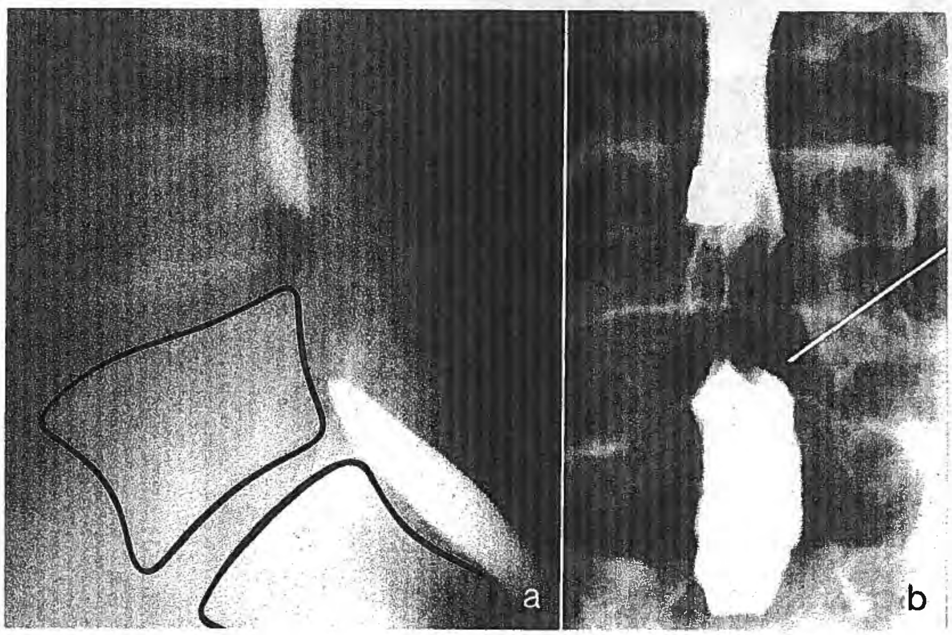


Figure 3.11. A mid-sagittal T2 weighted MR image showing a large thoracic disc prolapse projecting on to the dural sac and indenting the spinal cord

c) Myelography

The introduction of water soluble myelographic media such as Metrizamide or Omnipaque in recent years has greatly enhanced the accuracy of diagnosis of disc prolapses, particularly in combination with CT examination.

When MRI and CT examinations are not available, myelography should be used as a routine pre-operative investigation in cases of suspected disc prolapse. It is invaluable in the investigation of any atypical case and is especially useful in cases of suspected disc prolapse where there is advanced spondylosis shown on the plain x-rays, or in the presence of bony anomalies such as lumbar sacralisation. In these cases it will aid in the diagnosis of associated spinal canal stenosis (Fig. 3.12a, b), or it may help to identify the level of origin of a disc sequestrum and its distribution in the spinal canal (Figs. 3.13–3.15).



Figures 3.12a,b. Disc prolapse into a congenital narrow lumbar canal. A 62 year-old man (weight 110 kg) lifted a bag of cement, flexing and rotating his spine. He developed back pain and severe bilateral leg pain; these symptoms were relieved following excision of a small disc fragment and bilateral nerve root canal decompression laminectomy. **a** Lateral and **b** antero-posterior radiographs of the lumbar myelogram, showing gross obstruction of the iofendylate column. Note the symmetrical indentation at the upper end of the lower iofendylate column in (**b**) (marker), suggesting the association of true spinal stenosis. (Courtesy of Mr. B. Davie)

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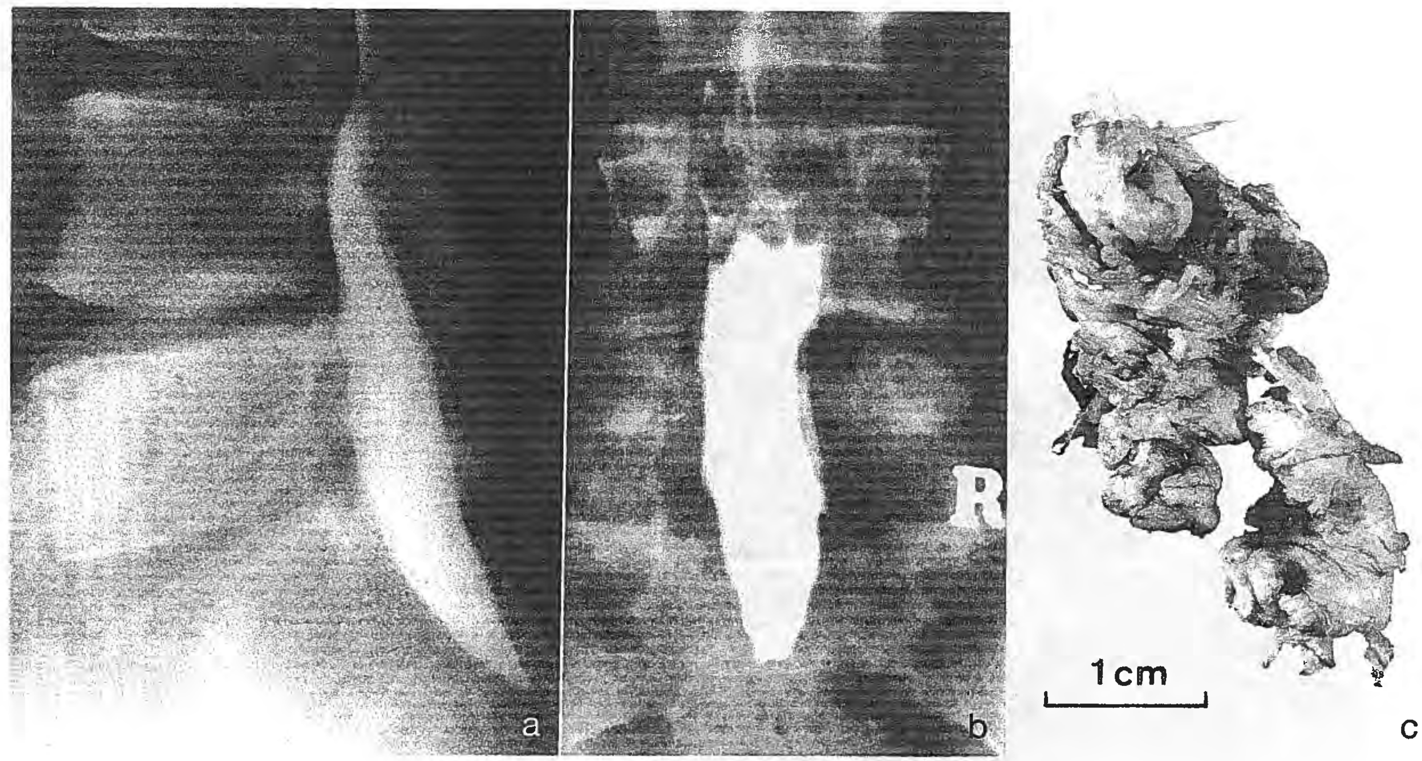
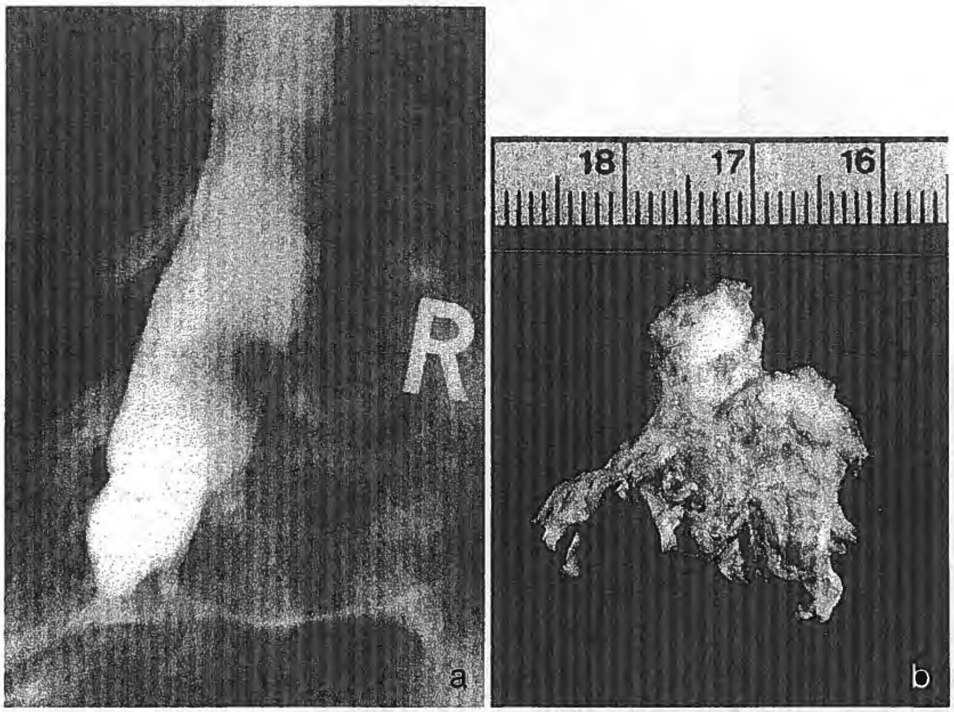
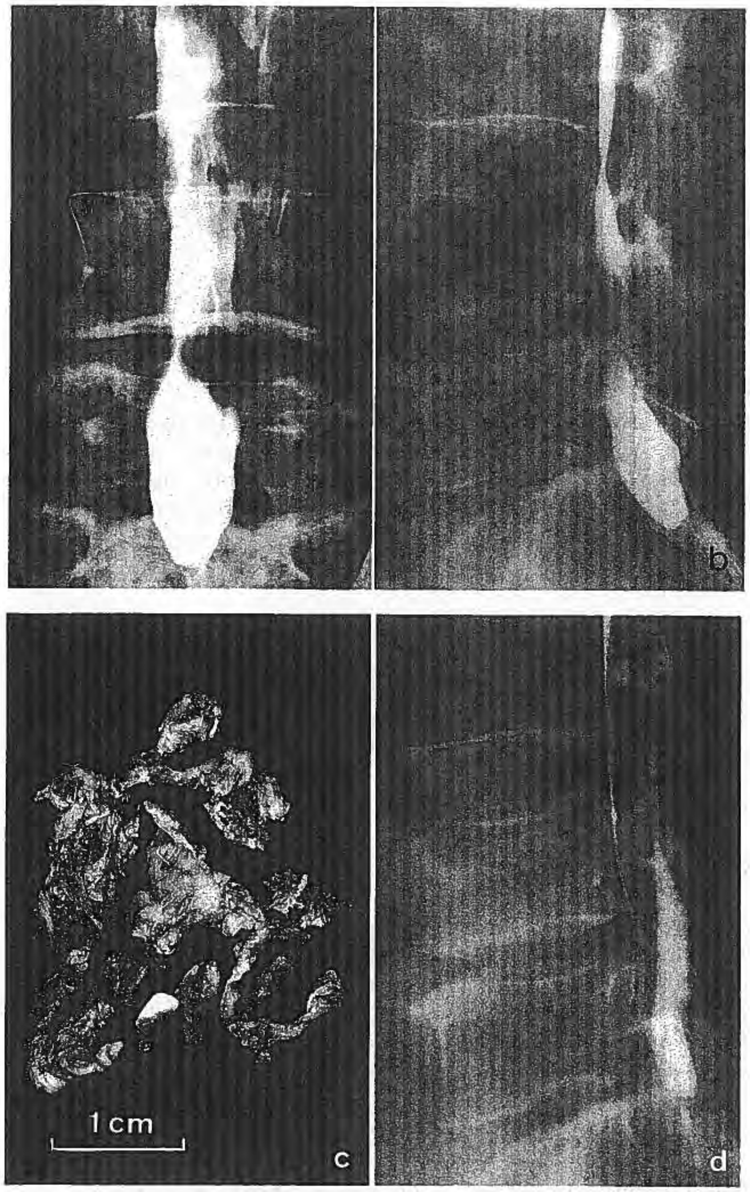


Figures 3.13 a–c. Sequestrated L4/5 disc with migrating fragments. **a** and **b**: Lateral and antero-posterior radiographs of the lumbar myelogram of a woman, aged 39 years, who had severe right-sided sciatica. The deformation of the dural sac is consistent with the presence of migrating sequestrated disc fragments. It is best seen in the antero-posterior view. **c** The photograph shows the appearance of the sequestrated disc material which was removed at operation, orientated to correspond with its position in vivo



Figures 3.14a,b. **a** A right-sided, slightly oblique view of a radiculogram in a 27 year old male showing a large central and right sided filling defect at L5/S1. This represented a massive disc sequestration stemming from the L5/S1 disc and extending distally in to the sacral spinal canal between the S1 and the S2 nerve roots. **b** A photograph of the specimen removed at operation. This consisted of mixed elements of disc tissue including vertebral end-plate cartilage



Figures 3.15a–d. Massive disc sequestration following twisting of the lumbar spine treated by disc excision and posterior interbody fusion. A 53 year-old male jeweller suffered from intermittent back pain for 13 years. While using a powered floor-standing machine, he twisted his spine and suddenly developed severe left-sided sciatica. **a** and **b** Antero-posterior and lateral radiographs of the lumbar myelogram, showing a large filling defect at the L4/5 disc space. **c** The sequestrated disc fragments removed at operation. **d** Lateral radiograph taken after operation showing the restored normal outline of the dural sac. Bone grafts are seen between the vertebral bodies of L4 and L5; they were inserted through the spinal canal following disc excision

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d) C.S.F. Examination

Some authors recommend routine examination of the C.S.F. in the investigation of disc lesions, to test its dynamics and contents (Mercer and Duthie, 1964), while others with extensive experience in the management of spinal conditions rarely do so (Armstrong, 1965; Northfield and Osmond-Clarke, 1967).

The normal protein content of C.S.F. lies between 15 and 40 mg/ml (Bickerstaff, 1973). In lumbar disc prolapses rises up to 100 mg/ml may be seen, with figures as high as 1,000 mg/ml in the presence of marked spinal block. However, many would hold the view that changes in the protein content are rarely of practical use in diagnosis. Johnson (1972) discusses the mechanisms of absorption of C.S.F. and states: "It appears that a subsidiary pathway is via the large spinal veins around the emerging nerve roots". Abnormalities of serum albumin may be found in collagen diseases, those changes being reflected in the C.S.F. with the appearance of abnormal albumins, "para-albumins", in it. With advances in the understanding of C.S.F. physiology, it is logical that surgeons should make greater use of more recent biochemical techniques of analysis of this fluid, especially in some of the non-prolapsing varieties of disc lesions discussed in this chapter. Whenever myelography is undertaken, a sample of C.S.F. should be obtained for cytological and chemical testing.

e) Discography

This investigation is rarely indicated as an aid to the diagnosis of disc prolapses. In atypical cases of severe sciatica with minimal abnormal physical signs and normal myelographic findings, a discogram may help to clarify the diagnosis (Wilson and McCarty, 1969). In combination with CT examination foraminal and extra-foraminal disc prolapses at unusual sites can be identified.

f) Intra-Osseous Spinal Venography

Intra-osseous spinal venography has not been used widely in the English-speaking world. German observers claim that when it is used with tomography it is just as reliable as myelography in the diagnosis of lumbar disc protrusion and prolapse. The special value of this procedure is noted in acute cases of massive midline prolapses involving the cauda equina (Vogelsang, 1970). MRI with gadolinium enhancement has rendered this investigation almost obsolete (see Chapter 2).

g) Electrodiagnostic Tests

Technical and interpretative difficulties in the use of electromyography have been described by Simpson (1972).

3.5. *Indications for Surgical Treatment*

Absolute indications for operations are:

a) Major neurological deficits, such as: Acute cauda equina compression due to massive disc sequestration or the prolapse of a small fragment of disc tissue into an abnormally small lumbar spinal canal; paraparesis due to thoracic disc prolapse, brachial paresis or quadriparesis due to cervical disc prolapse.
b) Persistent or recurrent pain, with or without abnormal physical signs, in the extremities. This is the most common indication for surgery after an adequate trial of conservative treatment in cases of lumbar or cervical disc lesions.
c) Progressive neurological deficits, such as paraparesis, foot drop or quadriparesis.
d) Persistent spinal deformity, such as lumbar scoliosis or marked lumbar flexion deformity which may be found in certain cases of lumbar disc prolapse or spinal tumour.

3.6. *Treatment for Lumbar Disc Prolapses*

a) Discussion

i) Surgery

In the lumbar region, a limited unilateral inter-laminar approach may suffice for the removal of discrete small rubbery disc prolapses, but it can only be recommended in young people. Where disc sequestration has occurred or in cases where rather desiccated disc tissue is found, more extensive intra-disc space curettage should be carried out and at the same time a careful bilateral nerve root canal decompression performed. Such a procedure performed at the time of laminectomy for disc fragment excision reduces the late problems of recurrent nerve root irritation that may arise from nerve root canal stenosis on one or both sides, resulting from secondary disc space narrowing. In these circumstances, there is little justification for extending the operation to include posterior spinal fusion (Spurling, 1949). Indeed, the failure rate is high, graft resorption being very common when inter-laminar fusion has been attempted after exploration of the spinal canal. In addition, late spinal canal stenosis may lead to recurrent symptoms which are difficult to manage. Postero-lateral inter-transverse fusion is more reliable in these circumstances if spinal fusion seems warranted because of gross vertebral instability (Watkins, 1959).

From the point of view of the relief of sciatic pain, recent long term reviews indicate that "laminectomy" alone will produce good results (Jackson, 1971; Naylor, 1974), variations in the actual technique of laminectomy exerting little effect on the outcome.

Where most of the disc remnants are removed in some cases of massive disc sequestration, gross vertebral instability can occur. Posterior interbody spinal fusion performed through the spinal canal, either by the technique described by Cloward (1952) or that recommended by Wiltberger and Abbott (1958), offers a solution to a difficult problem (Fig. 3.15d).

Numerous reviews analyzing the results of various forms of treatment for disc prolapse and spondylosis in the lumbar region are available. Basically it is impossible to compare series published by different authors for two reasons: firstly, because indications for operation vary so widely; secondly, because the operative techniques and pathological findings described are also variable.

Authors everywhere agree on a number of matters:

- compensation patients always respond more slowly to treatment than do private patients;
- the results of simple disc fragment excision for frank disc prolapse are good in more than 80% of cases;
- prolonged paralysis before operation may not recover completely following it; and
- paralysis seen for the first time after operation usually recovers rapidly and completely.

Cervical disc prolapses can be treated almost exclusively by anterior disc excision thereby avoiding the more painful procedure of posterior exploration of the cervical canal.

Thoracic disc prolapses are rare. They are usually found between T9 and T12 vertebrae though upper thoracic lesions do occur. MRI has increased the rate and accuracy of their diagnosis (Fig. 3.11).

ii) Chymopapain

Intra-discal injection of chymopapain (Discase), a proteolytic enzyme, was introduced into clinical practice in 1963 for the treatment of disc prolapse (Smith and Brown, 1967). Clinical diagnosis is confirmed by discography, following which the enzyme preparation is injected through the discogram needle.

Biochemists have been sceptical of its use because of the difficulty of standardization of the enzyme preparations and the potential for damage of tissues other than nucleus pulposus, should it escape from the intervertebral disc space (Lowther, 1972). Chymopapain, nonetheless, found its way into quite wide use especially in some parts of the U.S.A. and Canada. The difficulties in assessing its efficacy in treatment have been highlighted by MacNab (1973), because there is no general agreement on clinical syndromes presented by a disc herniation. He quotes the following results assembled from a nationwide review undertaken by Lyman Smith in 1972: in 2,557 patients there was marked improvement in 1,769 (70%), slight improvement in 340 (13%) and no improvement in 448 cases (17%).

Although chemonucleolysis is no longer widely used in North America even by its former most ardent proponents, persistent interest in this method of treatment has led to the establishment of a Society for Intradiscal Therapy.

A number of controversies continue to provoke debate. *Anaphylaxis*, the major life threatening complication has attracted most attention, leading to developments such as prophylactic skin testing and medication regimes. Arguments about the administration of chymopapain under *general anaesthesia* or under neuroleptic analgesia appear to have been resolved in favour of the latter method. Attitudes to the use of *discography* have swung between two absolutes, either contraindication or indispensability. The real danger with the use of discography appears to be the over diagnosis of disc prolapses bearing in mind that leakage of dye into the spinal canal is not necessarily an indication of the presence of a disc prolapse into the spinal canal. Discography is essential before the injection of any neucleolytic agent into the intervertebral discs for one reason only; *if the discography gives rise to venography of the epidural veins, then this should constitute an absolute contra-indication to the injection of chymopapain,* which may then find its way into the epidural venous system and produce major neurological complications such as paraplegia, quadriplegia, or sub-arachnoid haemorrhage.

Chymopapain is still widely used in Europe particularly in France, Belgium and Germany. In the recent monograph Focus on Chemonucleolysis, Bonneville (1988), the complications of neucleolysis are discussed and the statement made on page 105 "The paraparetic and paraplegic syndromes are only found in the North American series". This suggests an immunity on the part of Europeans to these complications. This statement is difficult to accept on a scientific basis, particularly when the real mechanism of the causation of these complications has remained unexplained.

b) Technique for Surgery

i) Pre-Operative Preparation

These routines are set out in Chapter 10. X-rays of the patient's spine should always be available in the operating theatre.

ii) Anaesthesia

General anaesthesia with muscular relaxation and mechanical ventilation is most commonly employed. Cardiac monitoring is recommended.

iii) Positioning

Of all the factors which may be critical to the success of this operation, none is more important than the position in which the patient is placed before operation commences. A variety of suitable postures is shown in the following illustrations (Figs. 3.16–3.19).

Prone Position

The most versatile and easily managed is the prone position. A supporting sponge rubber U-piece is simple to construct and inexpensive. The right arm is shown dependent and supported on a well-padded arm rest which is suspended below the level of the table. Ulnar neuritis may occur unless the arm is carefully postured in this way. The left arm may rest by the patient's side. The table is angled in the centre. The surgeon's assistant and other observers will have unobstructed views of procedures throughout the course of the operation. The entire range of surgical manoeuvres that may be required for the execution of even the most complex operation, including trans-dural excision of prolapsed disc tissue, can be accomplished in comfort and without undue constraints on the duration of the operation.

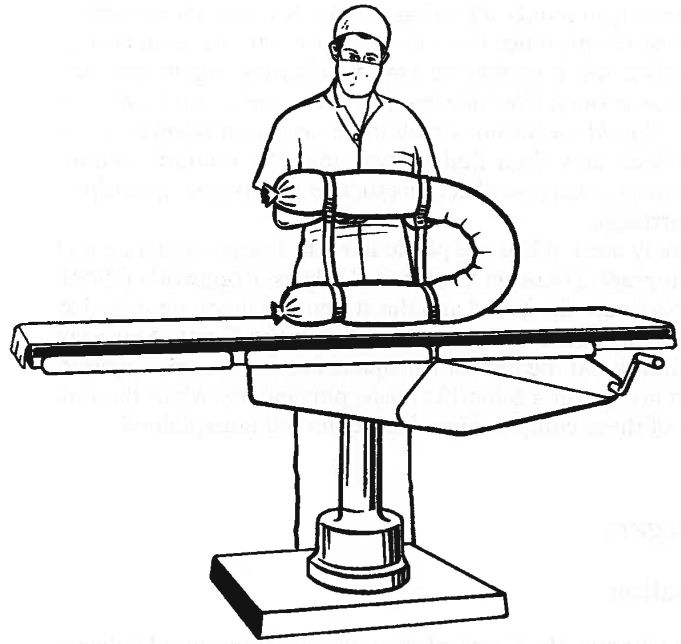

Figure 3.16. A drawing illustrating a simple supporting sponge rubber "U"-piece

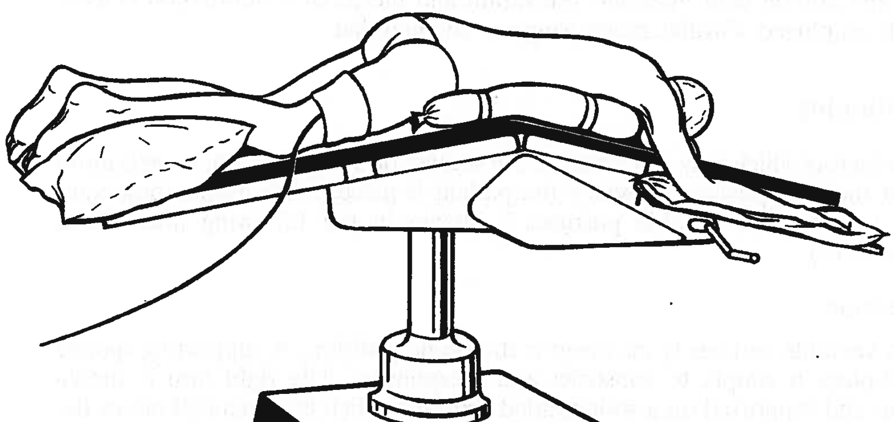

Figure 3.17. The posturing of the patient on this "U"-piece. The right arm is shown dependent and supported on a well-padded arm rest which is suspended below the level of the table. Ulnar neuritis may occur unless the arm is carefully postured in this way. The left arm may rest by the patient's side. The table is angled in the centre

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Kneeling Position

In this position, with the use of a simple frame to support the buttocks, excellent operating conditions are provided. Use of this posture can only be recommended for operations of short duration. Alternatively, the patient may be placed in this position with pillows under the chest so that the abdomen is unsupported. A pillow is placed under the patient's feet and a restraining strap across the legs, though venous obstruction in the lower limbs is then likely to occur. The table is angled. The major objections to the use of this particular posture revolve around the difficulties of setting the patient in position and of dealing with emergencies, which may require the patient to be turned rapidly into a supine position. Particular attention should be paid to the ulnar nerves in this position.

Lateral Position

The use of this position can be recommended in special circumstances, for example, when the patient is extremely obese or when there are special chest problems which may complicate anaesthesia. A pillow should be placed between the patient's legs, a restraining strap crossing the iliac crest, and a sandbag placed above the dependent iliac crest. The table is angled in the centre. There are objections to the routine use of this position: (i) the assistant surgeon is rarely comfortable and has a restricted view of the operation field; (ii) lighting of the wound area may be difficult; (iii) haemorrhage control is often more difficult to obtain as is access to the nerve root canal on the dependent side of the spine.

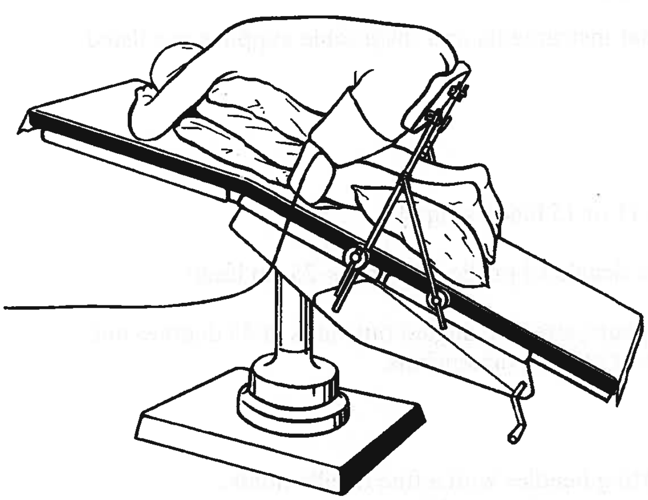

Figure 3.18. A drawing depicting the kneeling position. A simple frame is used to support the buttocks

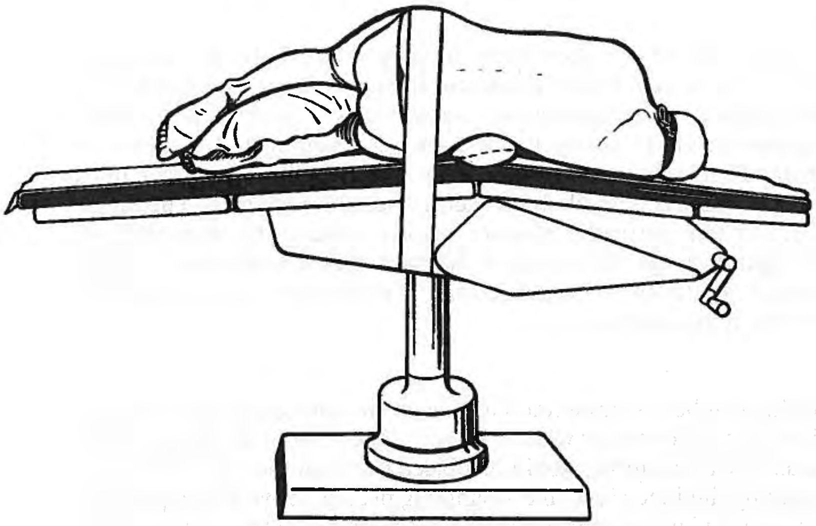

Figure 3.19. The lateral position. The use of this position can be recommended in special circumstances, for example, when the patient is extremely obese or when there are special chest problems which may complicate anaesthesia. Note the pillow between the patient' s legs, the restraining strap crossing the iliac crest, the sandbag placed above the dependent iliac crest. The table is angled in the centre. There are objections to the routine use of this position: 1. the assistant surgeon is rarely comfortable and has a restricted view of the operative field; 2. lighting of the wound area may be difficult; 3. haemorrhage control is often more difficult to obtain, as is access to the nerve root canal on the dependent side of the spine

iv) Instruments (Figs. 3.20–3.21)

The recommended essential special instruments and disposable supplies are listed below:

1. Self-retaining retractors.
2. Fine sucker.
3. Bayonet forceps.
4. Long-handled carrier for size 11 or 15 blade scalpel.
5. Watson-Cheyne probe.
6. Nerve root retractor, such as a Scaglietti probe (10 inches–25 cm long).
7. A range of bone rongeurs.
8. A range of pituitary-type rongeurs, straight, angled outwards at 45 degrees and at 90 degrees with cutting tips of varying dimensions.
9. Hammer.
10. Fine osteotomes and chisels.
11. Ring curettes.
12. 6/0 suture material on fine cutting needles with a fine needle holder.
13. Patties and haemostatic gauze or sponge materials.
14. Bone wax.
15. Bi-polar coagulator.

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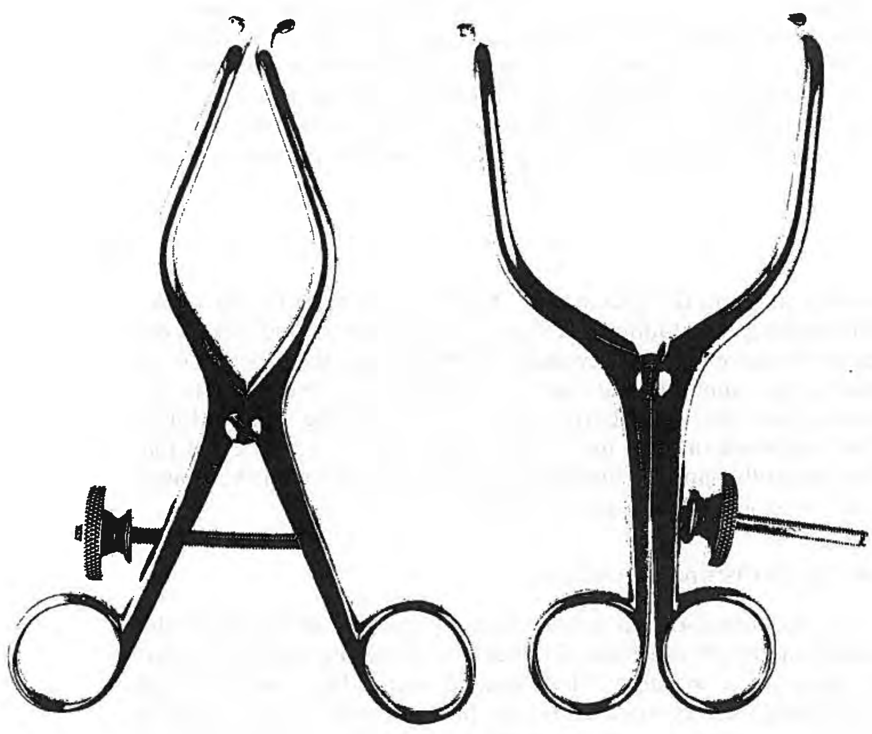

Figure 3.20. A photograph showing the modified Gelpi retractors, which are recommended for use in almost any situation where the spinal canal is to be explored

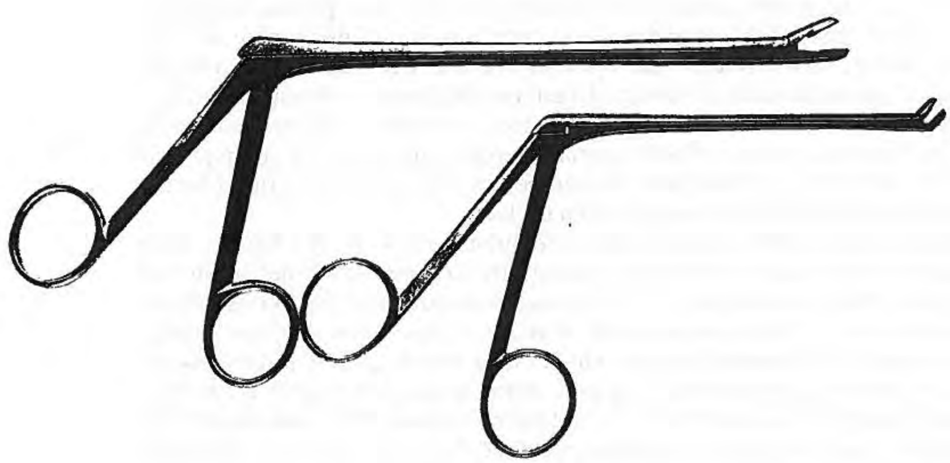

Figure 3.21. A photograph of straight and angled pituitary rongeurs which should be available in various shaft lengths and cup sizes for use in the surgery of disc prolapses

Before the skin incision is made the surgeon should once again inspect the patient's X-rays, paying attention to vertebral anomalies, such as spina bifida occulta and sacralization and noting certain lesions such as spondylolisthesis or isolated disc resorption. The level of the planned exposure of the spine should be noted.

Radiographs of the lumbar spine taken in the operating theatre are often of poor quality and cannot, therefore, be relied upon to identify a particular spinal level.

v) Incision

The skin incision is made in the mid-line or slightly to the right or left of the spinous processes, extending longitudinally a short distance above and below the vertebral interspace to be explored. It is deepened at once through the subcutaneous fat layer to the level of the lumbo-dorsal fascia. In extremely obese patients the depth of thc subcutaneous fat layer between the skin and the lumbo-dorsal aponeurosis over the lumbo-sacral area may be 12 cm or more. In such cases this fatty tissue should be carefully handled, avoiding excessive burning with the coagulating diathermy (see "Wound Closure", pp. 144, 145).

vi) Separation of the Paraspinal Muscles

An incision is made in the lumbo-dorsal aponeurosis on one side of the tip of the spinous process approximately 5 mm from the mid-line using the cutting current diathermy passed through a suitable blade-shaped end. The lumbo-dorsal aponeurosis is a thin shining silvery membrane, the fibres of which are orientated largely transversely. This structure acts as an extensor mechanism in lumbar spinal movement through its attachments to the powerful latissimus dorsi and abdominal wall muscles (Fig. 3.22).

Immediately beneath it are the silvery vertically orientated fibres of the sacrospinalis aponeurosis (Fig. 3.23). The incision continues proximally and distally adjacent to the sides of the spinous processes and parallel to the interspinous ligaments. Some bleeding will occur at this stage from posterior branches of the lumbar arteries related to the middle of the side of each spinous process. The muscle mass may be retracted with a closed dissecting forceps placed into the depth of the space, so that the diathermy blade may cut the musculo-tendinous attachments from the inferior surfaces of the spinous processes and laminal margins and from the interspinous ligaments near their bases. Throughout this procedure the smoke generated by the diathermy cutting tip may be evacuated with a sucker.

The muscle mass is next separated from the outer surface of each lamina using an appropriate elevator such as the Cobb, taking care to preserve the periosteum of the lamina. *This manoeuvre should be carried out cautiously and sub-periosteal dissection avoided as this inflicts unnecessary damage to the laminal blood supply.* Following the use of the muscle elevator which raises the paraspinal muscles laterally to the level of the apophyseal joint capsule, which should be carefully preserved, further bleeding may be encountered from posterior branches of the lumbar arteries and veins in this area. Bleeding is readily controlled following insertion of cotton Raytec swabs, (bearing X-ray markers), packed into the depths of the wound along its length. When these are removed later, a few individual bleeding vessels may need to be coagulated with diathermy.

If necessary the same approach is then repeated on the opposite side of the spinous processes, preserving the interspinous ligaments until the paraspinal muscle mass has been similarly separated from the roof of the spinal canal. Cotton Raytec swabs are again inserted and a self-retaining retractor of the surgeons's choice is then prepared for insertion. When a small unilateral disc prolapse is to be removed, special retractors are available which will permit exposure of the interlaminar space on one side only. These vary from speculum shaped instruments to retractors with one narrow blade coupled with a probe-like limb. These are advocated by surgeons who practise micro-discectomy or so called minimal intervention surgery.

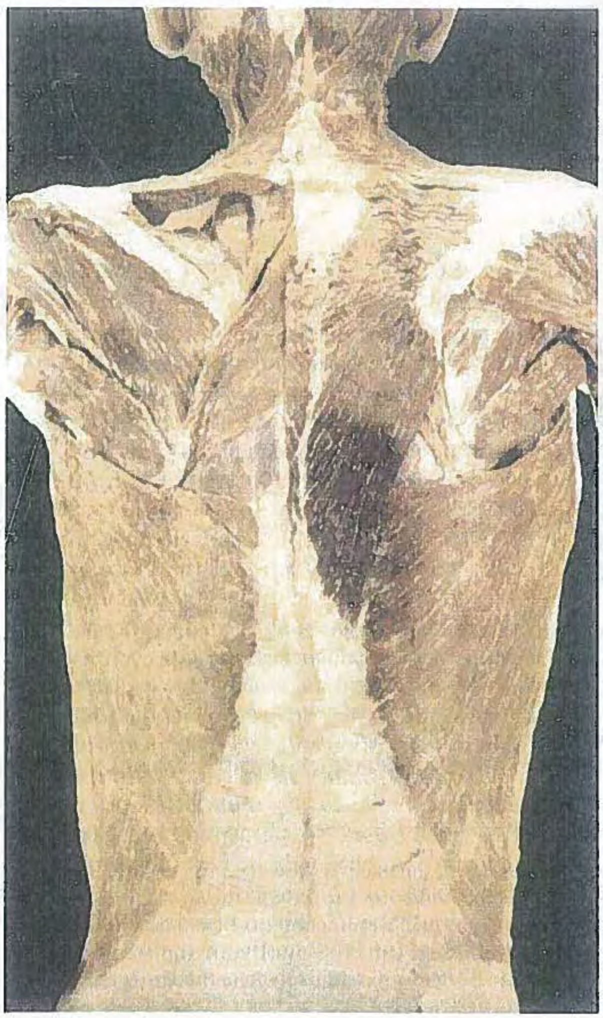

Figure 3.22

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Figure 3.23. A photograph of a dissection of the lumbo-sacral spine seen from behind. In the lower half of the specimen on the left side, the intact thoraco-lumbar fascia is seen with its shining silver fibres orientated largely transversely. Above this the paraspinal muscles have been removed. On the right side the cut edge of the thoraco-lumbar fascia is visible. Beneath this thin membrane the vertically orientated aponeurotic fibres of the sacrospinalis muscles can be seen. [Reproduced with permission of the editor John E. Nixon from: Spinal Stenosis, p. 21, London: Edward Arnold, 1991]

Figure 3.22. A photograph of a dissection of the muscles of the back to show the large triangular shaped lumbo-dorsal aponeurosis, the apex of which extends up towards to the mid-thoracic spine, the base of which lies across the iliac crests inferiorly. The attachments of the latissimus dorsi and abdominal muscles to its lateral edge on both sides can be seen. (Photographed with the permission of the Dean of the Faculty of Medicine Professor Graham Ryan in the University of Melbourne)

Unless the technique described is followed carefully, considerable blood loss may occur, even during this preliminary stage of the approach to the disc prolapse (Figs. 3.24, 3.25). Presuming both sides of an intervertebral disc space are to be exposed the cotton Raytec swabs are removed from the lower end of the wound on either side of the spinous process. Hand held retractors expose the back of the sacrum allowing the first self-retaining retractor to be inserted and fixed in place. This procedure is repeated at the upper end of the wound and a second self retaining retractor inserted.

When the self-retaining retractors have been positioned, the surgeon should take note of the time of their application. *These instruments obstruct the circulation in the separated paraspinal muscles. At the end of an hour they should be removed for*

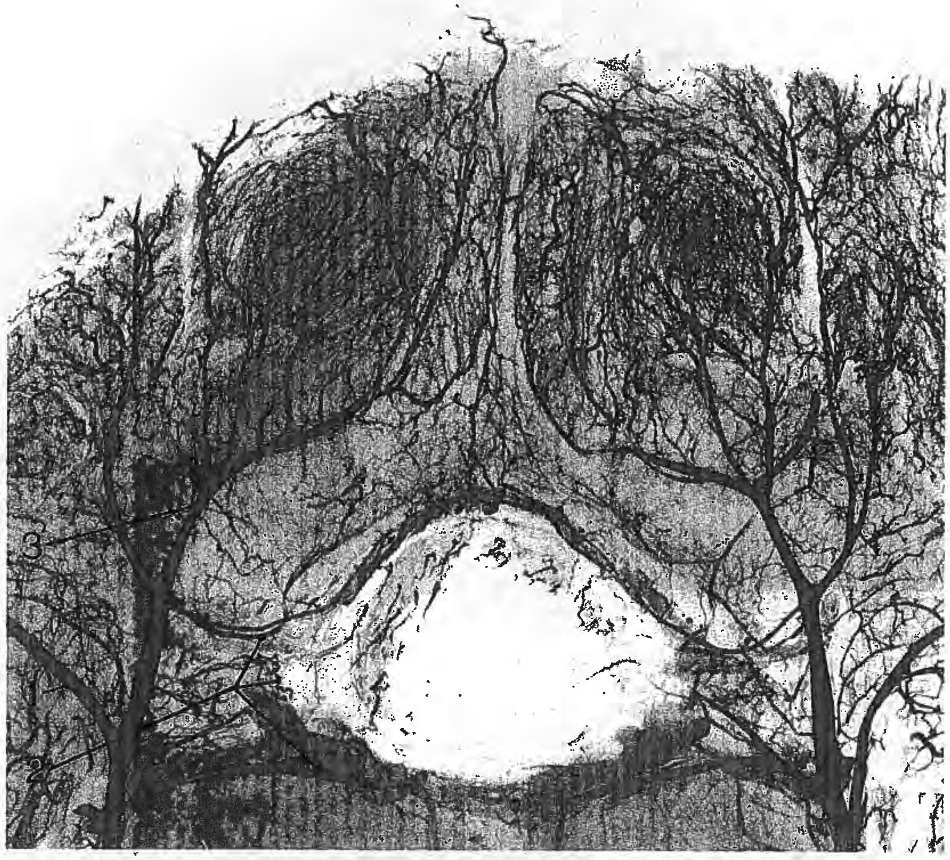


Figure 3.24. A thin transverse section to show details of the arterial distribution in relation to the spinal canal, the vertebral body in front and the lamina and spinous process behind. At the level of the intervertebral foramen, note: *1* the anterior abdominal wall branches; *2* the intermediate or spinal canal branches; and *3* posterior to the intervertebral foramen, the posterior branches in relation to the lamina and spinous process

about five minutes to prevent muscle damage. During the rest period the wound should be irrigated with Ringer's solution or normal saline.

At this stage Raytec swabs are again packed firmly along one of the paraspinal gutters while attention is focussed on the opposite side to identify the lumbo-sacral junction. Soft tissue remnants of muscle fibres and fat are then removed from the interspace which is to be opened. This cleaning up process should involve the use of the sucker through which fatty tissue can be removed. The sucker should then be used as a retractor placed inferior to the shining silvery facet joint capsule in the region of the pars interarticularis of the inferior lamina. While the sucker is being manipulated in the left hand the surgeon may then use either a curette or a straight pituitary rongeur with an appropriate sized cup to take off the muscle remnants from

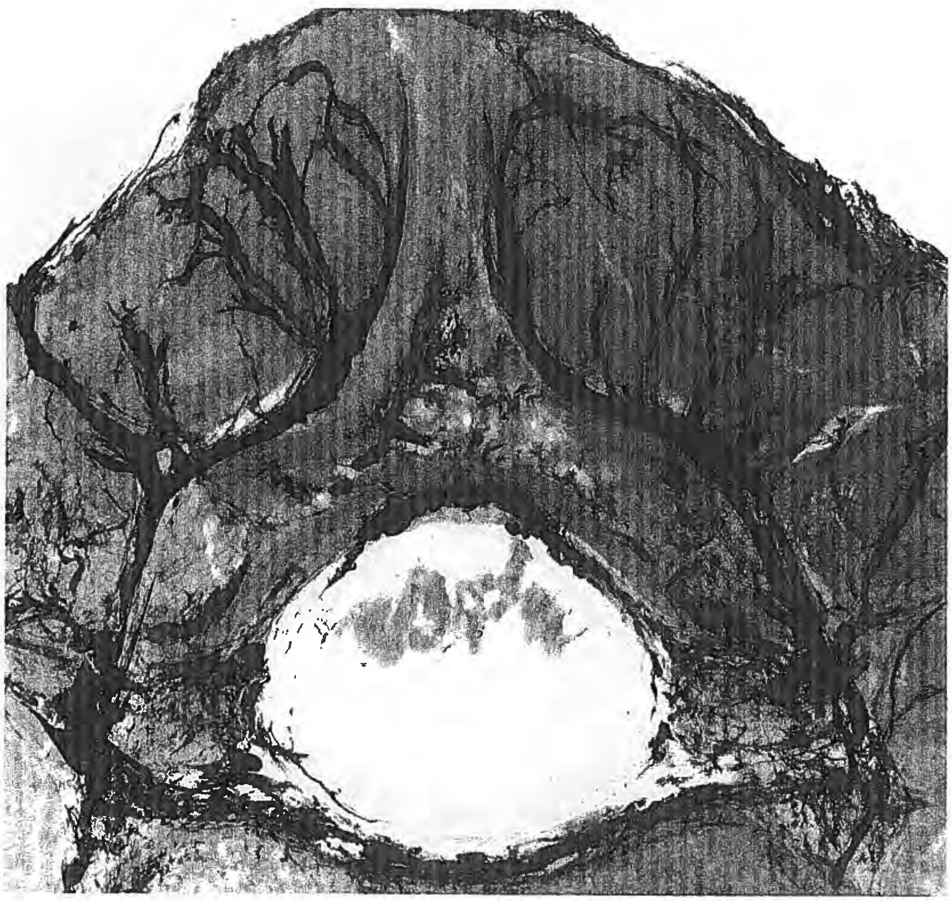
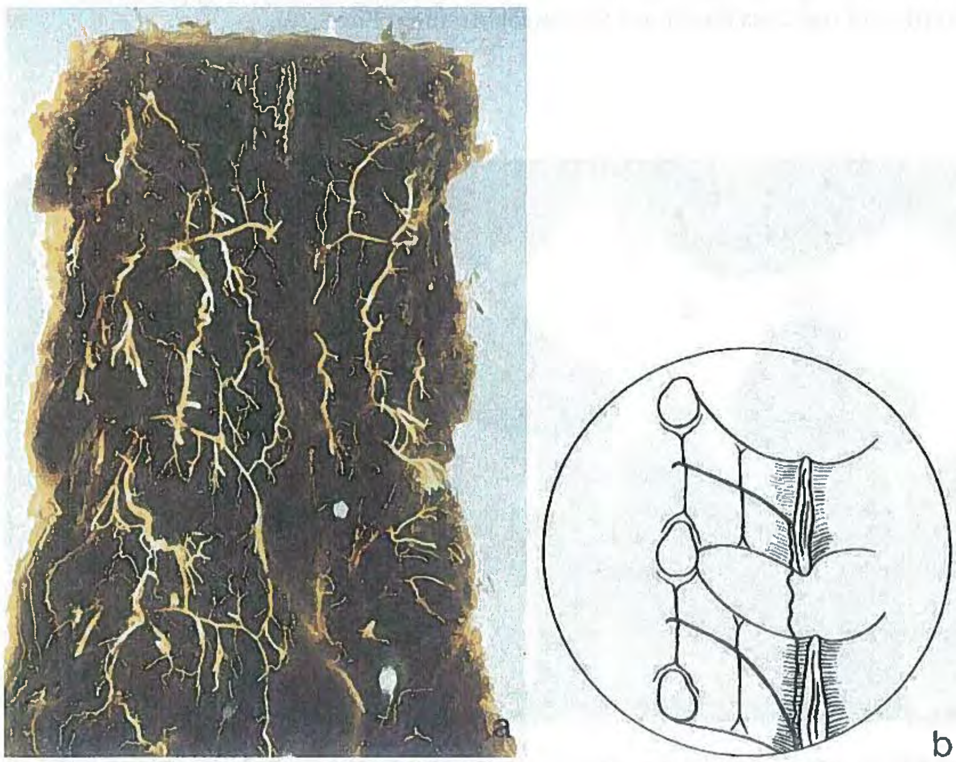


Figure 3.25. A radiograph of a transverse section of a lumbar vertebra from an adult to show the relations of the main stems of the lumbar veins (posterior external vertebral venous plexus) to the spinous process and lamina. [Reproduced by courtesy of J. B. Lippincott and Company from: Clin. Orthop. Rel. Res., No. 115 (1976)]

the interspinous ligament and the adjacent laminal margins together with remnants of soft tissues from the posterior surface of the ligamentum flavum.

Bleeding should not be a problem during these manoeuvres providing the sucker tip is used as a retractor in the manner described. On the other hand if fatty tissues and muscle remnants are *removed inferior and lateral to the facet joints* at individual interspaces profuse haemorrhage may be precipitated and the resultant efforts to control it with diathermy have the potential to inflict serious damage not only on the blood supply of the muscle but on the blood supply of the nerve root in the intervertebral foramen.

The main stem of the posterior branch of the lumbar artery is found constantly at the middle of the outer edge of the pars interarticularis. From it, arcuate branches pass upwards and downwards towards the capsules of the apophyseal joints (Figs. 3.26a, b, 3.27). Haemorrhage points are easily identified although care must be



Figures 3.26a,b. A photograph of the posterior aspect of the upper lumbar spine of an adult prepared by the Spalteholz method, following injection of the lumbar aorta. The specimen is slightly tilted to the right side to provide a clear view of the posterior spinal branches of three adjacent lumbar arteries. An explanatory diagram is shown alongside, in which the main course of each lumbar artery across the back of the lamina and up the middle of the spinous process is shown with its ascending and descending vertical muscular branches and the arcuate systems formed around the facet joints

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taken not to diathermy the main stem far anterior to the anterior margin of the pars interarticularis. Damage to entrant neural arteries at the intervertebral foramen is thereby avoided. The main stem of the posterior branch of each lumbar artery is accompanied by the corresponding and somewhat larger vein (Crock and Yoshizawa, 1977).

In cases where exposure of both sides of the interspace may be required, the detailed clearing process just described is completed on the opposite side. At this stage, it will be noted that there are some silvery *capsular fibres* extending medially on to the yellow *ligamentum flavum* for some distance at its upper margin where it passes beneath the inferior margin of the superior lamina of the interspace (Fig. 3.28). These fibres should be incised at their inferior laminal attachment and then removed with a straight pituitary rongeur from below, the jaws of which should be directed beneath the superior laminal margin, parallel to its anterior surface.

Portions of the inferior surface of the superior lamina at the interspace may need to be excised using an outward-angled rongeur. Some surgeons favour the use of chisels or gouges for this particular manoeuvre. Bone wax may be applied to the cut surface of the cancellous bone to control bleeding (Fig. 3.29).

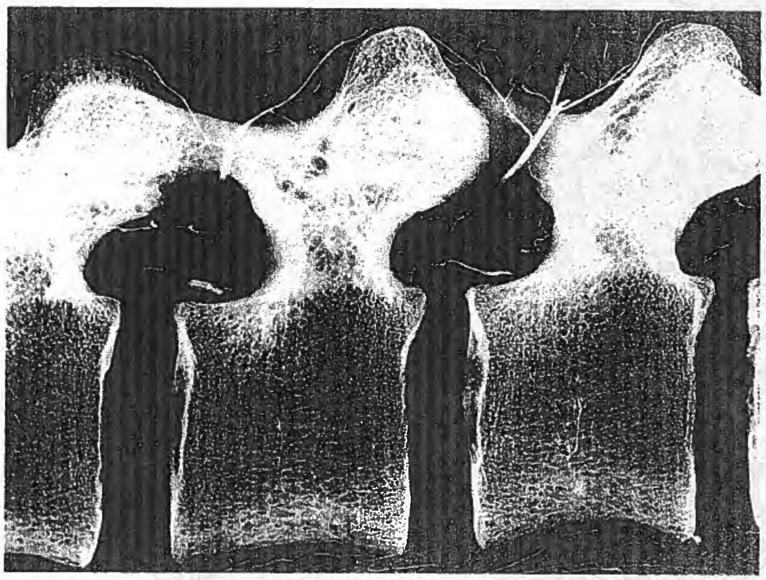

Figure 3.27. A radiograph of a thin sagittal section of the lumbar spine, showing the relations of the posterior branches of two lumbar arteries as they course backwards behind the intervertebral foramina. These arteries are constant lateral relations of the pars interarticularis of each lamina. In the intervertebral foramen shown on the left, the anterior and posterior spinal canal branches of the lumbar artery can be seen, separated by a clear band, this area being occupied by the nerve root at that level. Note also the branches which encircle the facet joint system and supply it. [Reproduced by courtesy of J. B. Lippincott and Company from: Clin. Orthop. Rel. Res., No. 115 (1976)]

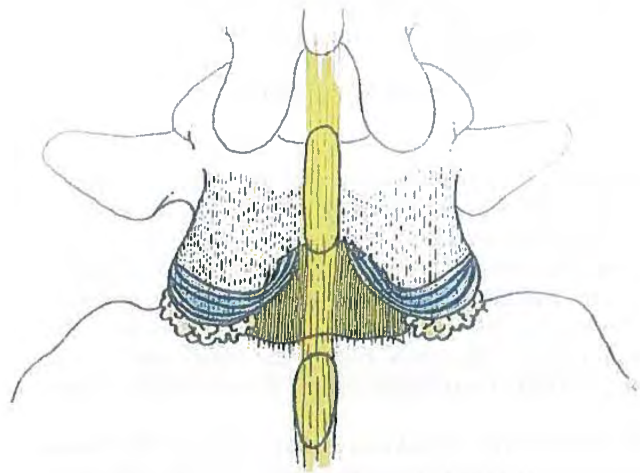

Figure 3.28. A drawing depicting the relations of the ligamentum flavum. The extra-synovial fat pads are shown in exaggerated form. Note the extension of capsular fibres on to the posterior surface of the ligamentum flavum and adjacent inferior laminal margins

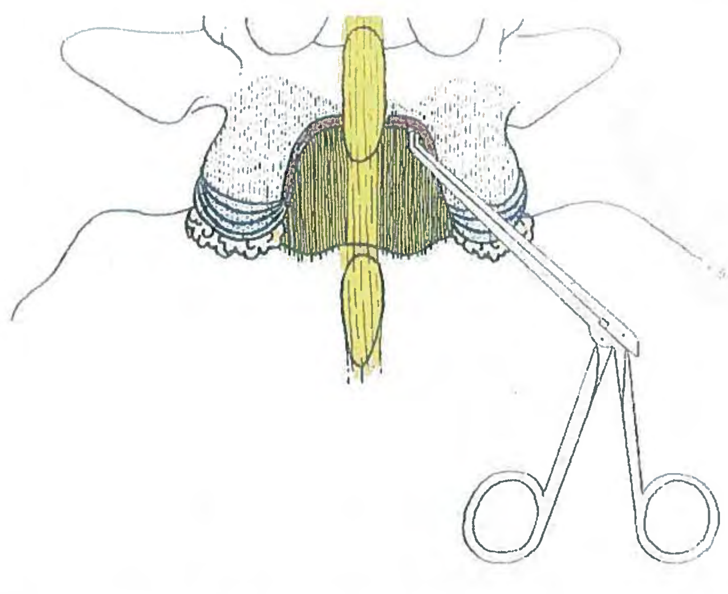

Figure 3.29. A drawing showing the method of removal of portions of the inferior surface of the superior lamina at the interspace, using an outward-angled rongeur. In some cases the interspinous ligament may be removed along with a portion of the inferior surface of the spinous process at the upper level of the interspace

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vii) Opening of Spinal Canal

This can be performed in a number of ways. Two techniques will be described, one using a fine toothed forceps and small scalpel blade such as a number 11 or number 15, the other combining the use of a 45 degree forward-angled curette with a 2 mm cup with the use of a fine toothed forceps and scalpel of appropriate size.

a)

The ligamentum flavum may be incised vertically in the mid line. The cut edge is picked up with a fine toothed forceps and the incision deepened until either epidural fat or the dura itself is exposed. The blunt end of a Watson Cheyne dissector may then be used to widen the opening into the spinal canal. Through the vertical split in the ligamentum flavum thus created a small moistened cotton patty is inserted between it and the epidural fat using the curved end of the dissector. The ligamentum flavum is then cut in a lateral direction, first at the lower edge of the interspace, until a flap is raised and turned out laterally and then along the upper edge of the interspace.

Even at this early stage of opening the spinal canal, the presence of a large prolapse can be suspected if the insertion of the patty or patties is difficult as they are pushed laterally under the ligamentum flavum.

When the ligamentum flavum has been turned laterally as a flap to the level of the apophyseal joint, a fourth incision is then commonly made in it, again in a vertical direction to excise the flap. Some surgeons simply raise a flap of ligamentum flavum and retract it laterally during the procedure allowing it to fall back into place at the end of the operation.

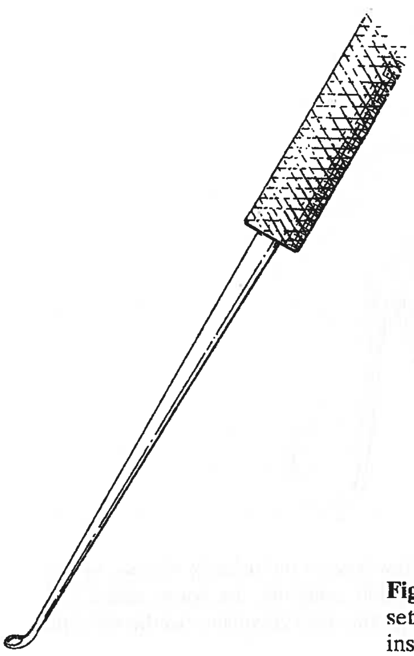

Figure 3.30. A drawing to show the 2 mm cupped curette set at an angle of about 45 degrees to the shaft of the instrument

b)

Using a 45 degree angled curette with a 2mm cup the thin inferior fibres of the ligamentum flavum which overlap the superior margin of the inferior lamina can be scraped off defining the superior margin of this lamina. The angle of the curette is then changed so that the curette is passed into the spinal canal immediately to the anterior surface of the lamina and moved from lateral to medial side until the inferior attachment of the ligamentum flavum lies free. This done, a 45 degree angled rongeur may be inserted allowing removal of a small portion of the upper margin of the inferior lamina (Figs. 3.31, 3.32).

The free edge of the ligamentum flavum can then be grasped with a fine toothed forceps and the blunt end of a Watson Cheyne dissector inserted with a small patty allowing the safe dissection of the ligamentum flavum and its removal either with the use of a fine scalpel or piece-meal with an angled pituitary rongeur, the epidural fat and dura being held out of the way with a patty and sucker. This second method of removal of the ligamentum flavum is particularly applicable in cases of spinal stenosis where gross pathological changes have occurred in the ligamentum flavum,

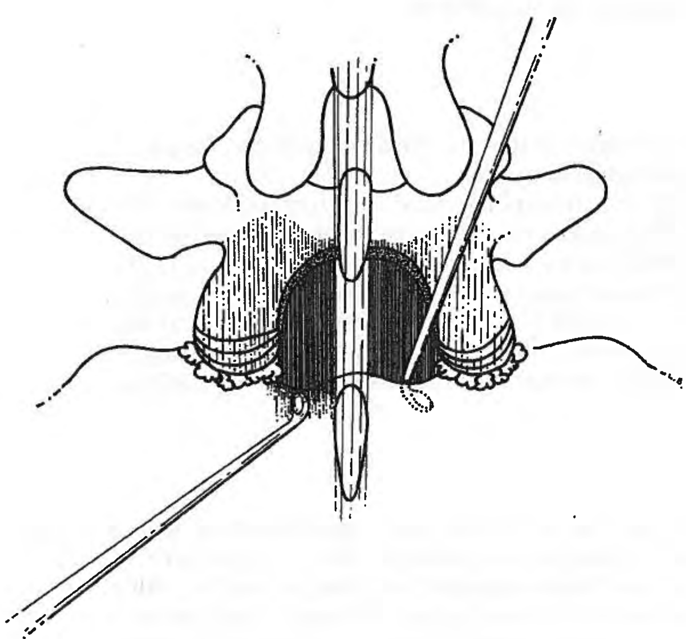

Figure 3.31. A drawing depicting on the left side the method of using the curette to remove the superficial fibres of the ligamentum flavum which pass on to the dorsal surface of S1 lamina just beyond its superior margin. On the right side following removal of these loosened fragments of ligamentum flavum the curette is introduced cautiously beneath the superior margin of the S1 lamina and manipulated from medial to lateral side to free the attachment of the ligamentum flavum from the bone

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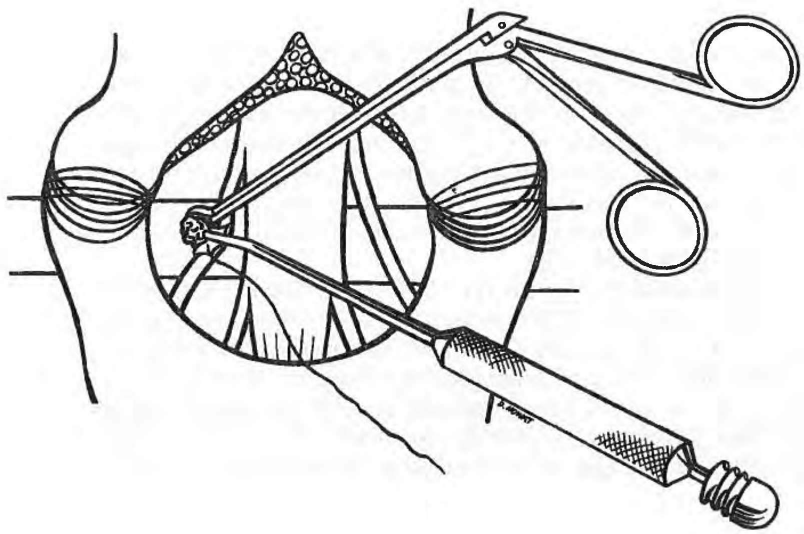

Figure 3.32. A drawing depicting the disposition of the sucker and patty and straight pituitary rongeur at the time of removal of a fragment of prolapsed tissue

rendering it thickened, atrophic or calcified. In such circumstances dural injury is less likely to occur with the use of this technique.

Following this initial opening into the spinal canal, the surgeon must then identify certain landmarks. The Watson-Cheyne probe is invaluable for this purpose. Either the blunt or curved end may be inserted depending on the size of the protrusion at the affected level. If the prolapse is small, then the blunt end may be inserted laterally so that the pedicle on the inferior side of the intervertebral disc space may be palpated. The regional nerve root is then palpated. Moving upwards, the posterior surface of the disc may be felt and the disposition of a prolapse assessed.

viii) Extending Exposure

Wider exposure may be required and this is usually most easily achieved with a 45 degree outward-angled rongeur. Assuming, for example, that it is necessary to remove more of the outer edge of the ligamentum flavum, then the sucker with a moistened patty on its tip may be used to retract the dura and nerve roots towards the mid-line, while the rongeur is inserted beneath the edge of the ligamentum flavum under direct vision. Depending on the size of the prolapse, it may or may not be possible to insert the angled rongeur. If attempts are made to force the foot-plate of the rongeur between the ligamentum flavum and the nerve root which is being pressed backwards by a large disc prolapse, the root may be bruised or crushed. On occasions, even a thin rongeur cannot be inserted. The interspace will then need to be enlarged, either superiorly or inferiorly or in both directions, until sufficient space has been created to allow identification of the nerve root as it traverses the interspace.

With a large sub-rhizal prolapse at the L5/S1 level, for example, it may be necessary to enlarge the interspace by removal of part of the superior border of the lamina of S1, commencing initially in the mid-line and passing laterally, and to perform a decompression of the S1 nerve root canal by removing the medial portion of the S1 facet flush with the inner margin of the S1 pedicle. In the operation of nerve root canal decompression, the apex of the facet also needs to be removed (see p. 35).

ix) Management of Venous Haemorrhage

During the more complicated manoeuvres of this type, haemorrhage from the internal vertebral venous plexus surrounding the nerve root and lateral to it may occur. This haemorrhage is usually not troublesome when the patient is in the prone position. On occasions, however, the internal vertebral venous plexus may be distended and brisk venous haemorrhage may occur following damage to some of the radicular branches of this system of veins. The detailed anatomy of the anterior internal vertebral venous plexus in the lumbar region is described on pp. 19, 20. Venous haemorrhage is always readily controlled with the gentle use of a patty and sucker as illustrated in Fig. 3.32. Occasionally, bleeding from one of the large venous radicles can be troublesome and it may be necessary to identify this using the sucker and a patty. The bleeding points are grasped with the bayonet forceps and coagulated with low-voltage or bipolar coagulating currents.

At other times, bleeding from several points of the plexiform system of veins can be controlled by light packing with a haemostatic substance held in place with a moistened patty.

Bleeding should be minimal, and good exposure of the field obtained before any attempt is made to retract the nerve root for the final exposure of prolapsed disc material.

x) Excision of Disc Tissue

For the sake of clarity and brevity, special points of technique will be described in relation to individual types of disc prolapse.

Small Sub-Rhizal Prolapse

Partial excision of the ligamentum flavum on one side will afford satisfactory access to the canal. Initially, identification of the landmarks of pedicle, disc and affected nerve root is made using the sucker and patty as a medial retractor and the blunt end of the Watson-Cheyne dissector in the lateral part of the canal.

Blunt dissection will separate the epidural fat, and the nerve root can usually be easily retracted medially. The discrete rounded prolapse with intact annular fibres is then outlined and a suitable root retractor inserted. The surgeon may use the sucker with a moist patty on its tip as a retractor laterally in the interspace while the assistant holds the nerve root medially. In a dry field it should then be possible to incise the annular fibres over the prolapse in a cruciate fashion using a No. 11 or 15 blade scalpel. The prolapsed tissue then begins to emerge spontaneously and it may be picked out with a straight pituitary rongeur of appropriate dimension varying from 1 to 4 mm bite.

Only a small volume of disc tissue can be removed in such cases and curettage of the interspace is not recommended.

Large Sub-Rhizal Prolapse

In such cases, adequate exposure on the side of the prolapse is essential. Technical details for the enlargement both superiorly and inferiorly have been outlined above. Identification of the affected root may be a problem, because in such circumstances the root is often flattened and its lateral margin not easily identified, being of the same colour as the disc prolapse beneath it. Use of an operating loop may be helpful, as it is essential under such circumstances to identify the nerve root sleeve at its junction with the dura above or to identify the main stem of the nerve root at the level of the inferior pedicle. By either method, with the use of an appropriate nerve root dissector, the outer edge of the nerve root can be identified and retracted medially. Very fine straight and curved pituitary rongeurs will be required in such a case to *remove the first of the fragments* of prolapsed tissue, possibly through a minute incision in intact annular fibres. Only after the initial removal of fragments with small instruments will it become possible to complete the dissection and retraction of the nerve root medially from the bulk of the prolapse.

As the tension on the nerve root is released, its retraction becomes easier. The opening in the annular fibres may be enlarged under vision and rongeurs of increasing cup size inserted for removal of free disc fragments from the interspace. The sucker with a patty on the end of it may be used as a retractor held by the surgeon in his left hand, while with the rongeur in his right hand, the fragments are lifted out from the interspace (Fig. 3.30). In such cases, quite large amounts of the disc material may be removed, but the risk of penetration of rongeurs deep into the interspace with the possibility of damage to intra-abdominal structures is high (Fig. 3.33 a, b). The use of ring curettes is recommended in such cases for curettage of loose disc fragments and vertebral end-plate material. *When large amounts of disc material have been removed, of the order of several grams of tissue, then it is wise to perform nerve root canal and foraminal decompressions on both sides of the interspace,* completing removal of ligamentum flavum far laterally and of the inner margins of the superior articular facets of the inferior vertebra, to the level of the inner margins of the pedicles. In addition, with angled rongeurs it may be necessary to remove the apices of both the superior facets on the inferior side of the interspace. *Excision of the whole facet joint in the course of this operation must be avoided.*

The Management of Sequestrated Disc Fragments

Free fragments of disc tissue in the spinal canal may pose specific problems at operation. If, for example, free fragments of disc tissue are found at the lumbo-sacral level, yet the posterior annular fibres of the L5/S1 disc space are found to be normal, exploration of the higher interspace is essential. In these circumstances careful palpation of the L5/S1 disc with the blunt end of the Watson Cheyne dissector, beneath the dural sac towards the mid-line, will be necessary before it can be safely assumed that the disc tissue has not prolapsed from that interspace. If, on the other hand, the L4/5 interspace has been exposed and a rather adherent nerve root re-

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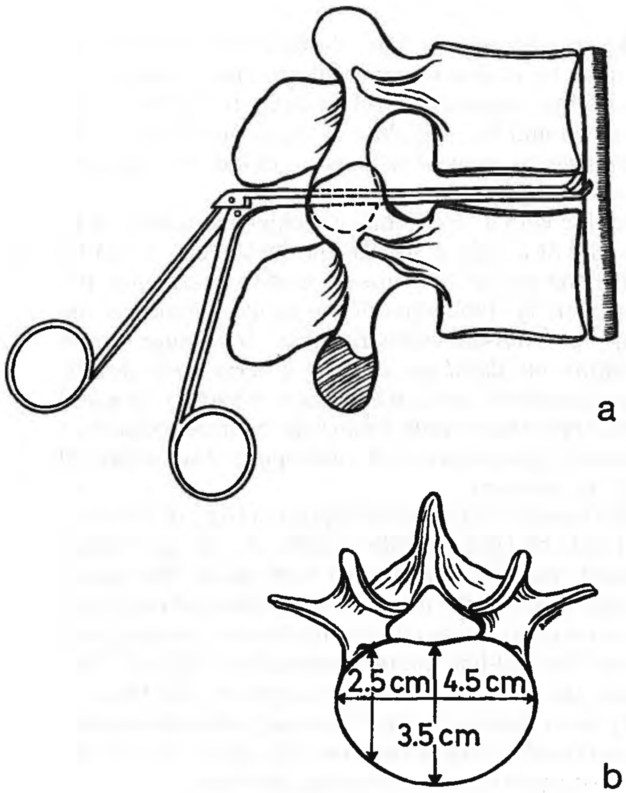

Figures 3.33 a,b. **a** A drawing to highlight the potential danger of penetration of a rongeur through the disc space into the abdominal cavity where great vessels or other intra-abdominal structures may be injured. **b** A drawing to illustrate the dimensions of a lumbar vertebral body in an adult of average size

tracted from the back of the disc to reveal a circumscribed rounded defect in the annulus, then free sequestrated disc material may be found at the lower interspace. Identification of the orientation of sequestrated disc fragments has been greatly aided by MRI with gadolinium enhancement (Figs. 3.7 a, b, 3.8 a, b, 3.9).

Central Disc Prolapse

The presence of a central disc prolapse is usually, though not always, suspected in the early stages of opening of the spinal canal. For example, it may be opened on one side and the nerve root which comes into view cannot be retracted towards the midline, though the disc beneath and lateral to it appears normal. In such a case, digital palpation of the dural sac is essential and will lead the surgeon to establish this diagnosis. Wide exposure is then required even involving excision of the whole of the spinous process and central part of the arch of the lamina on the superior side of the interspace.

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Trans-Dural Approach

Having determined to remove the fragments by a trans-dural approach, then the special instruments listed above must be available, especially the fine sutures and needle holders which will be required to repair the dural opening. In addition long lintine strips with attached threads should be available, as these may need to be placed along each edge of the dural sac to prevent seepage of blood into the sub-arachnoid space after the dura has been opened.

The dura is incised in the mid-line with a No. 15 blade scalpel and a protective probe or a bistoury introduced beneath the dura so that the incision in it can be completed over the desired length. *The use of low vacuum suction is essential,* the sucker tip being guarded by a small patty. Filaments of the cauda equina can be retracted easily to either side using smooth rounded instruments. *At no stage should an unguarded sucker be placed within the dural sac itself as a nerve root may be avulsed up the sucker.* The actual process of removal of disc tissue is usually easy and can be rapidly accomplished by the trans-dural route following separate incision of the dura and the posterior longitudinal ligament over the disc space. *The prolapsed tissue often emerges on one side of this ligament.*

Cerebrospinal fluid is allowed to escape. It should be aspirated from the wound, but at all times the sucker should now be covered with a patty. An inexperienced surgeon or an inexperienced assistant may, from any point onwards in this operation, inflict irreversible damage on filaments of the cauda equina. Remembering that the vessels of the cauda equina are minute, only smooth rounded instruments should be used to retract the filaments from the mid-line laterally on each side (Fig. 3.34).

Bearing these hazards in mind, the actual process of removal of disc tissue is easily and rapidly accomplished by the trans-dural route following separate incision of the dura and the posterior longitudinal ligament over the disc space. *It is likely, however, that the prolapse will have emerged on one side of this ligament.*

Depending on the volume of disc material that can be removed with straight or angled pituitary rongeurs of varying sizes, so the question of curettage of the disc

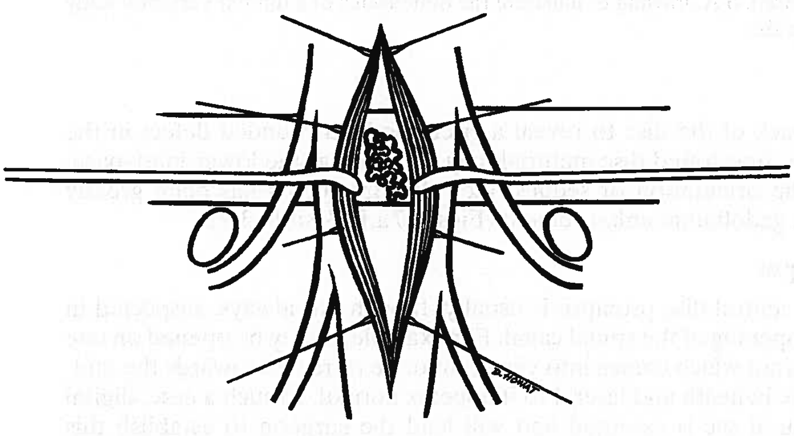

Figure 3.34. A drawing to illustrate exposure of a central disc prolapse trans-durally, filaments of the cauda equina being retracted from the mid-line laterally on each side with smooth rounded instruments

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space may arise. If large quantities of disc material can be removed easily, it is wise to use a ring curette to clear other remnants, recalling once again the risk of instruments penetrating into the abdominal cavity.

Although some authors recommend closure of the anterior layer of the dural sac following this procedure, this is not always necessary. However, careful closure of the posterior layer should be effected using a continuous 6/0 dural stitch. The retaining sutures which were earlier inserted, are used to retract the dura in the final stages of closure and care is taken at all times to avoid transfixion of any of the cauda equina filaments in the closing suture.

In cases of this type, especially when many fragments of intervertebral disc tissue have been removed from the interspace, it is wise to perform bilateral nerve root canal decompression to complete the procedure, to prevent recurrence of sciatica later following reduction in height of the disc space.

xi) Disc Prolapses Associated with Other Special Problems

Spinal Canal Stenosis

This situation should be recognized pre-operatively in most instances, especially if myelography has been performed. The disc prolapses found in these cases are often small. It is essential to perform an adequate spinal or nerve root canal decompression on both sides in such cases.

Nerve Root and Other Anomalies

The recognition of nerve root and vascular anomalies requires excellent technique during the exposure. A lower lumbar nerve root sometimes arises from the dural sac at right angles, passing directly laterally through the intervertebral foramen across the posterior surface of the disc. Mistaken easily for a prolapse at operation, it may be incised, excised or avulsed in error.

Isolated Disc Resorption

Unilateral sciatica in cases of isolated disc resorption is not common (Crock, 1976). The most important part of the surgery for this condition is the nerve root canal decompression and "foraminotomy" which can usually be performed with preservation of the relevant laminal arch. The "disc prolapse" in such instances usually consists of a small fragment of vertebral end-plate cartilage, which may be adherent to the under-surface of the nerve root. Careful dissection is required to remove it, as the root may be flattened in these circumstances.

Spondylolisthesis

Disc prolapse may occur at the level of a spondylolisthesis or above it. Excision of the prolapsed disc fragments is essential, but questions of complete spinal canal and nerve root canal decompression including removal of the loose lamina, together with decisions on the use of spinal fusion techniques then arise.

xii) Upper Lumbar Disc Prolapse

Upper lumbar disc prolapses may occur in the L1/2, L2/3 area in association with the conus medullaris in some cases. Operations in this area carry hazards of spinal cord injury, and retraction of the dural sac must be performed with great care at all times. Similarly, the introduction of large-jawed rongeurs or large ring curettes may be hazardous. Extra-peritoneal approaches to these anterior prolapses can be recommended with confidence.

Microdiscectomy and Percutaneous Lumbar Discectomy

As indicated in the introductory paragraph in this chapter the use of minimal invasive procedures for disc surgery is increasing. Interested readers are referred to "The Principles of Microsurgery for Lumbar Disc Disease", McCulloch J., 1989, and to "Percutaneous Lumbar Discectomy" edited by Mayer M. H. and Broch M., 1989, listed in the bibliography.

xiii) Extra-Foraminal Disc Prolapse

This type of disc prolapse is uncommon, although it can be readily identified with CT scanning, CT discography, or MRI examination of the spine (Fig. 3.10).

The level of disc prolapse should be confirmed with control radiographs in the operating theatre. A short skin incision is made over the middle of the appropriate sacro-spinalis muscle mass. The thoraco-lumbar fascia is then split in the line of the skin incision and the muscle fibres beneath it separated by blunt dissection. Microsurgical type retractors can be inserted to expose the vertically orientated fibres of the intertransverse muscle. The medial border of this muscle is identified between the two transverse processes at their junctions with the pedicles. The fibres are separated from the upper surface of the inferior transverse process and retracted laterally. The nerve root is then seen where it lies outside the intervertebral foramen. An operating microscope is useful in deep dissection of this type, but it is not essential. With careful blunt dissection, the nerve root may be separated from the disc prolapse, which is removed in the usual manner, under vision. The main branches of the lumbar artery and its accompanying veins are intimately related to the lateral aspect of the emerging nerve root. They should be identified carefully with blunt dissection. Haemorrhage from them should not be a problem. However, in this situation diathermy should be used with extreme caution if bleeding becomes troublesome (see Figs. 1.19, 1.20 in Chapter 1).

xiv) Preserving the Bony Canal

In the past it has been common practice to cut a narrow channel in a lamina, between the two ligamenta flava related to it, while seeking an elusive disc prolapse. This interference with the roofing apparatus of the spinal canal is to be avoided, particularly in cases with spinal canal or nerve root canal stenosis, because it may lead to the development of stenosis of the canal following growth of new bone into the area of the laminal defect (see Chapter 9, pp. 302, 307). Exploration of an intervertebral disc space can be accurately and competently performed through a limited inter-laminar exposure, carried out along the lines recommended above. If no lesion is found at one level, due to error, then it is better to look at the next level upwards or downwards from the primary exploration without disturbing the integrity of the lamina. This problem should not arise if investigations of good quality have been obtained before surgery.

xv) Wound Closure

Haemostasis must be obtained before wound closure. Venous bleeding from the spinal canal can always be controlled with small pledgets of gelfoam or equivalent substances applied to the bleeding sites. Bleeding from the cut surfaces of bone is occasionally troublesome. It is readily stopped by applying bone wax to the oozing surfaces. When the self-retaining retractors are removed some bleeding points, arterial, venous or both, may be identified in the paraspinal muscles. These should be coagulated with diathermy.

Undue haste, poor haemorrhage control and careless handling of rongeurs or root retractors may lead to serious dural injuries. Indeed, dural tears may be inflicted even before the ligamentum flavum has been opened if rongeurs "slip" into the spinal canal.

Dural tears are most likely to occur in complicated cases, for example, where there is associated spinal canal stenosis and opening of the canal proves difficult, or again, in the course of separating an adherent root from a disc prolapse. These defects should be identified carefully and repaired with fine sutures. Extensile exposure of the dural sac and nerve roots may be required, involving removal of adjacent spinous processes and excision of the centre of one or more laminae. The partes interarticulares must always be preserved and facet joint capsules left intact.

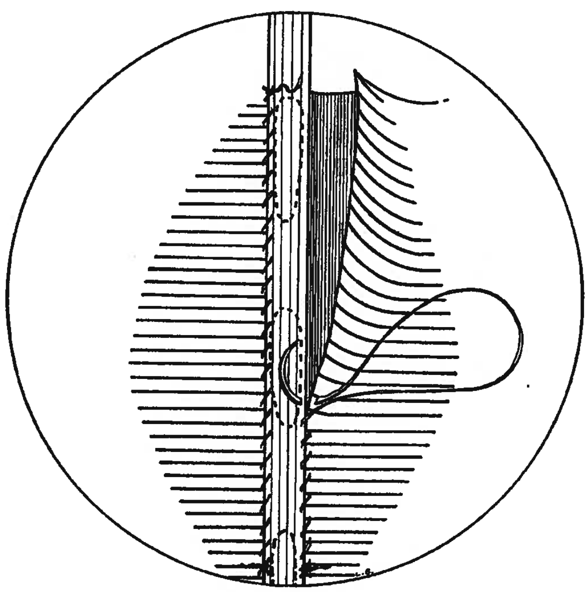

Figure 3.35. A drawing to show the recommended method of re-attachment of the lumbodorsal aponeurosis to the supraspinous ligaments using a continuous fine suture first on one side then on the other

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Deep sutures should not be used to approximate the paraspinal muscles. The lumbo-dorsal aponeuroses should be sutured to the mid-line supra-spinous ligaments as shown in Fig. 3.35. Providing the spinous processes and the integrity of the interspinous ligaments has been preserved, drain tubes are not required.

The skin is best closed with fine absorbable subcuticular sutures such as 3-0 Dexon.

In extremely obese patients with thick layers of subcutaneous fat, the use of multiple sutures in this tissue should be avoided. Rough handling of it with forceps or retractors and the excessive use of diathermy to control bleeding from it will likely result in leakage of liquified fat from the wound post-operatively. Infection of this tissue plane may subsequently become troublesome. These problems can be prevented by closing the wound with a few widely separated tension sutures of heavy grade nylon mounted on long curved needles. A length of plastic or rubber tubing is threaded on to each suture so that the nylon having passed through the skin and full thickness of the fatty layer four centimetres on either side of the wound edge can be tied on one side of the tubing. The skin edges can then be brought together either with a subcuticular suture or with Steristrips[1]. Even with this special care, the dressings may become soaked with oedema fluid for several days after operation. The volume of this fluid leaking from such a wound can be surprisingly large and may raise the fear of a cerebrospinal fluid fistula. The wet dressings should be changed regularly, using aseptic technique, until the wound becomes dry.

[1] 3M Health Care Limited, 3M House, Morley Street, Loughborough, Leicestershire LE11 1EP.

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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. Clinical Features

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 Köhler 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.

Plain X-rays, and C.T. images in axial, coronal and sagittal planes provide excellent outlines of these lesions. MRI is not useful, unless the thoracic cord is compressed.

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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 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 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 had caused troublesome sacral pain for a number of years (Figs. 4.2 a, b).

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	L 3/4
46	M	T 10/11
42	F	T 11/12
46	F	L 3/4
45	F	L 5/S 1
51	F	T 9/10, T 10/11
33	F	T 12/L 1
38	F	L 1/2
57	F	L 4/5, L 5/S 1
47	F	L 1/2
56	M	L 1/2
60	F	T 8/9

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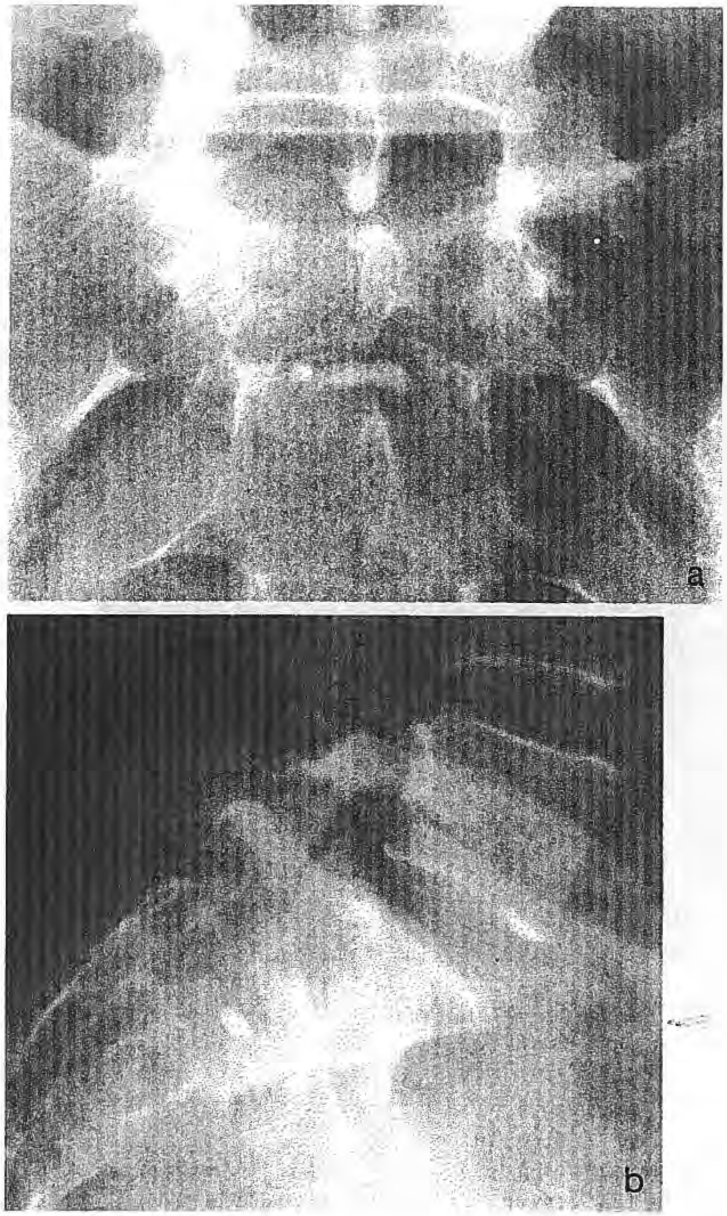
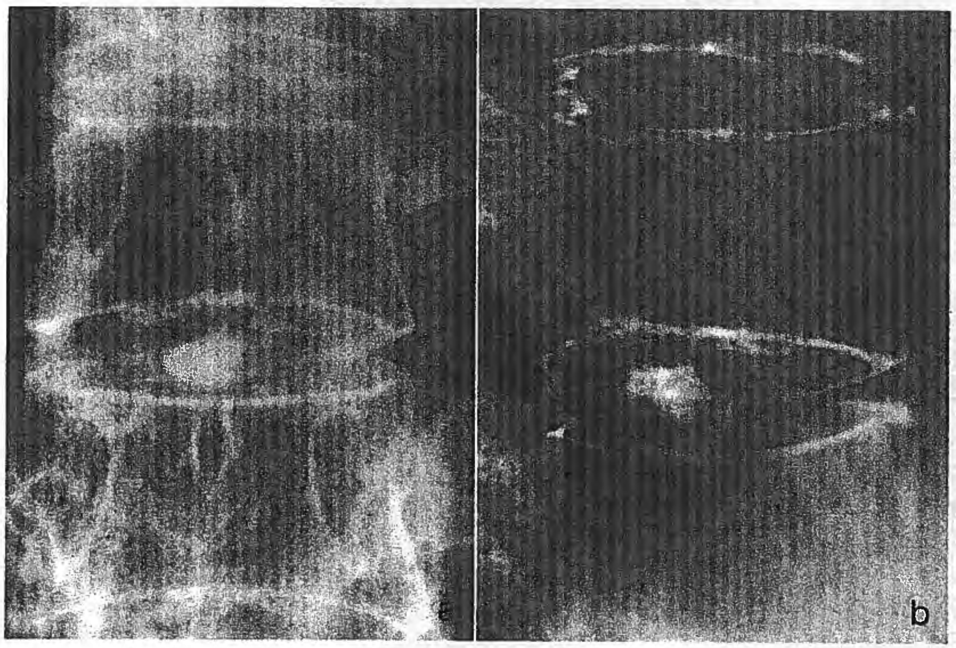


Figures 4.2. Antero-posterior (**a**) and lateral views (**b**) of the sacrum in a female aged 36, showing nucleus pulposus calcification in a rudimentary sacral intervertebral disc

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. 4.3 a, b, 4.4).
2. Widespread calcification of variable density giving the nucleus pulposus a fluffy outline (Figs. 4.5, 4.6).



Figures 4.3 a, 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

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

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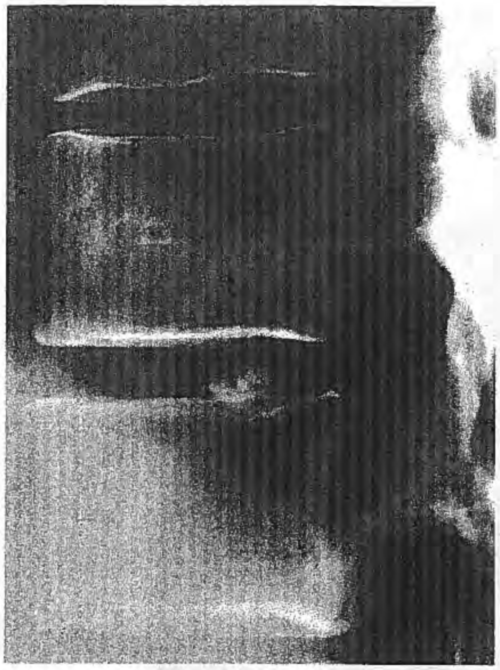
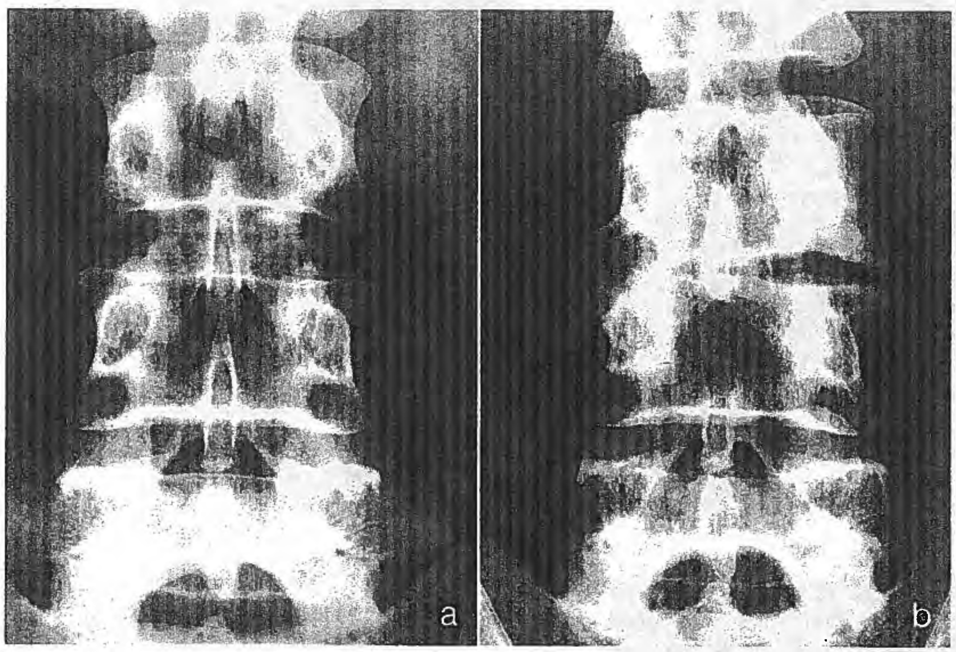


Figure 4.4

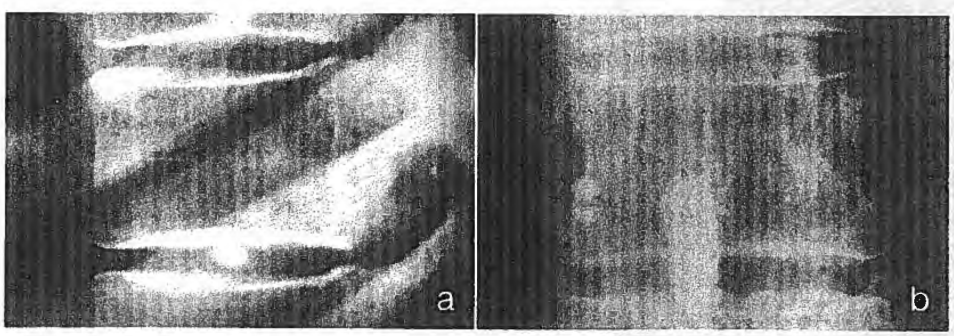
Figure 4.5

Figure 4.6

3. Small discretely outlined zones of calcification lying adjacent to one vertebral end-plate but peripherally located in the nucleus pulposus (Figs. 4.7 a, b).
4. Discrete aggregates of densely calcified material confined to the area of the nucleus pulposus (Figs. 4.8–4.10).



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



Figures 4.8 a, 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 inter-vertebral 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

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Figure 4.9

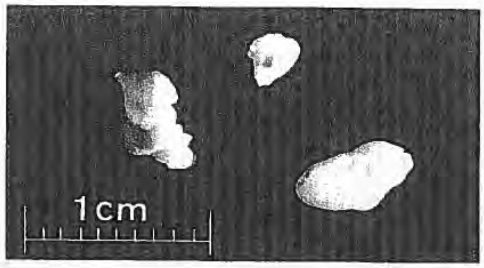

Figure 4.10

Figure 4.9. A lateral radiograph of the thoracic spine showing *type 4* nucleus pulposus calcification at the T 10/11 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

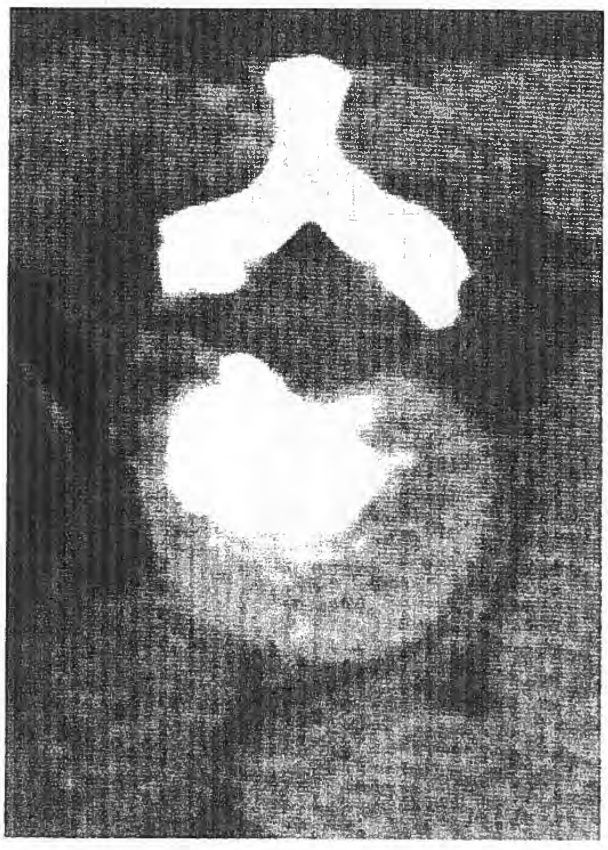

Figure 4.11. A computerised tomograph showing the pattern of calcification of disc tissues at the disc between the vertebrae T 11/12, in a female, aged 49 years. The calcification (type 2) is shown extending postero-laterally into the spinal canal where it is related to the antero-lateral aspect of the spinal cord on the left side

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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	T 8/9	L 1/2	T 8/9
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

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. 4.3, a, b, 4.4. These patients, one female (Figs. 4.3 a, b) and the other male (Fig. 4.4), presented 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.

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. 4.8 a, 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.

Table 4.3. Patterns of nucleus pulposus calcification

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

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.

In the past five years I have treated a further four women with lesions in the thoracic spine, only two of whom required operations, while the one male, with a lesion at T 12/L1 intervertebral disc, responded to conservative care.

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 recognised: congenital, isthmic, degenerative, traumatic, and pathological. The academic aspects of this subject will not be dealt with in depth in this chapter. 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.

Frederickson and colleagues (1984 and 1990) have published important observations on the natural history of spondylolysis and spondylolisthesis. They suggest that a child with spondylolysis or spondylolisthesis can be permitted to enjoy a normal childhood and adolescence without restriction of activities and without fear of progressive listhesis or disabling pain. Slipping may increase up to the age of 16 but does so rarely. Development of the pars interarticularis defect, with or without spondylolisthesis, does not cause pain in most patients. Knowledge of these important observations is therefore extremely important in advising patients who present with these conditions causing symptoms. The majority of them are likely to respond to conservative treatment.

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

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 male. In the extreme example of vertebral body slip, described as spondyloptosis, the pelvic outlet may become obstructed during labour, rendering Caesarean section essential (Fig. 5.2).

In practice, no single operation will necessarily produce a cure in symptomatic patients with spondylolisthesis. Hence it is necessary to make a careful analysis of each case, attempting to introduce some rationale to the planning of surgical treatment (Figs. 5.3 a–c).

In assessing individual patients with a view to selecting a particular type of operation, 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 of 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.

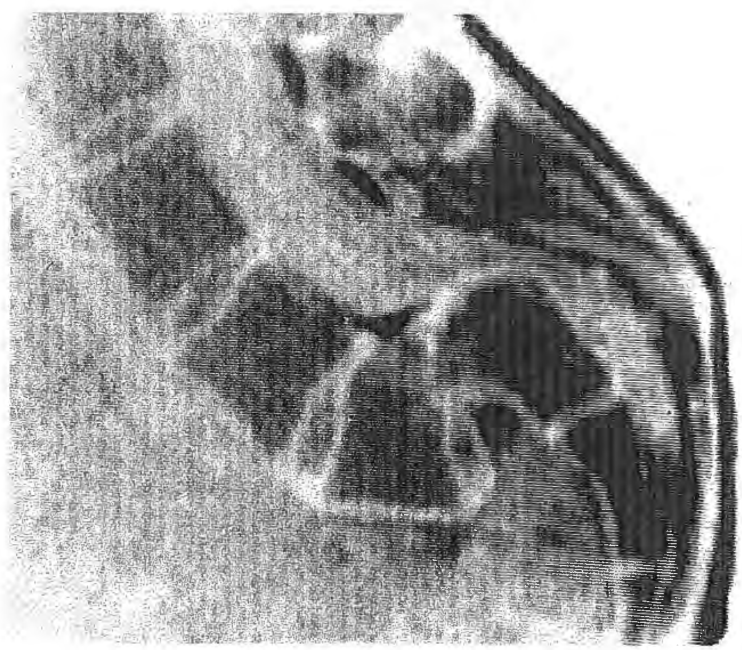
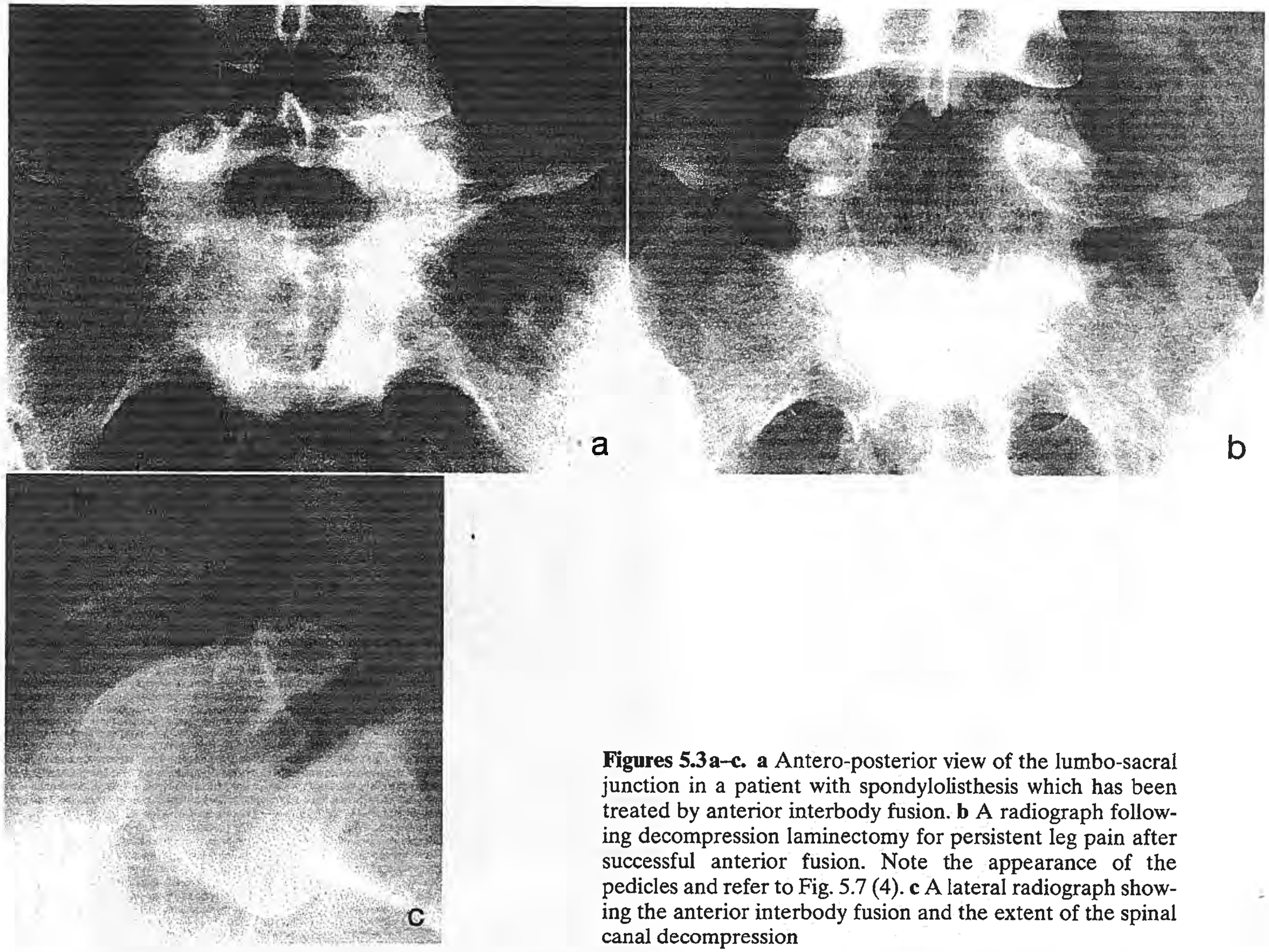


Figure 5.2. A mid-sagittal MR image showing the spondyloptosis at L5/S1 in a 16 year old girl whose photographs appear in Figures 5.13 and 5.16



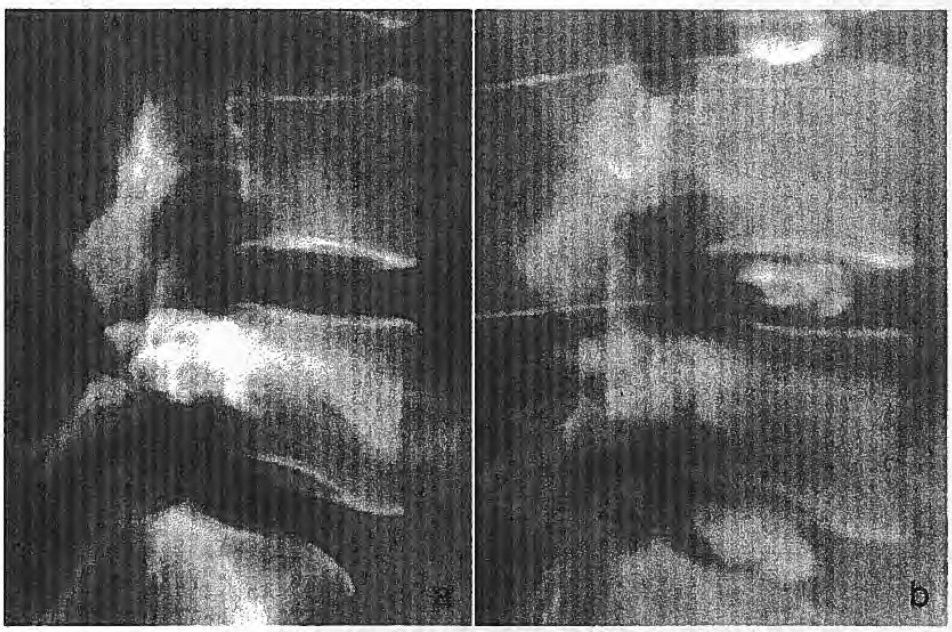
Figures 5.3a–c. **a** Antero-posterior view of the lumbo-sacral junction in a patient with spondylolisthesis which has been treated by anterior interbody fusion. **b** A radiograph following decompression laminectomy for persistent leg pain after successful anterior fusion. Note the appearance of the pedicles and refer to Fig. 5.7 (4). **c** A lateral radiograph showing the anterior interbody fusion and the extent of the 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 the 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 interarticularis 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. 5.4a,b). Before any surgical treatment is considered, infiltration of the pseudarthroses under bi-planar X-ray control, with the installation of local anaesthetic and hydrocortisone should be considered. Many patients become asymptomatic following this simple measure.



Figures 5.4a,b. 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

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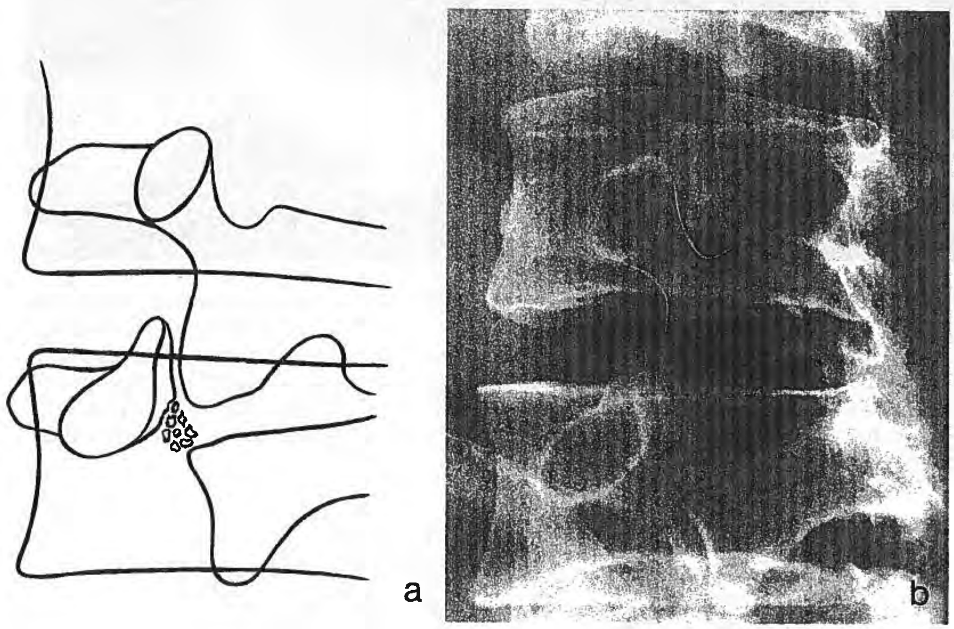
In the usual case with bilateral laminal defects, the spinous process, lamina and inferior articular processes remain as a single unit which is loose in the vertebral column. When the spinous process is grasped with an instrument during operation, this whole unit can be moved freely. It has been described 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 where they continue to compress the emerging nerve roots. 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. 5.5–7).



Figures 5.5a,b. **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

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Figures 5.7. **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

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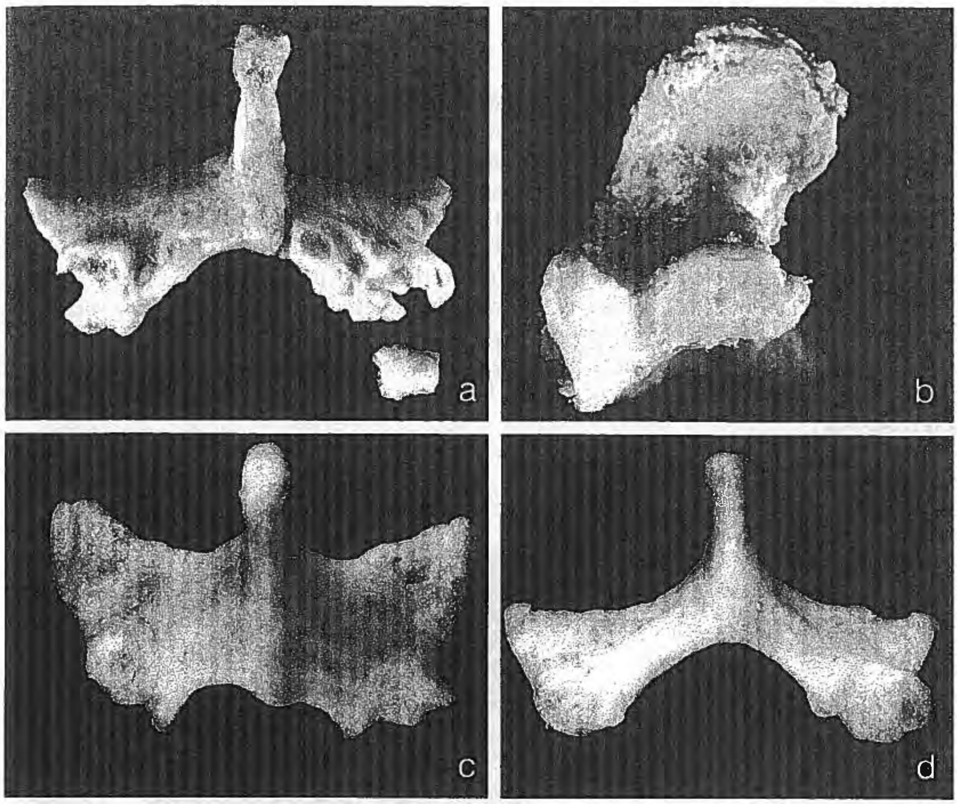
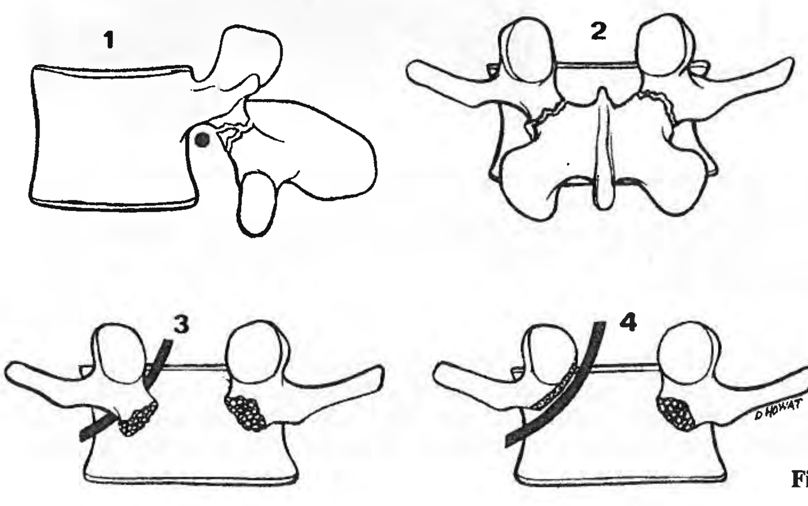


Figures 5.6 a–d. Photographs of loose laminae ("rattlers") removed at operations from patients with spondylolytic spondylolisthesis. The specimens have been photographed from above except **b**, which is a lateral photograph. In **a**, note the complex nature of the pseudarthroses with the loose body 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 asymmetrical nature of the pseudarthroses on either side of the lamina



Figures 5.7. 1–4

ii) State of the Disc Adjacent to Slip

The second parameter to be considered concerns the state of discs adjacent to the vertebral slip, both above and below it. MRI alone usually suffices to provide this information (Fig. 5.8). Where this technology is not available, discography may be an essential special investigation when 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. 5.9a,b). In other circumstances, the presence of disruptive disc lesions demonstrated by discography above the level of the spondylolisthesis may help in planning the extent of the spinal fusion procedure (Figs. 5.10a,b). Finally, in assessing the state of the discs in cases of spondylolisthesis, where unilateral sciatica is a problem and MRI is not available, lumbar radiculography may be used to exclude the diagnosis of disc prolapse, either at the level of the vertebral slip or at some adjacent disc space.

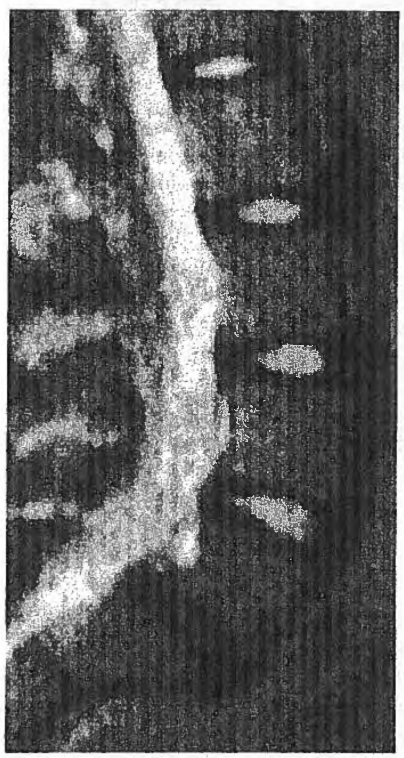
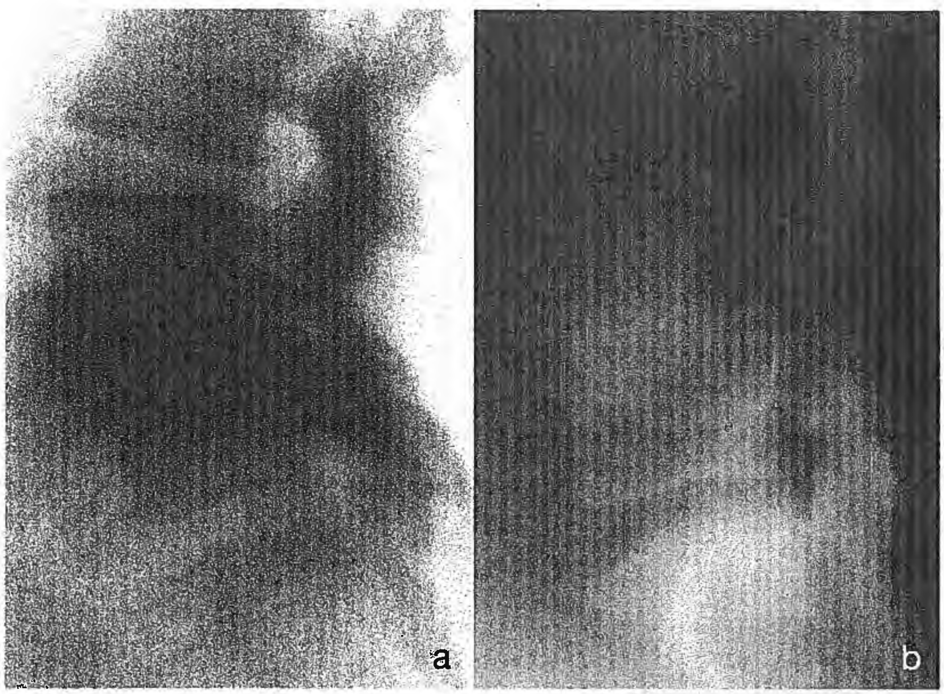


Figure 5.8. The mid-sagittal T2 weighted sequence MRI from a 20 year old female with Grade 1 spondylolisthesis at L5/S1



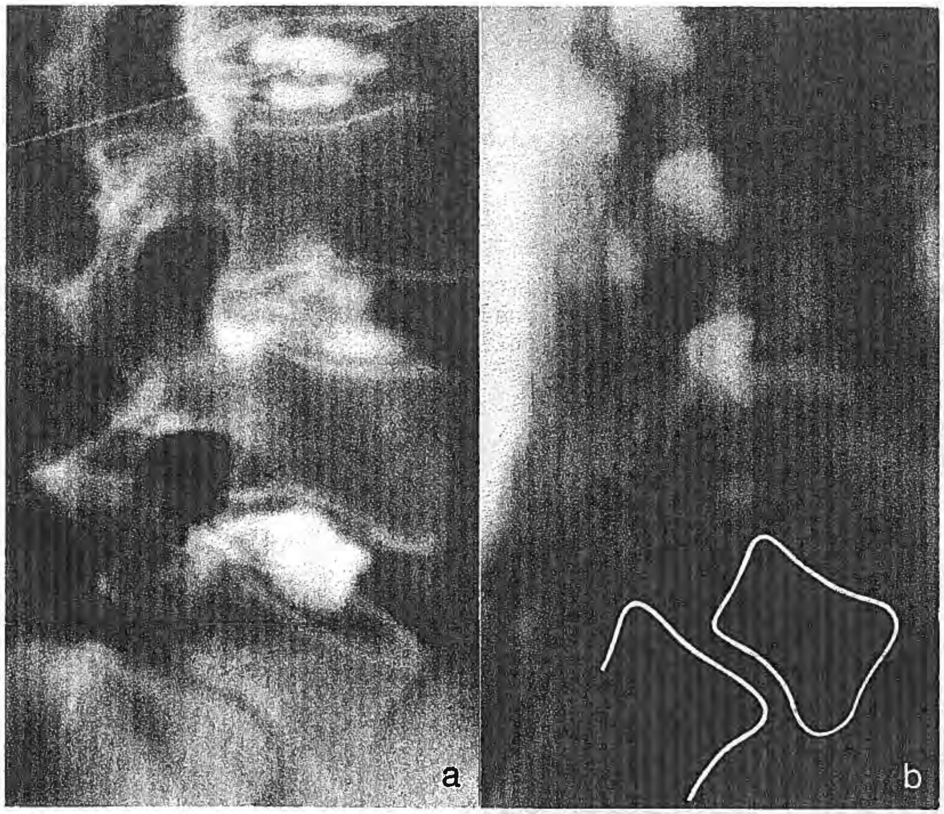
Figures 5.9a,b. **a** A lateral radiograph of the lumbar spine in a 45 year old man showing Grade 2 spondylolisthesis at L4/5. **b** Interbody grafts have been inserted transversely. The tomogram shows the appearance one year after operation

iii) Shape of the 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, myelography may be necessary if the symptoms include referred leg pain (Figs. 5.11a,b). In such cases, associated spinal canal stenosis may be found. CT or MRI examinations if available may render myelography unnecessary. In the presence of spinal stenosis in these cases it is probably safer to perform spinal fusion concomitantly with decompression of the spinal canal.

iv) Degree of the 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, in association with progressive narrowing of the related intervertebral disc (Figs. 5.12a,b). In the presence of Grade I or Grade II 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 histories of venous thrombosis. For cases with higher grades of slip, in which spinal fusion is being considered, standard methods of posterior fusion or intertransverse alar fusion may be consid-

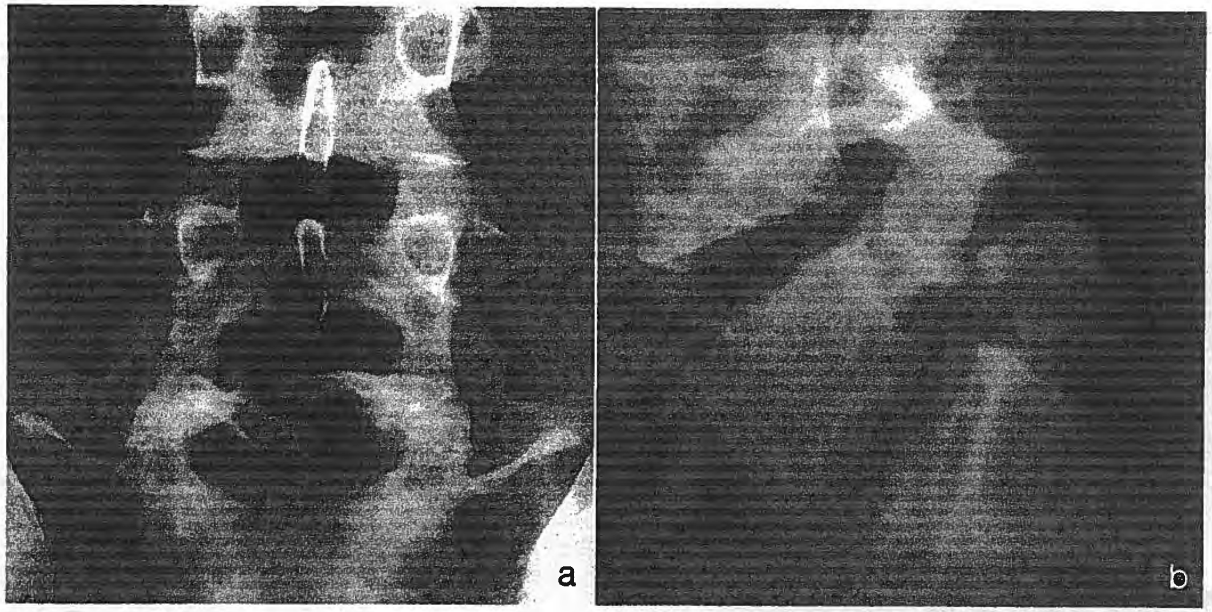


Figures 5.10a,b. a A lateral radiograph of the lumbar spine of a man aged 45, showing Grade 2 spondylolisthesis at L5/S1, with discograms at L2/3, L3/4 and L4/5. Post-traumatic disc disruptions are shown at each level, causing severe back pain. The patient had fallen from a height of 25 feet (8 metres). **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. 5.10 a

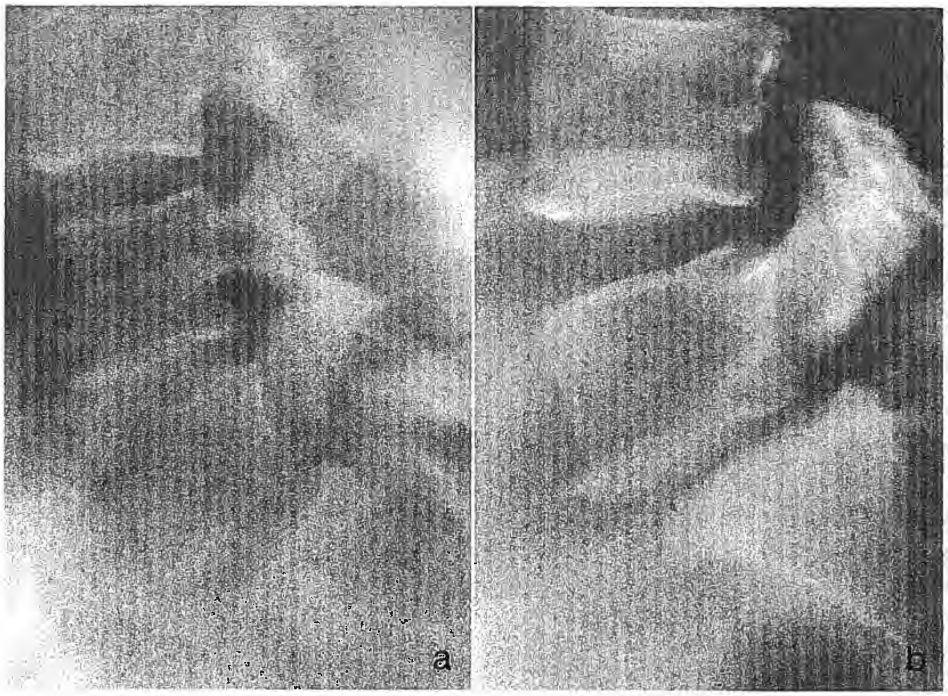
ered. Freebody (1971) has described a method for anterior lumbar interbody fusion applicable even in advanced grades of spondylolisthesis. This method calls for special training and even then its success rests on the surgeon having above average skill. In extreme cases the upper vertebral body may slip and roll off the lower vertebral end-plate, the condition being described as spondyloptosis.

Spondyloptosis is rare so that even experienced spinal surgeons may have dealt with only a few cases. Patients may present in early adolescence with grotesque deformity (Fig. 5.13). Following a period of bed rest muscle spasm often subsides and the scoliotic element of the deformity will decrease.

Wiltse (1990) has published a long term review of more than thirty cases treated satisfactorily by in-situ intertransverse alar fusion. In some of these patients neurological deficits resolved without spinal canal decompression and excellent ranges of spinal motion were regained after fusion.



Figures 5.11 a, b. **a** Antero-posterior and **b** 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



Figures 5.12 a, 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

Interest in the surgical treatment of high grade vertebral slipping has increased since pedicle screw fixation devices have become widely available in the past five years.

Attempts have been made to reduce the deformities of slip and roll by manipulation or traction prior to anterior interbody fusion with internal fixation.

Olerud (1988) has developed versatile instruments based on pedicle screws which may be inserted percutaneously, with which over a period of weeks the deformities can be reduced before spinal fusion is performed.

Treatment involving reduction and spinal fusion with internal fixation is always difficult and carries high risks of neurological damage, graft failure and recurrence of deformity (Figs. 5.14 a–c). Roy Camille *et al.* (1991).

In the presence of gross deformity such as that illustrated in Fig. 5.13, plain radiographs can be difficult to interpret whilst MRI provides excellent detail (Fig. 5.2). The pedicles of L 5 in this girl's spine were atrophic and unsuitable for placing pedicle screws percutaneously. The patient was placed prone on a Wilson frame with her legs resting on a canvas sling attached to a lifting device to allow hyperextension of the pelvis as an aid to reduction following spinal canal decompression.

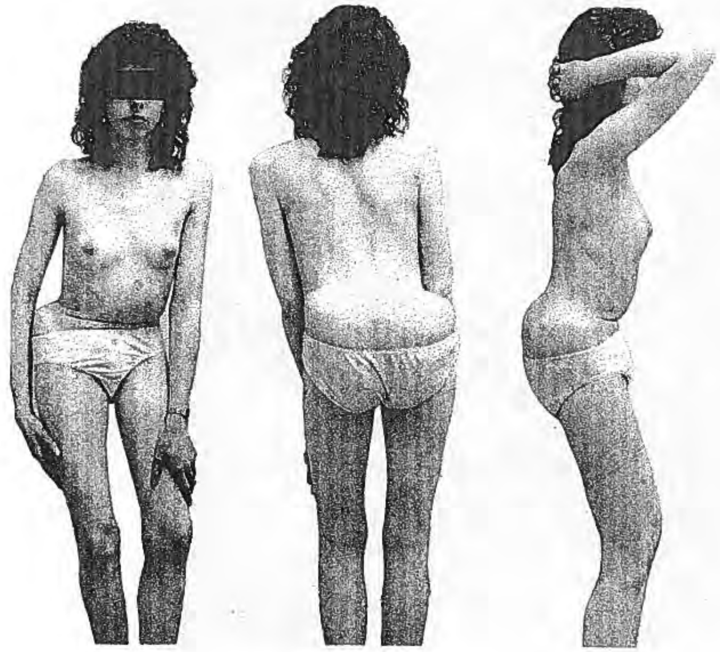


Figure 5.13. Pre-operative photographs of a 16 year old girl presenting with severe spinal deformity of acute onset associated with spondyloptosis of L5 on S1

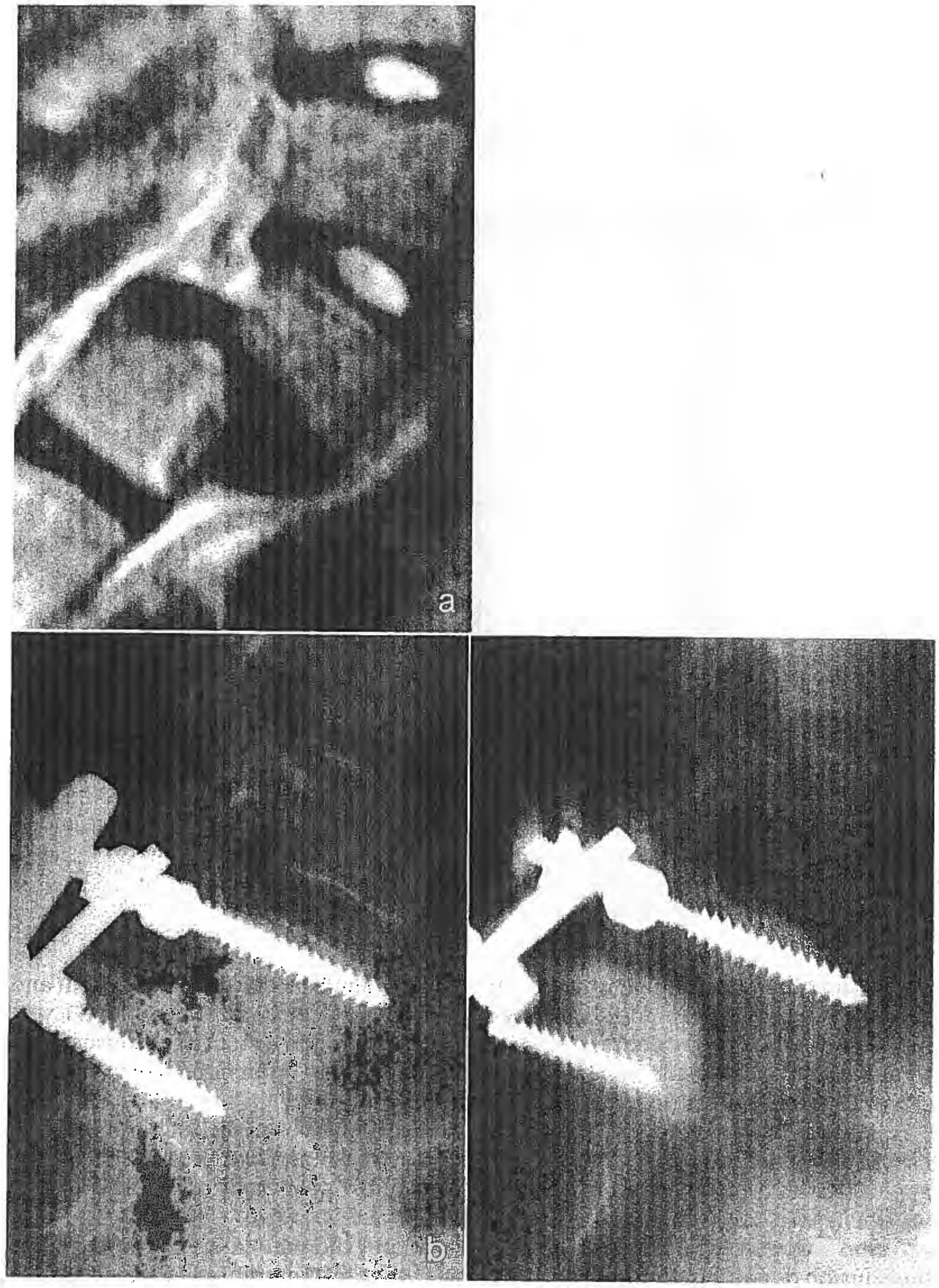
The fifth lumbar lamina was removed in toto. The S1 nerve roots were thin and tightly stretched over the posterior border of the superior end-plate of the S1 vertebral body. The intervertebral disc was excised in part and a stout probe inserted in to the disc space as the legs were elevated thus aiding in reduction of the vertebral slip of L5 on S1.

The pedicles of L5 were then carefully identified and pedicle screws inserted into both L5 and S1. Satisfactory reduction of the deformity was then fixed with the application of the pedicle screw fixation device illustrated in Fig. 5.15. The wound was then closed and the patient returned to the ward.

She was nursed, log-rolling, for one week and then an anterior lumbar interbody fusion operation performed using autogenous grafts cut from the left iliac crest. Difficulties should be anticipated at each stage of these operations because of regional anatomical distortions. Even exposure of the anterior surface of the lumbosacral disc following the first stage reduction proved difficult in this case.

Following the second stage operation the patient was fitted with a half spica.

The end result in this case was excellent with interbody fusion and pedicle screw fixation involving L5/S1 alone, without supplementary intertransverse alar fusion (Fig. 5.16).



Figures 5.14 a–c. **a** A mid-sagittal MR image showing spondyloptosis in an 11 year old girl at the L5/S1 level with normal discs above at L3/4 and L4/5. **b** A post-operative lateral view of the lower lumbar spine showing reduction of the spondyloptosis, fixation with Steffee pedicle screws and plates and an anterior interbody graft in situ. **c** A lateral radiogram two months after operation showing failure of the sacral pedicle screws with recurrence of the deformity. The device was removed and the deformity accepted. Fusion eventually occurred with slight further loss of position

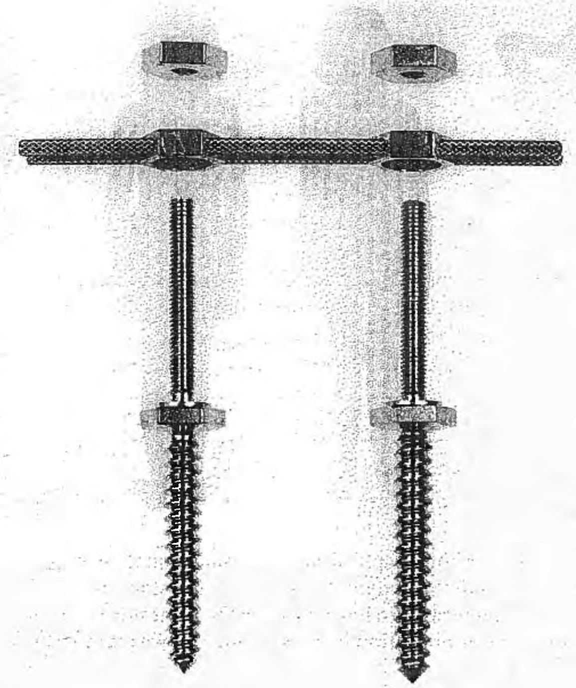


Figure 5.15. Photograph of the Crock Pericic pedicle screw fixation system which was used successfully in the treatment of the patient whose photographs appear in Figs. 5.13, 16. This spinal fixation system is manufactured by the Yufu Itonaga Co., Ltd., No. 31-20, 2-chome, Yushima Bunkyo-ku, Tokyo 113, Japan

In summary spondyloptosis can be treated successfully by in-situ intertransverse alar fusion. Its treatment by reduction and spinal fusion is far more complex, more time consuming and potentially more hazardous to the patient although the end result in successfully treated cases is clearly optimal.

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 the vertebral slip. Bilateral intertransverse alar fusion is usually effective.

The choice of treatment in patients with symptomatic degenerative spondylolisthesis follows the same general lines outlined above. Conservative spinal canal decompression with bilateral foraminotomies and nerve root canal decompression, preserving the midline structures and re-attaching the lumbo-dorsal fascia to the supraspinous and interspinous ligaments at the end of the procedure, gives good results in many cases. This type of spinal canal decompression may be combined with intertransverse fusion. Some surgeons favour reduction of these deformities with pedicle screws and either posterior interbody fusion or intertransverse fusion. In older patients with marked osteoporosis the simpler surgical procedures outlined above are often safer for the patient and provide satisfactory relief of symptoms.

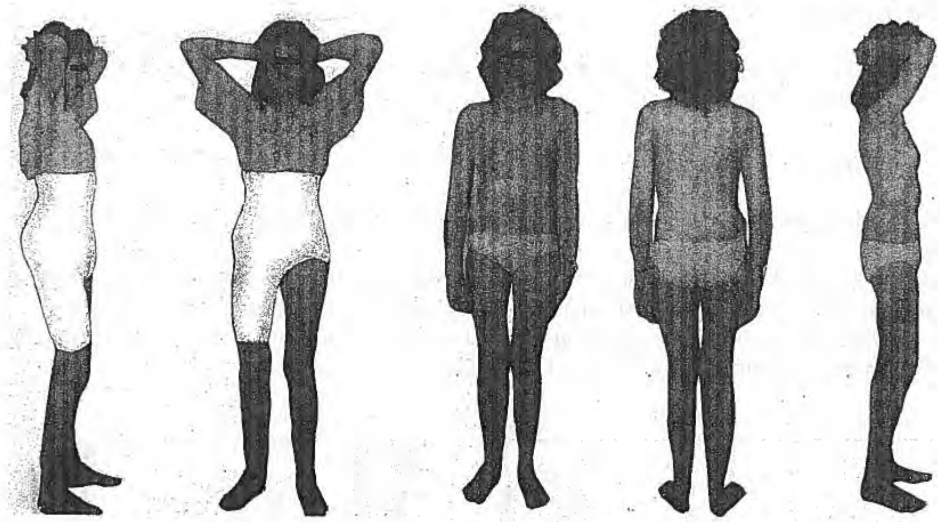


Figure 5.16. On the left post-operative photographs following spinal canal decompression and pedicle screw fixation with reduction of the spondyloptosis and second stage anterior interbody fusion between L5 and S1. The patient is wearing a half spica. On the right side of the photograph her appearance is shown six months after operation by which time she was symptom-free. (See Fig. 5.2)

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 blood transfusion facilities must be available. The patient's spinal X-rays and MRI must be displayed in the operating room.

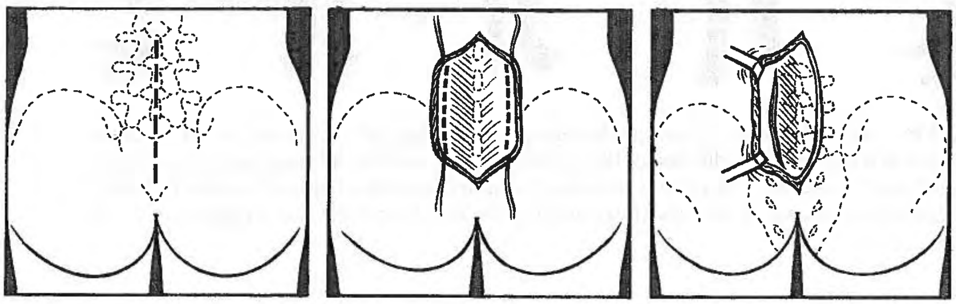
c) Positioning

Patients should be placed prone on a suitable frame to avoid compression of the abdominal cavity (see pp. 122–124).

d) Incisions

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

In adults, a midline skin incision is made and the skin flaps can be retracted to either side to allow parallel vertical incisions to be made in the lumbo-dorsal fascia for the paraspinal sacrospinalis splitting approach to the transverse processes and alar of the sacrum advocated by Wiltse (1978) (Figs. 5.17 a–c).



a b c

Figures 5.17 a–c. Drawings to illustrate the mid-line skin incision and the laterally placed incisions in the lumbo-dorsal fascia for the paraspinal sacrospinalis 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. 127–133. 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 may be 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. 5.18).

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

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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, from the outer aspects of the pedicles of L5 and cephalad from the outer aspects of the superior facets of L5, and then from the posterior surfaces of the transverse processes of L5.

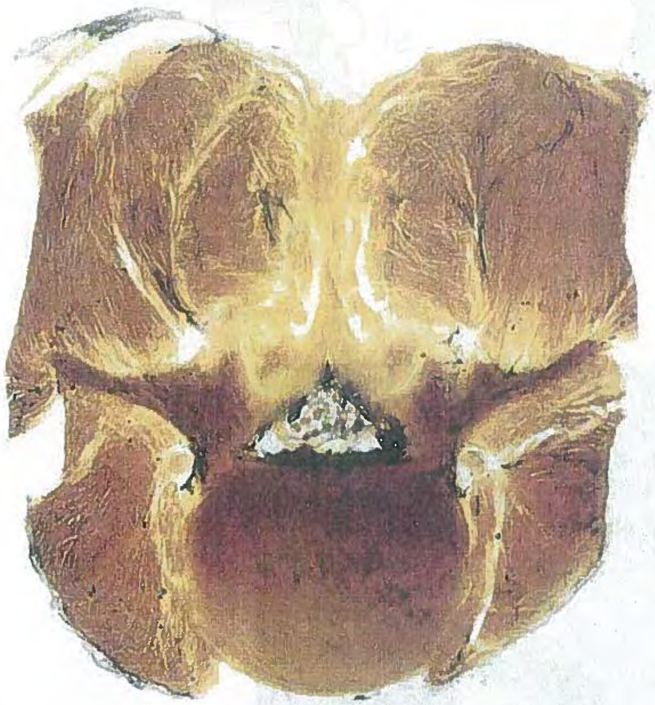

Figure 5.18. A photograph of a transverse section of a mid-lumbar vertebra, with the paraspinal muscles intact. The specimen has been cleared by the Spalteholz technique. Note the arrangements of the paraspinal muscles posteriorly, with a plane of cleavage clearly visible between the muscle bundles related 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

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Figures 5.19a–c. **a** A drawing of the lower lumbar spine seen from behind to show the inter-transverse 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 inter-transverse grafts in relation to the spine as a whole (see arrows)

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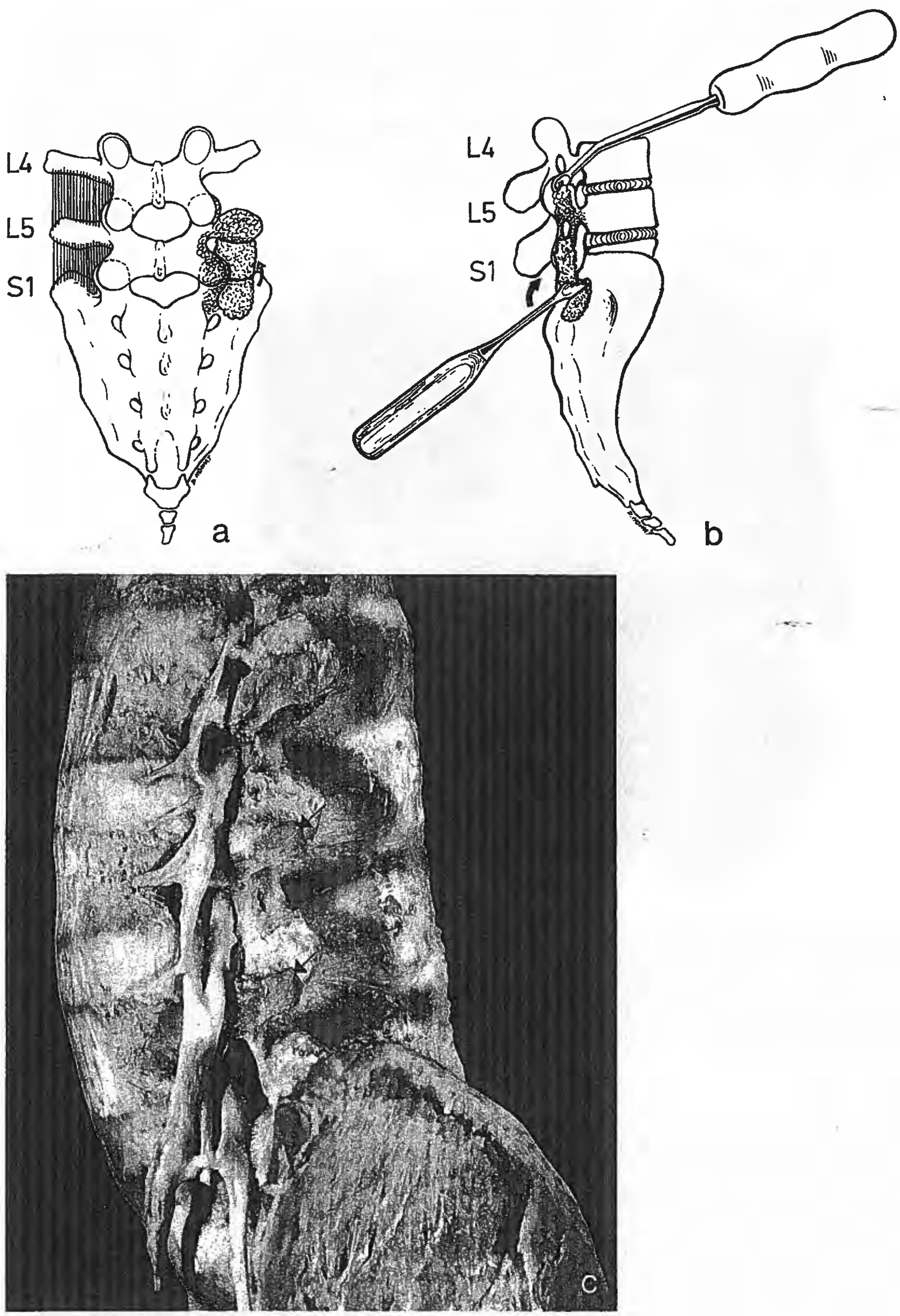

Figures 5.19 a–c

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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. 5.19 a–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 lumbodorsal fascia and the iliac crest on onc sidc.

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 and other strips should be placed accurately along the length of the spine extending upwards to the upper edges of the decorticated transverse processes. Cortico-cancellous strips, with the cortical surfaces directed outwards to lie facing the paraspinal muscles, should be packed in carefully. If chips of graft are pushed in roughly beneath the paraspinal muscles at the upper extremity of the fusion mass, they may come to lie above the decorticated transverse processes to which they were supposed to relate. The subsequent growth of "unwanted graft" is likely to occur, thereby setting the scene for late complications.

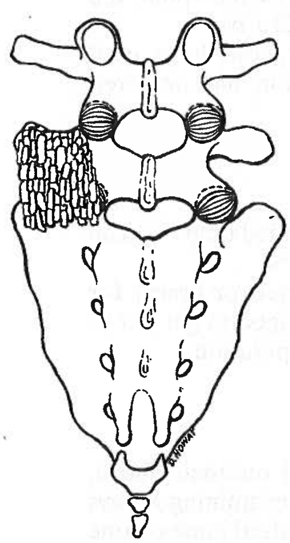

Figure 5.20. A drawing depicting the inter-transverse-alar graft mass on the left side

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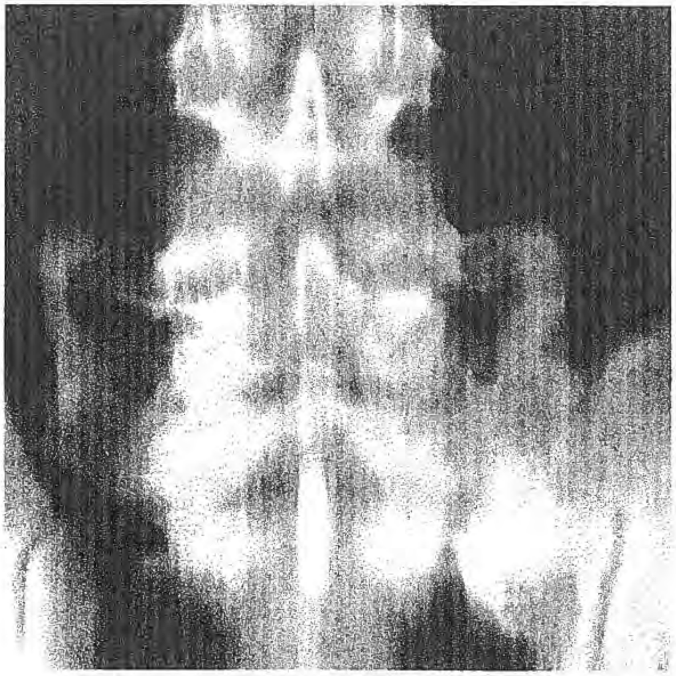

Figure 5.21. An antero-posterior tomogram showing satisfactory inter-transverse grafts at L4/5 in a patient with sacralization of the last lumbar vertebra (Mr. Chris Haw's case). Note the accurate termination of grafts at the L4 transverse processes

After placing the graft chips with equal care on both sides of the spine, the wounds should be closed with suction drainage (Figs. 5.20, 5.21, 5.23 a, b).

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. 5.22).

h) Post-Operative Care

Retention of urine is common. It should be managed as recommended on p. 94. The routine use of catheters is best avoided especially in female patients.

Following multi-level spinal fusions, the use of surgical corsets or braces for 2–3 months after operation 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

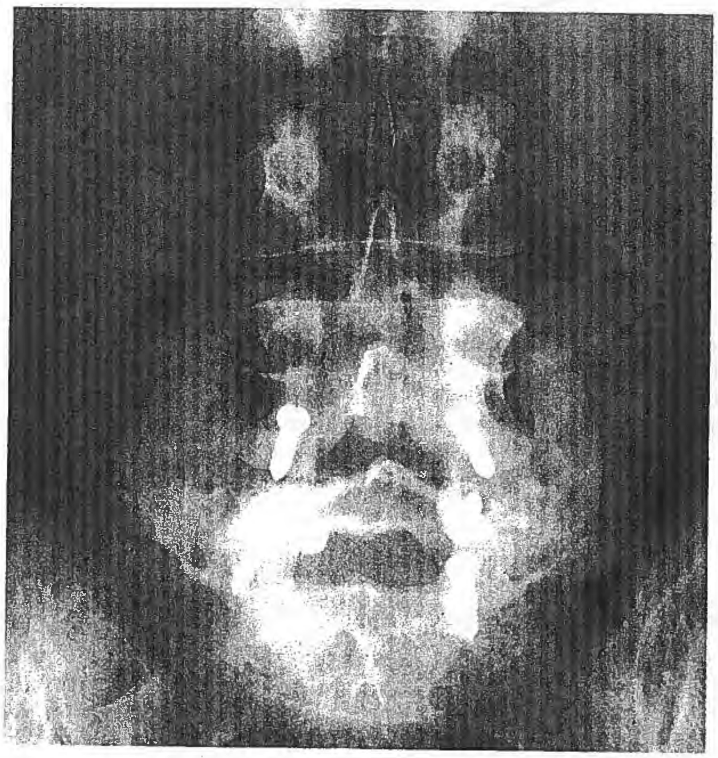

Figure 5.22. An antero-posterior radiograph of the lower lumbar spine showing a multi-level inter-transverse-alar fusion with supplementary screw fixation of the facets in the fused area (Mr. John Cloke's case)

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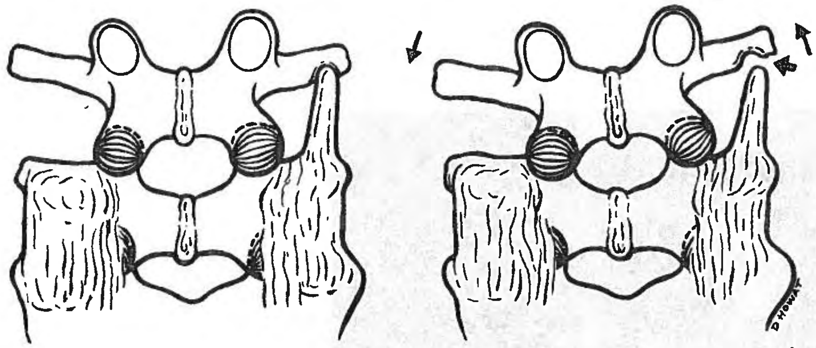


Figures 5.23 a, b. a A drawing showing inter-transverse-alar grafts with an "unwanted segment" of graft extending up on the right side producing a pseudarthrosis between the tip of the grafted bone and the transverse process above, **b** visible when the patient flexes to the opposite side. This is a cause of local chronic back pain easily relieved by excision of the "unwanted segment" of graft

or other side of the spine. Conversely, in other cases, grafted bone may hypertrophy and extend upwards in the spine 2 or 3 vertebral levels higher than planned. Segments of this "unwanted graft" may impinge on adjacent mobile posterior elements of the spine causing recurring problems such as back pain, muscle spasms and chronic spinal deformity (Figs. 5.23 a, b).

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

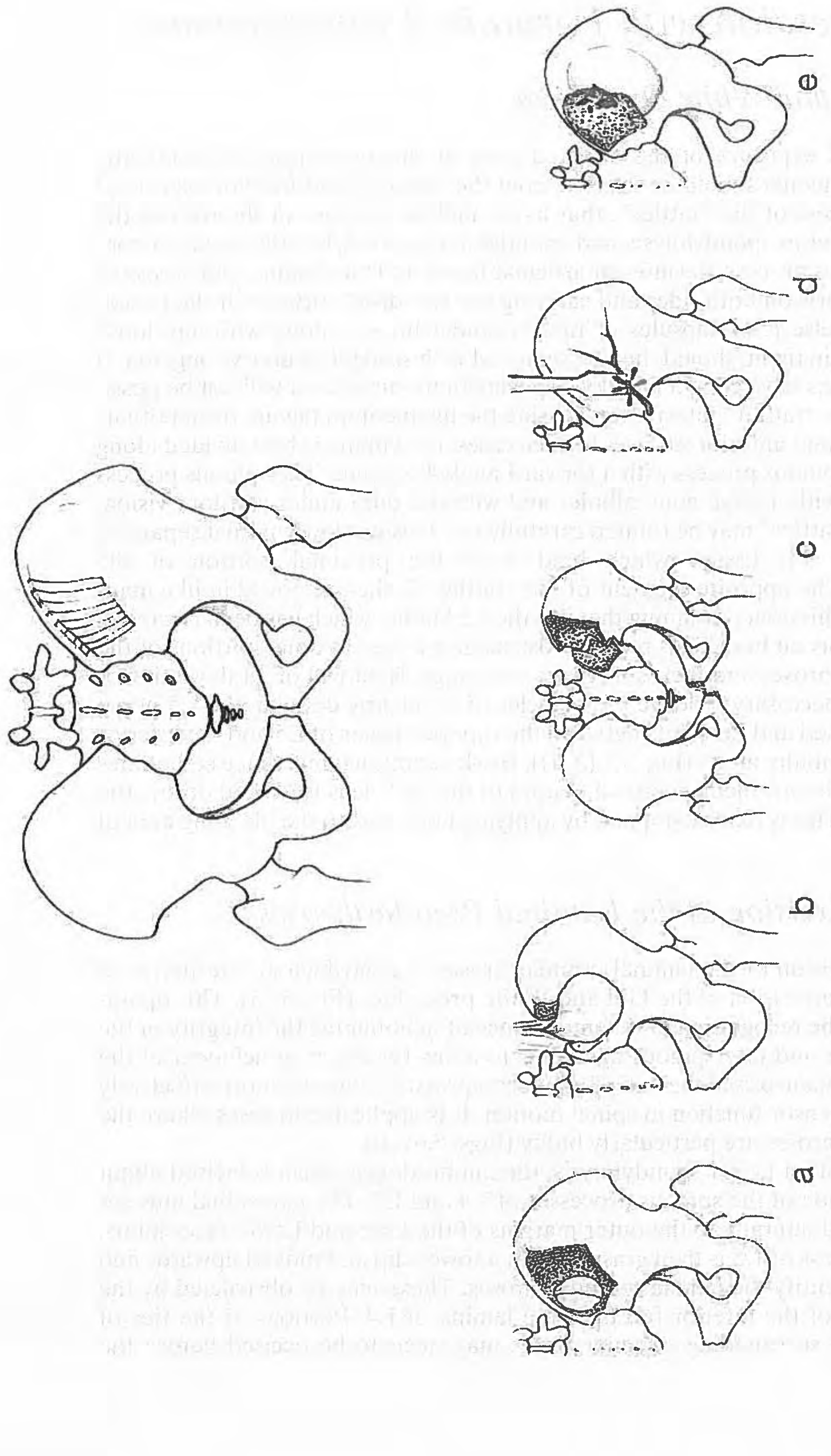
j) Infections

See pp. 286, 310, 314.

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. 5.24 a–e).



Figures 5.24a–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** Cross local sepsis

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

a) The Gill and White Operation

After the initial exposure of the affected area of the spine (pp. 127–133), 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 pseudarthroses. 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 (Fig. 5.6 a). 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 (Fig. 5.7 (3, 4)). Brisk venous haemorrhage sometimes occurs when the infero-medial cortical margin of the pedicle is breached during the decompression. This is readily stopped by applying bone wax to the bleeding area of the pedicle.

b) Simple Excision of the Laminal Pseudarthroses

Conservative excision of the laminal pseudarthroses is a satisfactory alternative to the radical decompression of the Gill and White procedure (Fig. 5.25). This operation is based on the recognition of the importance of maintaining the integrity of the spinous processes and interspinous ligaments to allow for the re-attachment of the lumbo-dorsal aponeurosis at the end of the decompression, thereby more effectively preserving its extensor function in spinal motion. It is applicable in cases where the laminal pseudarthroses are particularly bulky (Figs. 5.6 a, b).

In the case of an L5/S1 spondylolysis, the lumbo-dorsal fascia is incised about 5 mm on either side of the spinous processes of L4 and L5. The paraspinal muscles are then retracted laterally to the outer margins of the L4/5 and L5/S1 facet joints. The spinous process of L5 is then grasped with a towel clip and moved upwards and downwards to identify the laminal pseudarthroses. These may be obstructed by the inferior margins of the inferior facets of the lamina of L4. Portions of the tips of these facets with surrounding capsular fibres may need to be excised before the

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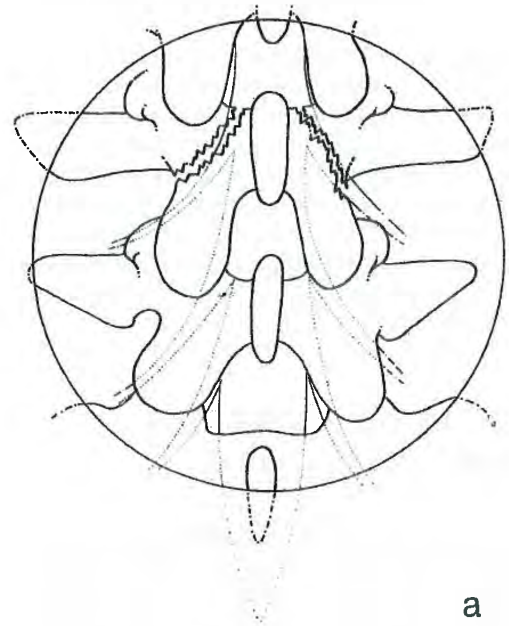

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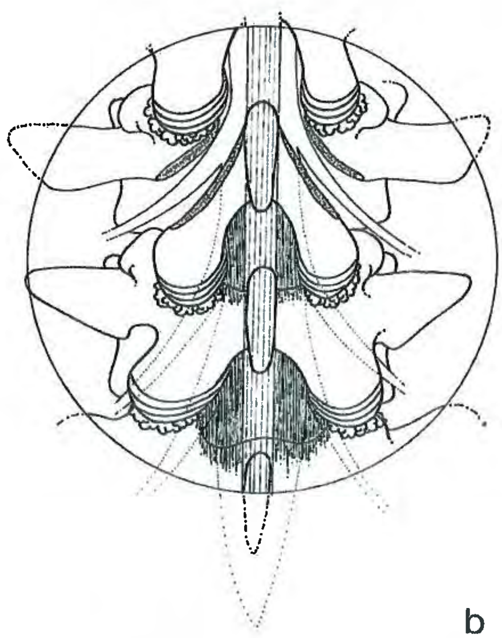

b

Figures 5.25. **a** A drawing showing bilateral spondylolytic defects in the lamina of L4 vertebra. **b** A drawing to show the appearances following excision of the pseudarthroses in a case of L4 spondylolysis. The "rattler" remains in situ with its ligamentum flavum undisturbed at L4/5. The interspinous ligaments are intact. The lumbo-dorsal aponeurosis is then re-attached to both sides of these ligaments at the end of the operation

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"false joints" in the L5 lamina can be identified. The ligamentum flavum between L4 and L5 laminae should be excised, allowing access to the pseudarthroses which should be removed with the use of appropriate instruments so that no damage is inflicted on the underlying nerve roots or the dural sac. Venous haemorrhage occurring from tributaries of the internal vertebral venous plexus surrounding the nerve roots should be controlled only with gelfoam or equivalent haemostatic agents, while pedicle vein bleeding will require the application of bone wax. Having completed the decompressions of the intervertebral foramina, the lumbo-dorsal fascia should be reattached on each side of the supraspinous and interspinous ligaments. Drainage of the wound is not required (Figs. 5.25 a, b).

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

While the Gill and White procedure 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 pseudoarthroses, with internal fixation using screws, has been recommended by Buck (1979). Scott (1987) has described an alternative method of grafting and fixation with tension band wires passed around the transverse processes.

6

The Surgical Management of Spinal Canal Stenosis

6.1. Introduction

With the phenomenal growth of interest in spinal disorders that has occurred in the past ten years, the various syndromes that arise in spinal stenosis are now more widely recognised. Although the range of conditions that may mimic it is broad, the differential diagnosis in the lumbar region has been largely centred around the distinctions between aortic vascular disorders and spinal stenosis. Peripherally for example, bilateral hip disease may give rise to symptoms similar to those of cauda equina claudication, while, centrally, cerebral atrophy may be attributed as the cause of unsteadiness of gait, with weakness sufficiently severe to cause the patient affected merely with lumbar canal stenosis to fall to the ground while walking.

Cervical canal stenosis is discussed in Chapter 7.

Because of its rarity in the thoracic spine, this condition as a cause of unsteadiness of gait is frequently overlooked or, if it is recognised, there is usually a prolonged delay between the time of the patient first presenting for advice and the time of establishment of the diagnosis.

Understanding of the mechanisms of the neurological symptoms and signs which arise in cases of spinal stenosis at any level is still incomplete. There has tended to be a preoccupation with the importance of vertebral canal dimensions. While these are important, particularly in the cervical and thoracic regions of the spine, it seems likely that vascular obstruction in the intervertebral foramina in the lumbar region, affecting predominantly the tributaries of the internal vertebral venous plexus, is primarily responsible for many of the symptoms in patients with lumbar canal stenosis. Professor Ooi has pioneered the use of myeloscopy and has persisted with its investigation for 20 years. He and his colleagues have been able to produce incontrovertible evidence supporting the theory that retrograde venous distension of radicular veins occurs in patients with cauda equina claudication. Swedish investigators have been able to demonstrate experimentally that persistent chronic venous obstruction of the cauda equina may lead eventually to the develop-

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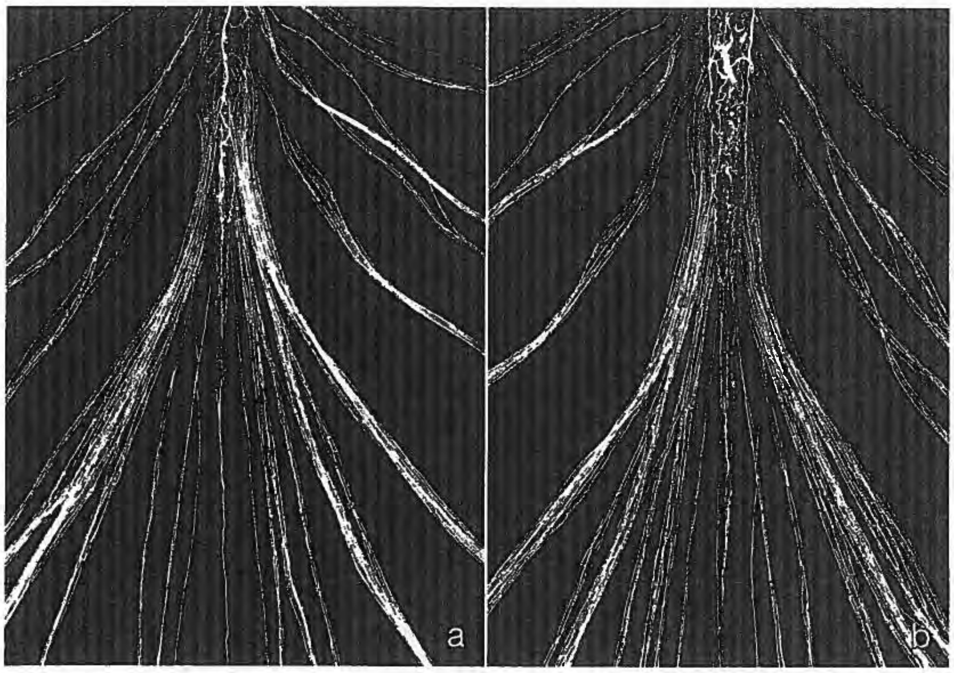
ment of arachnoiditis of the cauda equina, Olmarker (1990). Patients who develop this problem usually have paralytic manifestations, becoming excessively weak if not paraparetic after walking. Quite clearly in some cases, there are mixed contributions from both arterial and venous obstructions in the cauda equina.

Relevant aspects of the anatomy of the arterial and venous circulation of the cauda equina are shown in the accompanying illustrations (Figs. 6.1–3).

The arteries of the cauda equina arise from branches of the lumbar arteries just outside the foramina. Each nerve root carries an anterior and posterior radicular artery which runs uninterrupted from its origin to the major channels respectively on



Figures 6.1a,b. **a** A photograph of the anterior surface of the conus medullaris and cauda equina from a male aged 41 years, enlarged approximately one and a half times. In this specimen, the filaments of the cauda equina have been widely separated. *Their distal ends have been sectioned at the levels of their individual intervertebral foramina.* The arteries of the cauda equina and conus medullaris are clearly shown. Note the continuity of the vessels along the lengths of the filaments of the cauda equina, with the arteries on the surface of the spinal cord. Even at this magnification, the complexity of the arteries of the cauda equina can be appreciated. Note the numerous anastomoses, through ultra fine branches, between arteries coursing along adjacent nerve filaments. **b** A photograph of the dorsal aspect of the same specimen. The postero-lateral longitudinal arterial trunks, which in this specimen are rather fine, are clearly seen forming a loop distally at the tip of the conus, where they anastomose with the anterior median longitudinal arterial trunk of the spinal cord. The continuity of vessels extending along the course of the cauda equina to the arteries on the conus medullaris is shown. There is no suggestion of an area of hypo-vascularity in the region of the middle third of the cauda equina as previously described by Parke *et al.* (1981)

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Figure 6.2 a
(Legend see p. 190)

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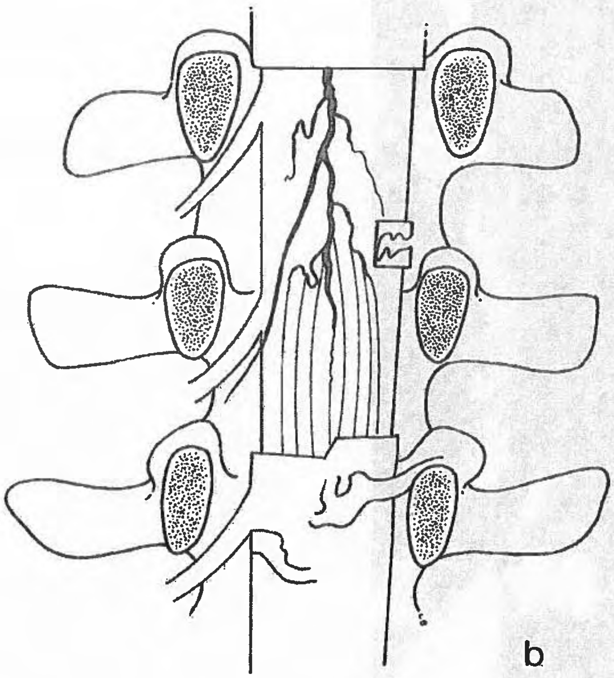

b Figure 6.2 b

Figures 6.2 a, b. **a** A photograph of the posterior surface of the conus medullaris and lower part of the thoracic spinal cord from a male aged 65 years. The specimen is viewed from behind. The laminae of T12/L1 and L2 have been removed. The pedicles of those vertebrae are seen on the left hand side. The dural sac is intact in the region of L2. Radicles of the *posterior internal vertebral venous* plexus (filled with white barium sulphate suspension) lie on its surface. They are in continuity with the anterior internal vertebral venous plexus on both sides. Above that level the dura, arachnoid membrane and pia mater have been removed. Note that the *anterior internal vertebral venous plexus* is completely filled with barium sulphate suspension. By contrast, the veins on the dorsal aspect of the conus are filled only with blood. On the left side of the specimen, a large dorsal radicular vein (dorsal vena radiculo-medullaris magna) is seen coursing downwards from the conus medullaris inside the dural sac. At the level of the pedicle of L1 vertebra two flecks of barium sulphate suspension lie within the clotted blood in this vein which tapers to a point as it emerges from the dura to join radicles of the anterior internal vertebral venous plexus in the epidural space. **b** A drawing to orientate the reader showing the conus medullaris and upper part of the cauda equina viewed from behind lying in the spinal canal from which the laminae of T12, L1 and L2 have been removed through their pedicles. The dural sac has been removed in part to show the veins on the surface of the conus medullaris and the course of the radicular vein on the left hand side extending from the surface of the spinal cord to penetrate the dural sac and join the anterior internal vertebral venous plexus

(Fig. 6.2 a see p. 189)

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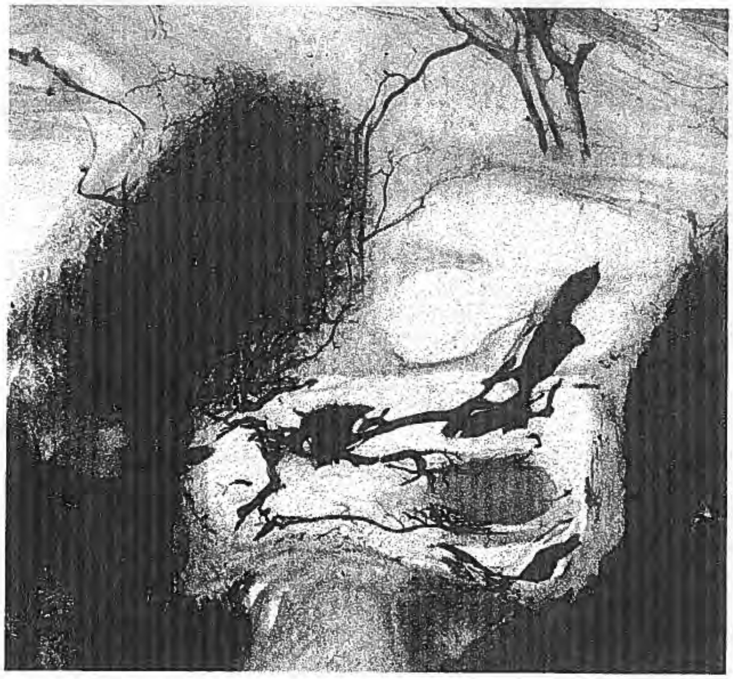
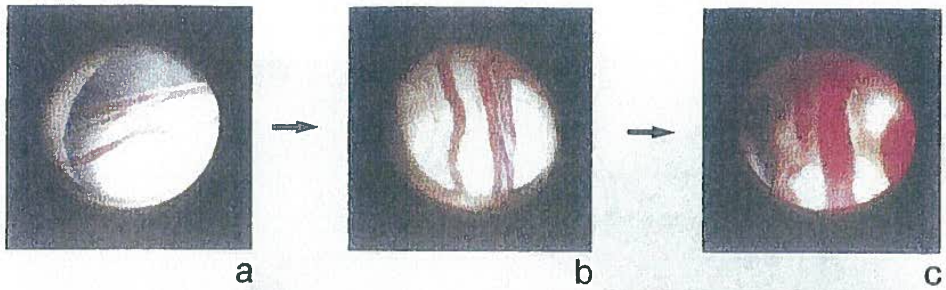


Figure 6.3. A photograph of a specimen from a male aged 68 years, cut in the sagittal plane through a lumbar intervertebral foramen. Details of the venous drainage of nerve roots in the foramen and their relationship to the anterior and posterior radicles of the internal vertebral venous plexus are shown. Note also the important relationship between veins in the pedicle and radicles of the internal vertebral venous plexus in the intervertebral foramen. [Reproduced with permission from "The Conus Medullaris and Cauda Equina in Man. An atlas of the arteries and veins", Crock *et al.*, Wien–New York: Springer, 1986]

the anterior and posterior surfaces of the spinal cord. There is no area of so-called hypo-vascularity in the cauda equina.

The venous drainage of the cauda equina rootlets is centrifugal, terminating after penetrating the dural sac in the region of the individual nerve root sleeves in the internal vertebral venous plexus. A valve-like mechanism between the intra-dural and extra-dural venous systems exists so that venous obstruction in the nerve root canals or intervertebral foramina will inevitably lead to engorgement of the intra-dural veins and nerve root oedema. The engorgement of these vessels has been beautifully demonstrated by Professor Ooi and co-workers (Figs. 6.4 a–c).

In the cervical and thoracic regions of the spine many of the pathological processes which lead to canal stenoses in these areas are related to the anterior surface of the spinal cord particularly in the mid-line. Compression of the arterial supply of the cord is probably the most important cause of the symptoms of myelopathy.



Figures 6.4a–c. a Myeloscopic findings in a 48 year old man with multi-level lumbar canal stenosis during bed rest. **b** While standing. **c** While walking. Note the dilatation of the veins on the cauda equina. [Reproduced by kind permission of Professor Ooi and the editor of SPINE]

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) Acromegaly.
   f) Following some spinal operations.

The experience of individual surgeons in treating cases of spinal stenosis due to different causes will vary, especially among those working in large cities where special units may be found dealing exclusively with spinal injuries, cancer patients and children (Figs. 6.5–14).

Spinal surgery has now emerged as a sub-specialty around the world and there are many surgeons devoted exclusively to its practice. It should no longer be regarded as exclusively in the realm of either orthopaedic surgery or neurosurgery so that the invidious comparisons between the skills of the two groups of surgeons should disappear.

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. Important contributions to the understanding of various aspects of spinal stenosis have been made by Kirkaldy-Willis, Paine, Cauchoix and McIvor (1974), Verbiest (1976), Weinstein, Ehni, and Wilson (1977). More recently, scholarly monographs on the subject have appeared, Postacchini (1989) and Nixon (1991).

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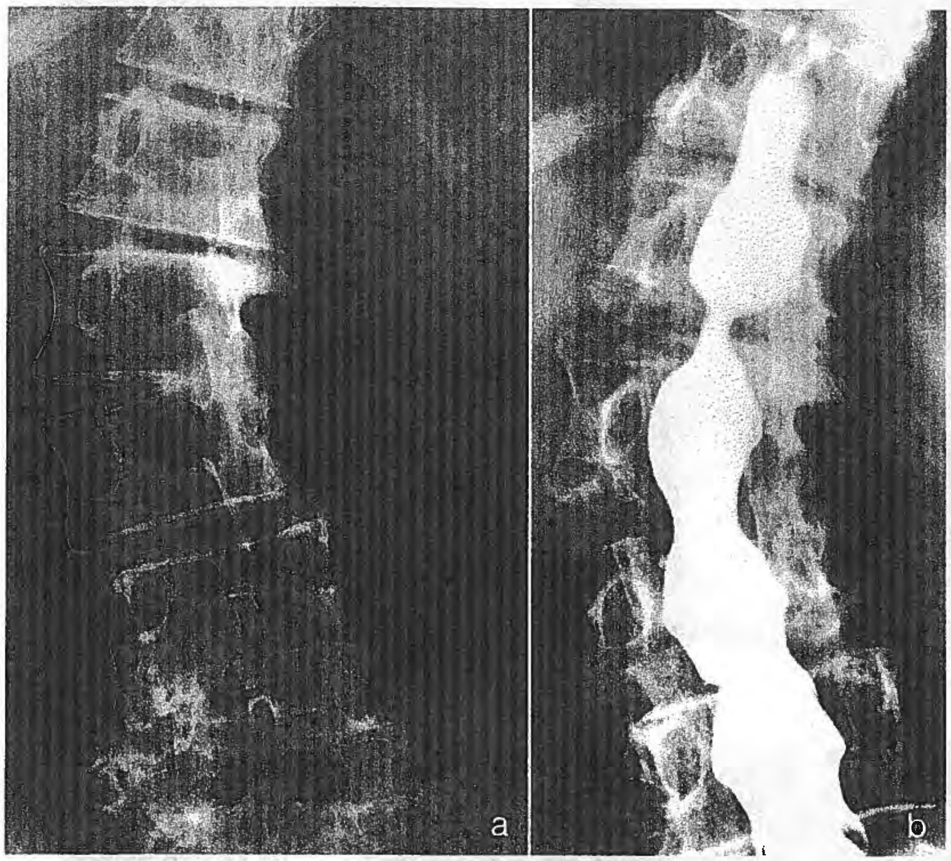
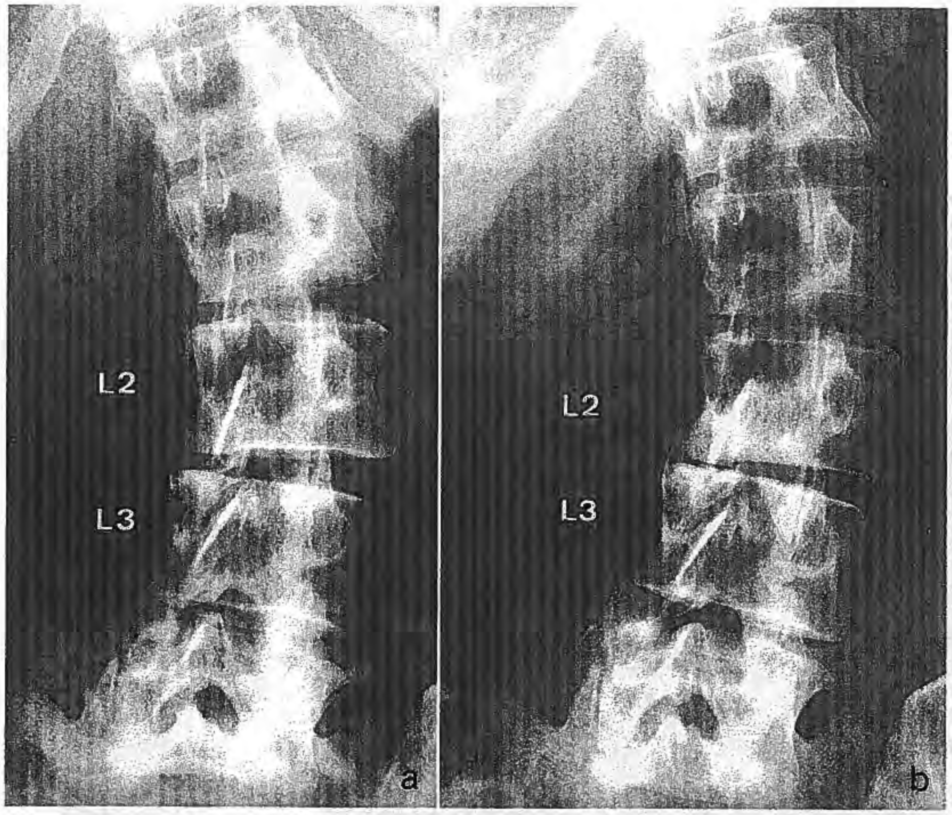
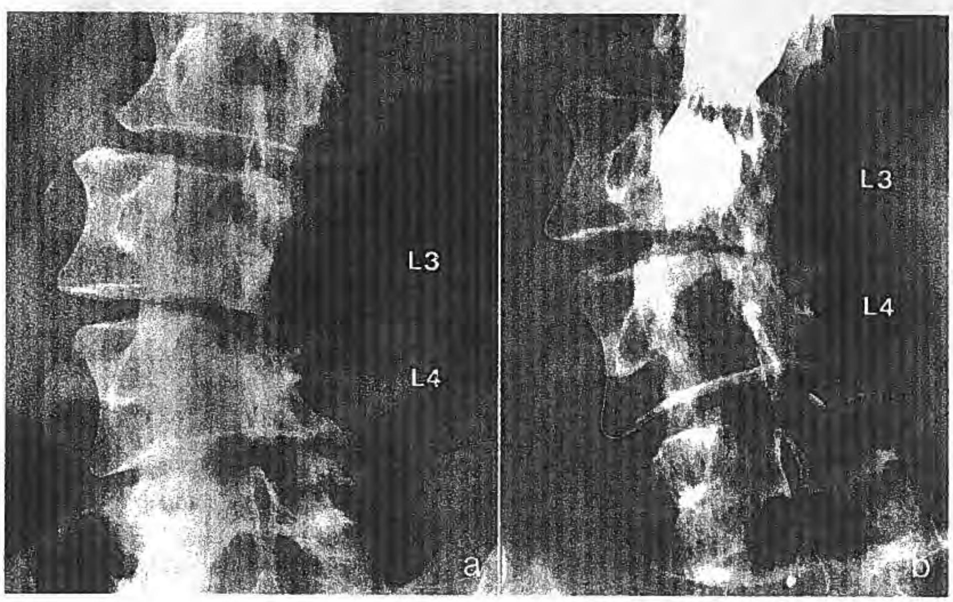


Figures 6.5a,b. **a** An antero-posterior radiograph of the lumbar spine of a woman of 66 years showing congenital fusion of the vertebral bodies of L2 and L3 with resultant scoliosis, further aggravated by degenerative spondylosis at the disc between L1 and L2. This patient presented with a cauda equina 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 6.6 a, b



Figures 6.7 a, b

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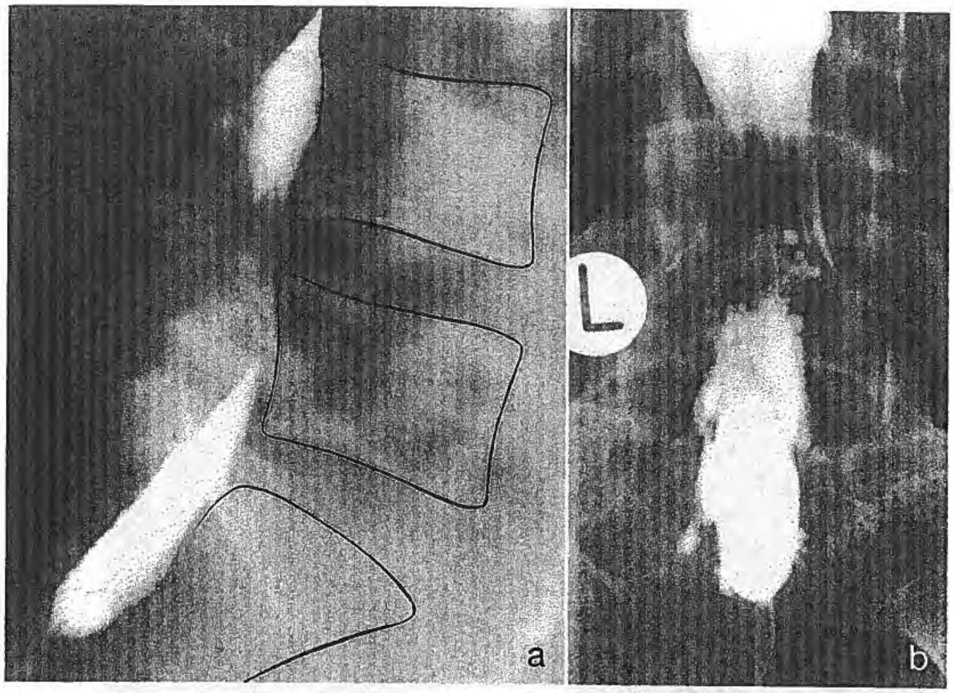

Figures 6.8a,b. **a** A lateral radiograph of the lumbar spine of a man aged 47 years presenting with classical symptoms of cauda equina claudication. Note the myelographic defect and the normal disc height at L4/5 and L5/S1. This is an example of incomplete obstruction and in such cases it is necessary 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

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Figures 6.6a,b. **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 6.7a,b. **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

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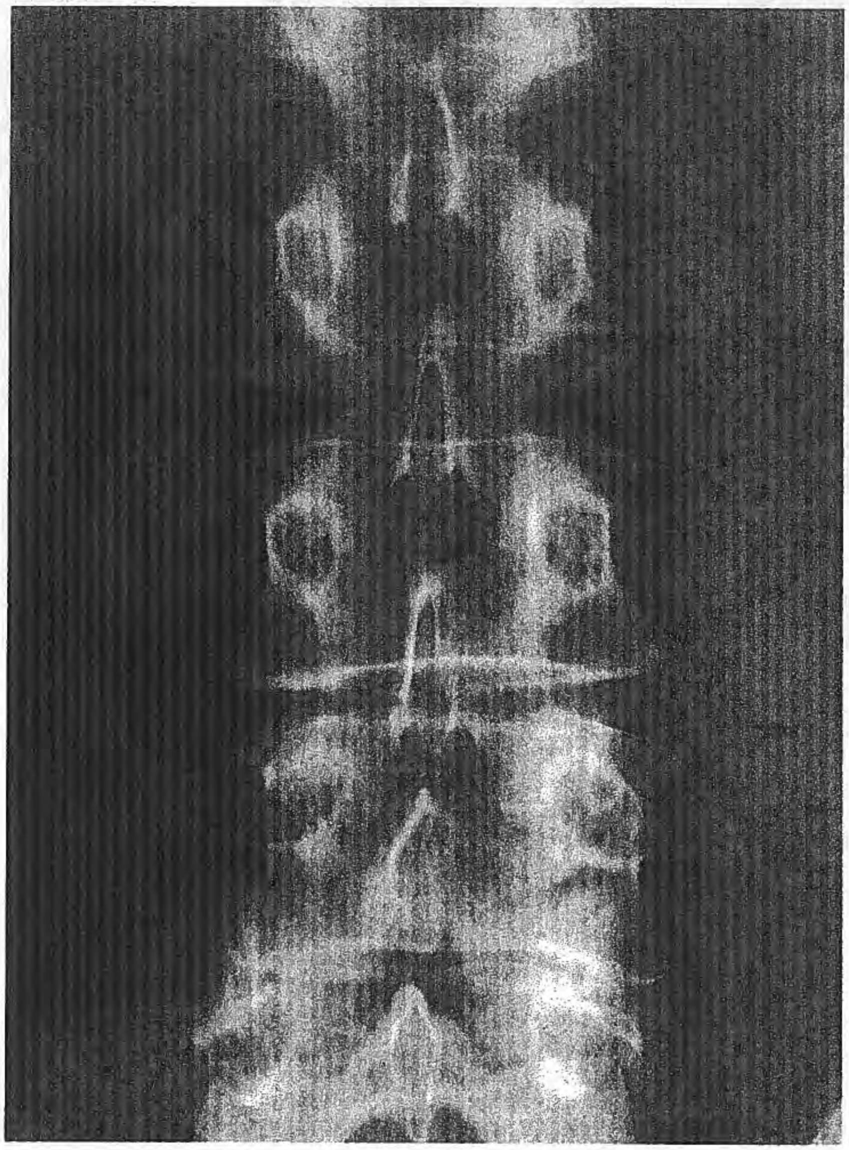

Figure 6.9. An antero-posterior radiograph of the lumbar spine in an adult in whom gross pathology is noted, particularly in the roof of the spinal canal. Although there is evidence of spondylosis at L3/4 with asymmetrical narrowing of the disc space, the major changes are in the laminal structures where facet hypertrophy, laminal thickening and spinous process interdigitation have reduced the interlaminar spaces at L2/3 and L3/4 to minute proportions

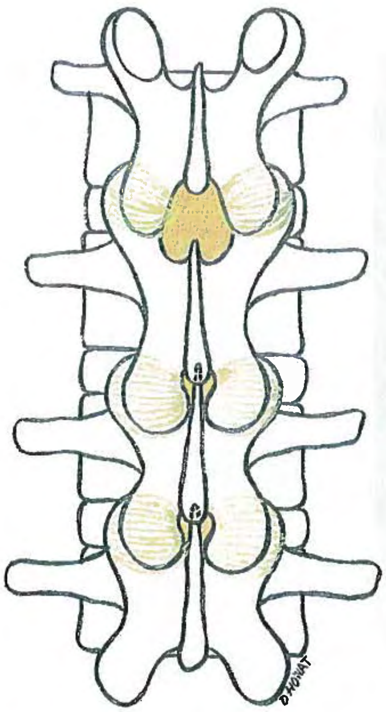

Figure 6.10. A drawing based on the X-ray shown in Fig. 6.9 to highlight the pathological changes which may occur in the roofing structures of the spinal canal leading to the development of multi-level canal stenosis. At the top of the drawing the ligamentum flavum is of normal proportions and there 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 of these levels

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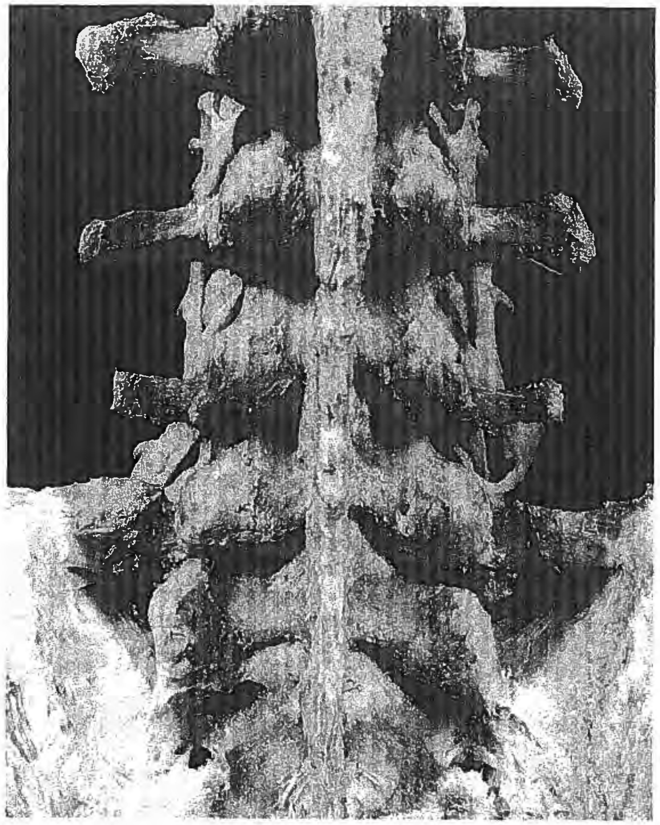


Figure 6. 11. A photograph of a dissection of a normal lumbar spine viewed from behind. Note the orientation of the facet joints at L3/4, L4/5, and L5/S1. These are separated widely from the mid-line, so that the ligamentum flavum can be seen clearly at each level. Shadows are cast on the ligamentum 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)

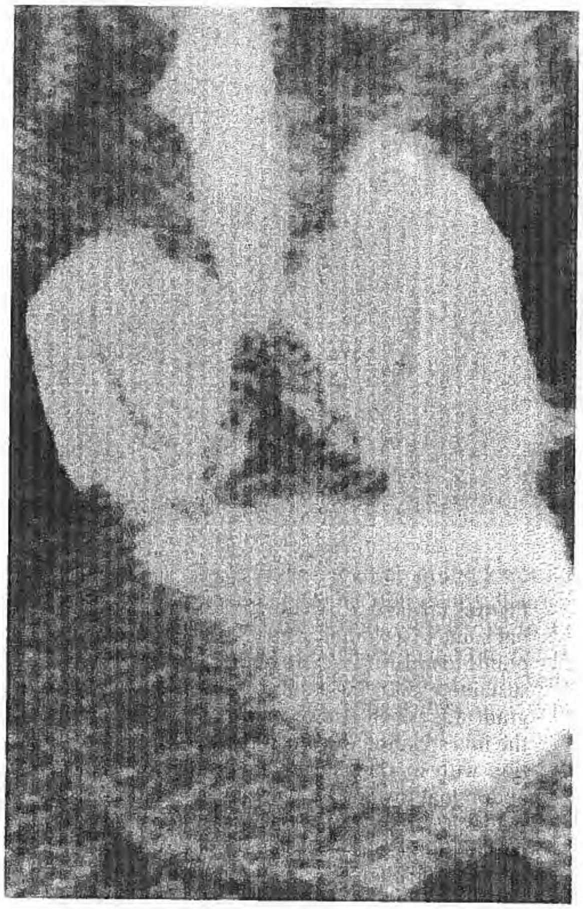
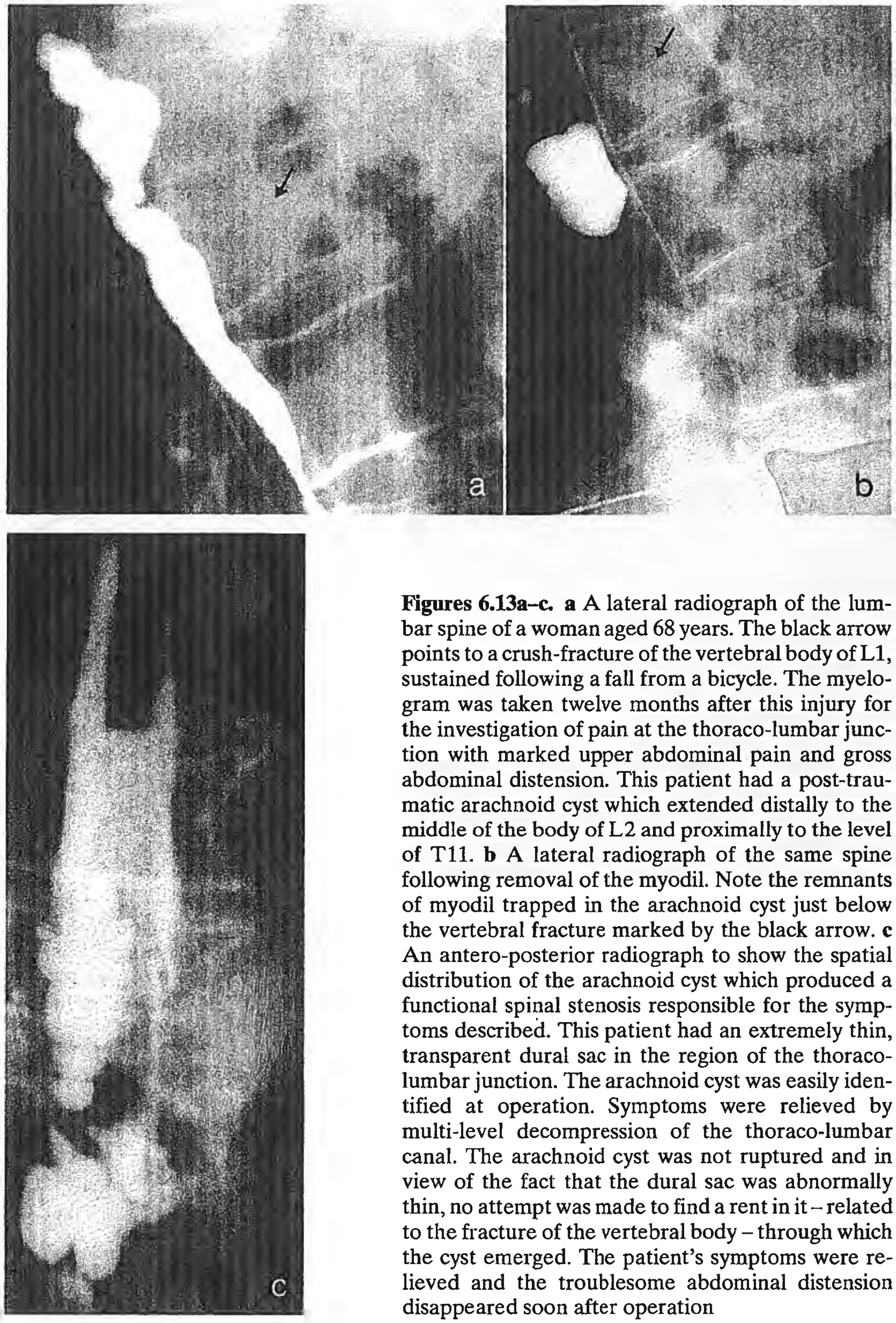
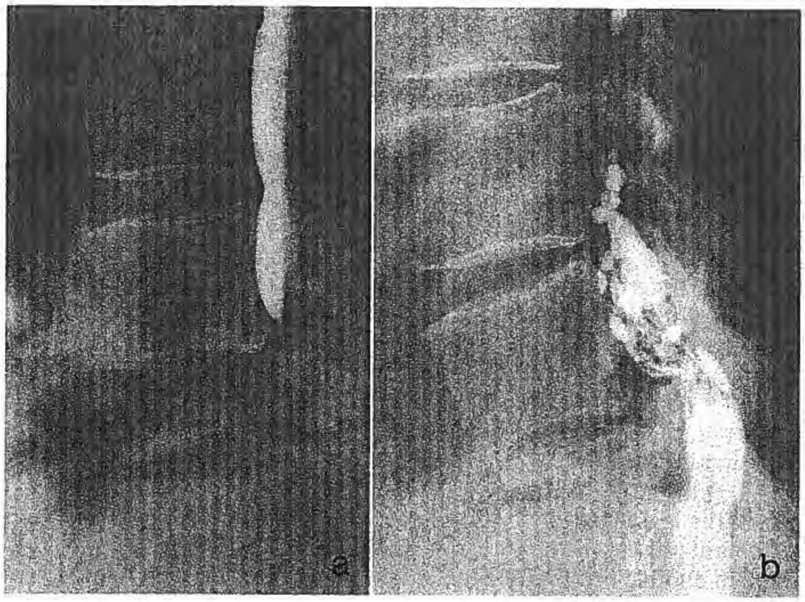


Figure 6.12. An axial CT image on the lumbar spine of an acromegalic patient aged 42 showing gross facet joint hypertrophy and osteoarthritis with ossification of the ligamentum flavum on both sides



Figures 6.13a–c. **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



Figures 6.14a,b. **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

6.2. Clinical Features

a) Symptoms

Most patients describe a variety of symptoms which may include:

a) Back pain
This is often aggravated by standing or walking. It may be the only symptom of which a patient complains in whom spinal stenosis can be demonstrated. Characteristically the back pain is relieved by bending forwards or by lying down.

b) Leg pain
Of variable distribution, unilateral or bilateral, and often fluctuating.

c) Paraesthesiae
Ranging from feelings of numbness and heaviness, sometimes with an associated burning pain, sometimes with a feeling of coldness in the limbs.

d) Weakness in the extremities
Ranging from unilateral loss of power resulting in sudden falls, to paraparesis, related to walking and relieved by rest. In cases of cervical canal stenosis or of

thoracic canal stenosis, spasticity of gait may be a prominent feature. Upper extremity involvement with symptoms similar to those experienced in the lower limbs, in cases of lumbar canal stenosis, may be present in those with cervical myelopathy.

e) Restless legs
Uncontrolled leg movements experienced especially at night in bed.

f) Disturbances of bladder function
Ranging from frequency to incontinence after walking.

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

Intermittent claudication of vascular origin can usually be distinguished easily 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;
- the detection of audible bruits along the course of the main arteries in the lower abdomen or in the limbs themselves.

b) Physical Signs

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

6.3. Radiological Investigations

a) Plain X-Rays

In congenital lumbar or cervical canal stenosis, certain findings can be important. For example, anomalies with block-vertebrae or hemi-vertebrae and scoliosis are frequently associated with stenosis. Narrowing of the spinal canal can be identified in lateral films when short pedicles and reduced inter-pedicular distances measured on AP films are found. Alterations in the pattern of orientation of facet joints at particular levels may also be important. In canal stenosis of degenerative origin, major changes are often found in the roof of the spinal canal, with gross hypertrophy of facet joints, shingling of laminae, and evidence of calcification or ossification of the ligamentum flavum. Gross lumbar scoliosis may occur due to asymmetrical narrowing of the disc spaces or to acute necrosis of the vertebral end-plates.

b) Computerized Axial Tomography

The use of this investigation has revolutionized the investigation of spinal stenosis in recent years, particularly in combination with radiculography. However, it has certainly not superseded the use of plain X-ray, radiculograms or MRI. Using bone windows and sagittal coronal and oblique reconstructions, when the technology is available, accurate estimates of the degree of stenosis at individual spinal levels can be made. Three-dimensional CT radiography shows promise of providing even more accurate depictions of stenoses in certain situations such as the occipito-cervical junction.

c) Radiculography

This investigation remains essential for planning surgical treatment wherever the sophisticated technology of CT scanning and MRI imaging is not available. Myelography provides 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. For example, by tilting the patient into head -down or erect vertical positions, the flow of dye can be observed with these changes in posture and distinctions 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. 6.5,6.7,6.8,6.13,6.14).

d) MRI

This is particularly valuable for identifying problems at the cranio-cervical junction, in the cervical spine or in the thoracic spine where it will provide the most accurate information about the changes induced in the dural sac or spinal cord. In the presence of cord involvement axial CT bone window studies should be used to identify the nature of the bony contributions to the stenotic lesions demonstrated in the MRI (see Chapter 7).

6.4. Conservative Treatment

Conservative measures must always be tried before surgery is recommended. Many patients with quite disabling symptoms will improve following physical therapy and the use of spinal supports. In very elderly people epidural injections of hydrocortisone can be useful, though if the patient's symptoms are made worse, this may be taken as an indication that the stenosis is sufficiently severe to require spinal canal decompression.

6.5. Surgical Treatment

Traditionally many doctors have been reluctant to recommend surgical treatment for elderly patients with spinal stenosis, for those with post-traumatic stenoses, particularly if associated with neurological deficits and for cancer patients. Developments in anaesthesia and resuscitation and in spinal surgical techniques have now combined to improve the results of surgery so much as to render that reluctance obsolete. That is not to say that contra-indications to the use of surgery in any of these patients do not exist.

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In elderly patients laminal bone is often osteoporotic and it bleeds readily. Conversely vertebral sclerosis may be found, the bone of the laminae being so dense that the use of chisels or diamond-tipped high speed burrs must be used to enter the spinal canal.

The normal ligamentum flavum is highly elastic, varying in thickness between 1.0 and 2.5 mm. Sometimes it is greatly thickened, retaining its elasticity. In other cases, while thicker than normal, it becomes inelastic and friable, containing visible patches of ectopic calcification. Complete ossification of the ligamentum flavum occurs in some cases following previous spinal surgery or spinal injury, in acromegaly and of course in ankylosing spondylitis. Occasionally it will be eroded by overlying osteophytes from the facet joints and its remnants may then be adherent to the dural sac.

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, the epidural fat may be absent in the stenotic area though this is not an invariable finding. The dural sac and its contents also may show important changes; the dura may be thickened and opaque, or thin and extremely friable. In rare instances it may be absent due to erosion by osteophytes which have projected into the dorsal aspect of the spinal canal from the facet joints.

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 (Figs. 6.15–17).

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 projecting backwards from the posterior margins of the vertebral body more frequently require to be removed in cases of cervical or thoracic canal stenoses. In the lumbar region, they may often be left undisturbed.

a) Selection of Levels for Decompression

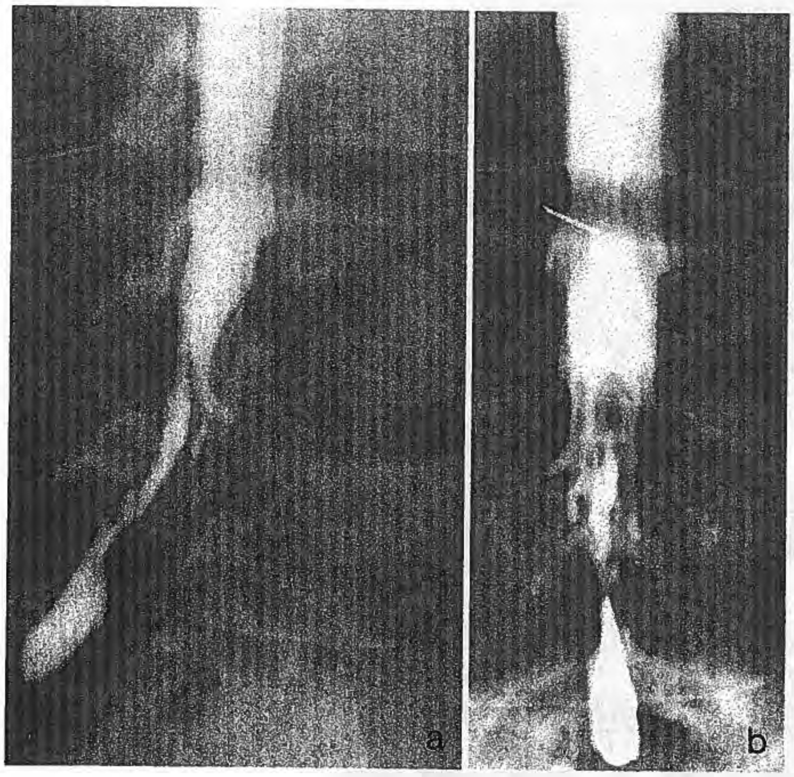
Where multiple level defects have been demonstrated, it is usually advisable to perform decompressions of the nerve root canals and intervertebral foramina and of the central canal at each of these levels.

In patients with unilateral leg pain, pre-operative nerve root blocks have been used by Van Akerveeken and Hasue. These authors aim to produce anaesthesia in nerve roots related to individual intervertebral foramina and then restrict the decompression operation to that particular level. As a general rule, it is wiser to perform bilateral foraminal and nerve root canal decompressions rather than to restrict the procedure to one side of the spinal canal.

b) Technique

i) Exposure

Exposure of the affected vertebral segments is obtained using the techniques described on pp. 127–133. Identification of the affected level or levels should be



Figures 6.15 a, b. **a** An oblique radiograph of the lumbar spine of a man aged 47 years showing classical myelographic appearances 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. 6.16 a–c)

confirmed by examining the patient's X-rays. X-ray control is not usually necessary, *providing the lumbo-sacral junction is identified visually as a routine, at least on one side of the S1 spinous process.* 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-laminar 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. *The use of diathermy to coagulate bleeding vessels anterior to the pars interarticularis should be avoided.*

Figures 6.16 a–c

ii) Enlargement of Bony Canal

The medial margins of the inferior facets at the level to be decompressed should be clearly defined. These are often very near the mid-line. Normal glistening silver fibres of the facet joint capsules are often obscured by masses of gangliform tissue projecting backwards from their inferior margins and covering their superficial fibres. This tissue should be incised and removed, paying particular attention to the lumbar vessels that may be adherent to it. The inferior capsular margin may be further obscured by an osteophytic outgrowth arising from the superior surface of the inferior lamina, the bar of bone projecting upwards to cover the capsular fibres of the adjacent joint. This bar of bone should be removed either with a high speed drill or with fine osteotomes. This will allow access to the hypertrophic medial margin of the facet joint which should then be excised, again, either with a high speed drill or with chisels, in such a way that the medial attachments of the facet joint capsule to the joint should not be disturbed, but sufficient bone and soft tissue should be removed to expose the underlying ligamentum flavum. These important stages in the procedure can be followed by examining in detail the dissection of the lumbar spine illustrated in Figs. 6.18–20.

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 laminae are osteoporotic, this manoeuvre can be carried out simply with a straight, short pituitary rongeur.

When the ligamentum 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

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Figures 6.16 a–c. **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. 6.15 a, 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 open following operation

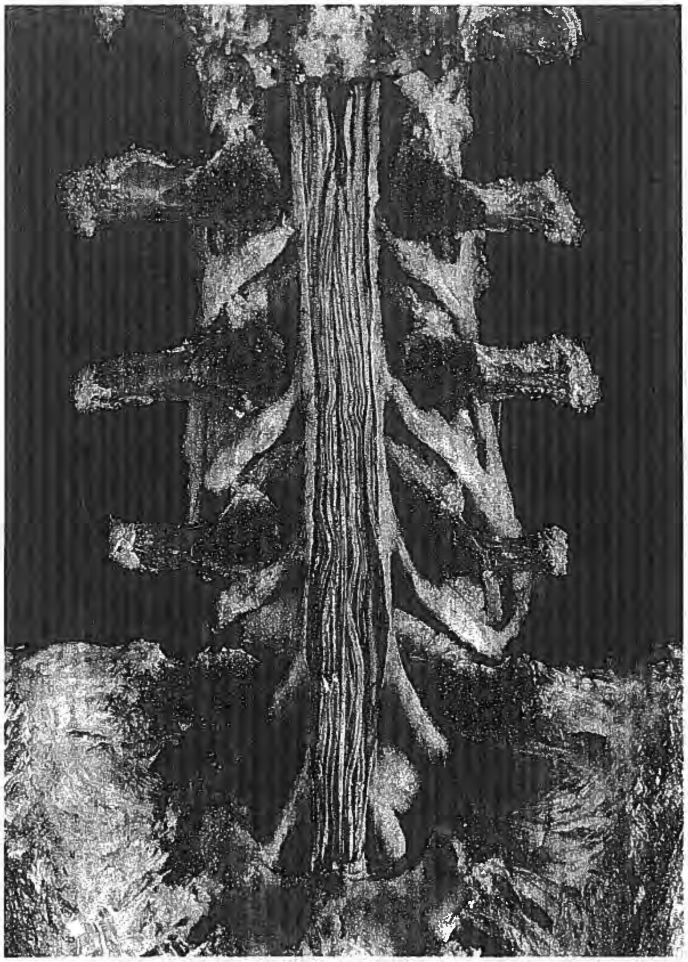

Figure 6.17. A photograph of a dissection of the lumbar spine from a woman aged 46 years. The posterior part of the dural sac has been removed to show the cauda equina which is still ensheathed in transparent arachnoid membrane. During explorations of the lower lumbar spine the dural sac is usually transparent and filaments of the cauda equina can be seen floating in the cerebrospinal fluid. (Dissected by Dr M. C. Crock)

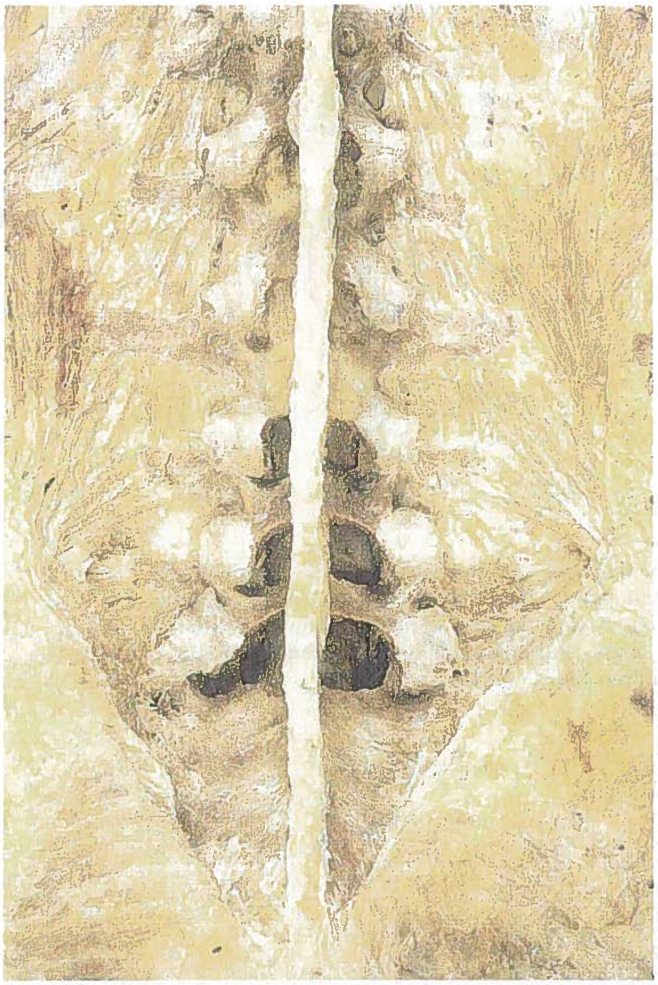

Figure 6.18. The photograph of a dissection of the lumbar spine to illustrate aspects of the technique of multi-level lumbar canal, bilateral foraminal and nerve root canal decompressions preserving the mid-line bony structures and interspinous and supraspinous ligaments. Towards the top of the picture at the L2/3 level the preliminary procedure which involved removal of the medial portion of the inferior facet of L2 along with the capsular extension on to the ligamentum flavum and including a few millimetres of the inferior laminal margin of L2 has been performed on both sides exposing the fibres of the ligamentum flavum. Note the striking difference in colour between the capsular fibres and the bright yellow of the ligamentum flavum itself. *The importance of stressing the appreciation of the normal anatomical colour of specific spinal structures cannot be overstressed. It is a valuable guide to the surgeon at every stage of spinal surgery but most valuable when difficult re-explorations of the spinal canal are undertaken.* At the L3/4, L4/5 and L5/S1 interspaces the decompression is complete. The dural sac and nerve roots can be seen and on the right side of the picture the outline of the internal vertebral venous plexus can be made out running parallel to the slightly glistening S1 nerve root sheath. (Dissected by H. V. Crock and reproduced by kind permission of Professor S. Sinatamby and the President and Council of the Royal College of Surgeons of England)

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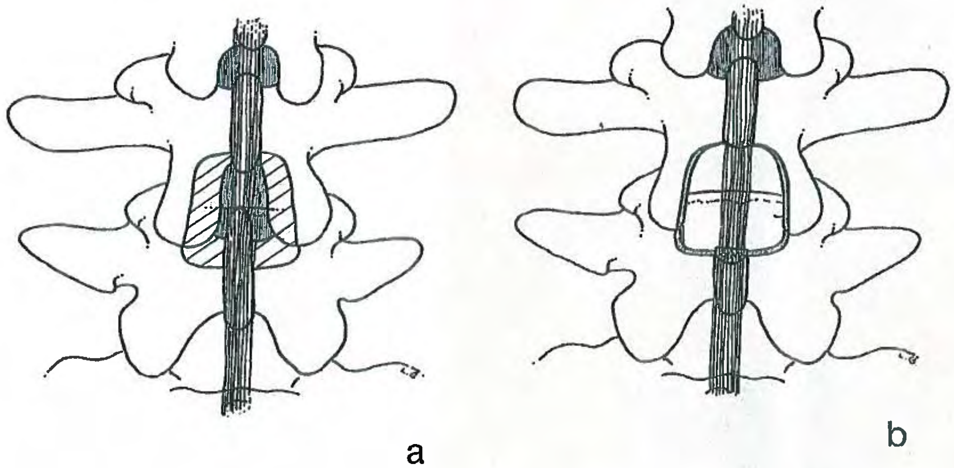

Figures 6.19 a, b. **a** A schematic drawing depicting typical pathological changes of facet hypertrophy at the L4/5 level. The hatched area outlines the extent of the dissection usually required to decompress the canal. **b** A schematic drawing showing the decompression completed with the interspinous ligaments and supraspinous ligaments still intact. The lateral extent of the bony dissection is in line with the medial borders of the pedicles of L5

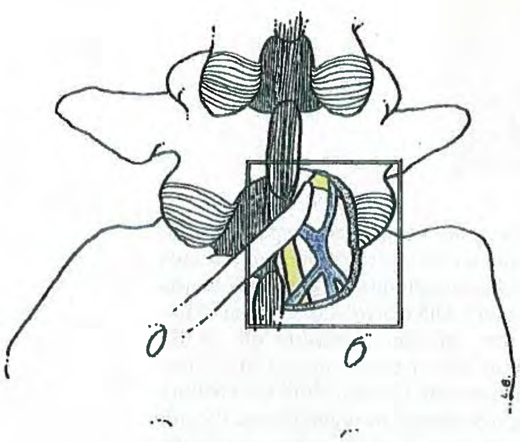

Figure 6.20. A schematic detailed drawing to show the typical appearances following successful nerve root canal and foraminal decompressions at L5/S1 on the right hand side. The probe is retracting the lateral margin of the dural sac and at its tip, the outline of the L5 nerve root can be seen. Refilling of the internal vertebral venous plexus and lumbar vein tributaries is prominent. Note that these vessels are often as large as the nerve roots which they surround and accompany

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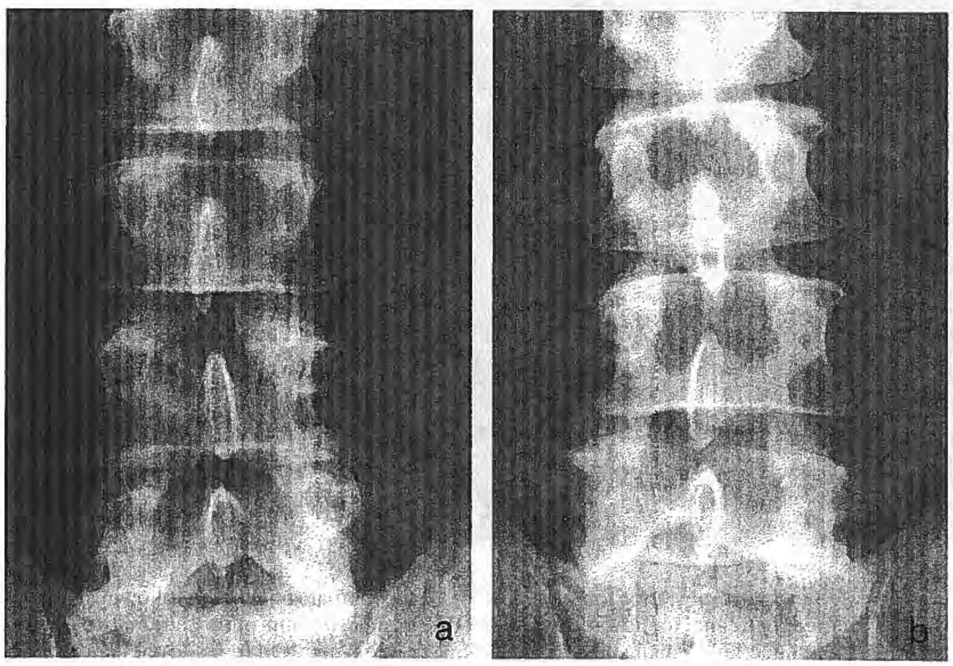
of the superior facet related to this pedicle should be excised flush with the inner margin of that pedicle. The line of this cut in the facet, where it emerges from the lamina, should mark the lateral extent of removal of bone.

In almost every case, even in those with degenerative lumbar scoliosis, it is possible to produce satisfactory decompressions of the spinal canal without disturbing the integrity of the supra-spinous and inter-spinous ligaments and the spinous processes to which they are attached, Tsuji (1991). Further details of the technique have already been described in Chapter 3 (Figs. 6.21 a, b).

Where it becomes necessary to remove the spinous processes and central segments of the laminae, the partes interarticulares should 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 (Fig. 6.22).

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.



Figures 6.21 a, b. a Antero-posterior photograph of the lumbar spine in a middle aged male patient with multi-level lumbar canal stenosis confirmed by radiculography. **b** The post-operative appearance following nerve root canal and foraminal decompressions at L2/3, L3/4 and L4/5 with preservation of the spinous processes and interspinous ligaments, followed by reattachment of the lumbo dorsal fascia at the end of the procedure

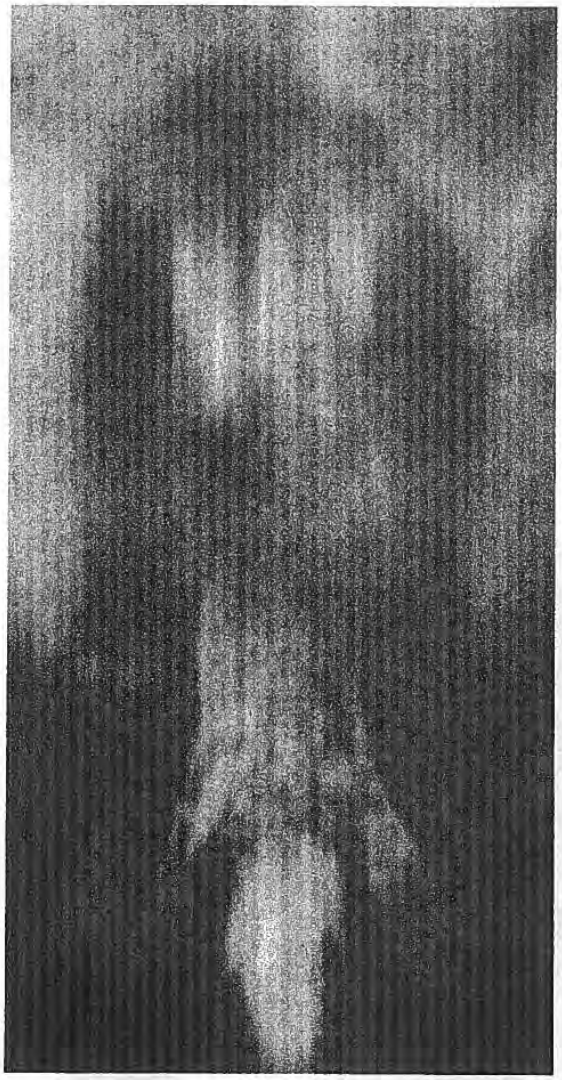


Figure 6.22. An antero-posterior tomogram of the lower lumbar spine taken following decompression of the spinal canal to show restoration of the normal contours of the dural sac following treatment for single level canal stenosis at L4/5. Note the smooth margins to the laminae on both sides of the vertebral 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. Multilevel decompressions of the lumbar canal may be carried out in this manner without fear of causing vertebral instability

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 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 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 and sutured to the laminal margins, thereby helping to relieve the venous obstruction between the intra-dural and extra-dural venous channels. Dissection should continue proximally either to the level where the dural sac pulsates or to a point where cerebrospinal fluid can be seen contained by the transparent arachnoid membrane.

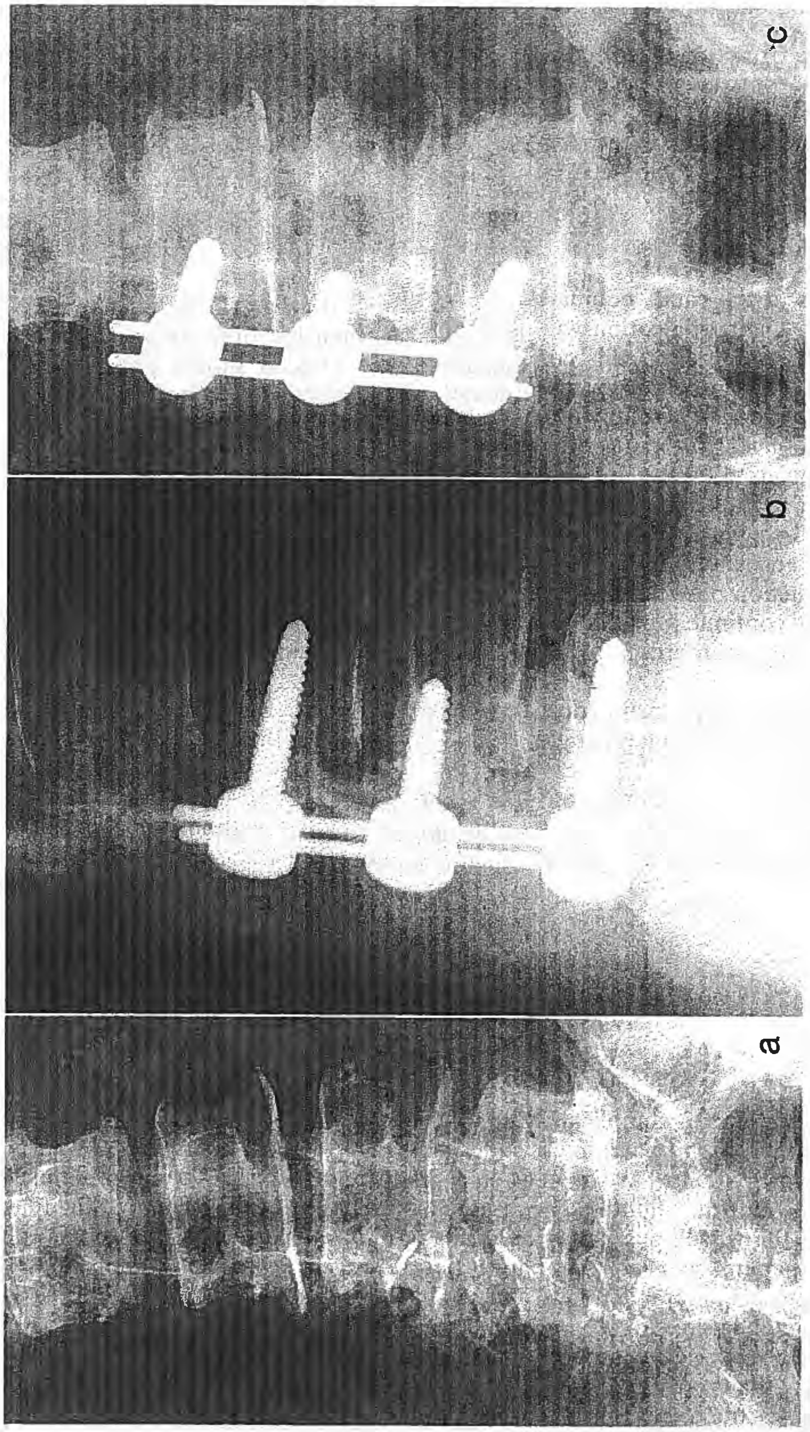
The margins of the opened dura should be fixed with a few interrupted sutures to the muscles along the lateral edge of the bony margins of the spinal canal over the area of the decompression.

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 fascia layer is tightly sealed.

6.6. Results of Surgical Treatment for Arachnoiditis

Although this is a rare complication of severe lumbar canal stenosis, more than twenty cases have been treated by this method. Managed post-operatively by early mobilization, the patients have been given daily doses of Aspirin 100 mg with multivitamin tablets for three months. The rationale of this therapy has been 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.



Figures 6.23a–c. **a** An antero-posterior photograph of the lumbar spine of a 57 year old Japanese lady with degenerative spondylolisthesis of L4/5 with symptoms of back pain and intermittent left sided sciatica related to effort. **b** A lateral radiograph following insertion of three pedicular screws with the Crock Pericic spinal fixation system. **c** An antero-posterior view of the same patient's spine following facet fusion. This patient remained symptom free three years after operation

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 and 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. In some of these cases, inter-pedicular pedicle screw fixation devices may be used with spinal fusion, either in the form of inter-transverse fusions, facet fusions or posterior interbody fusions (Fig. 6.23a–c).

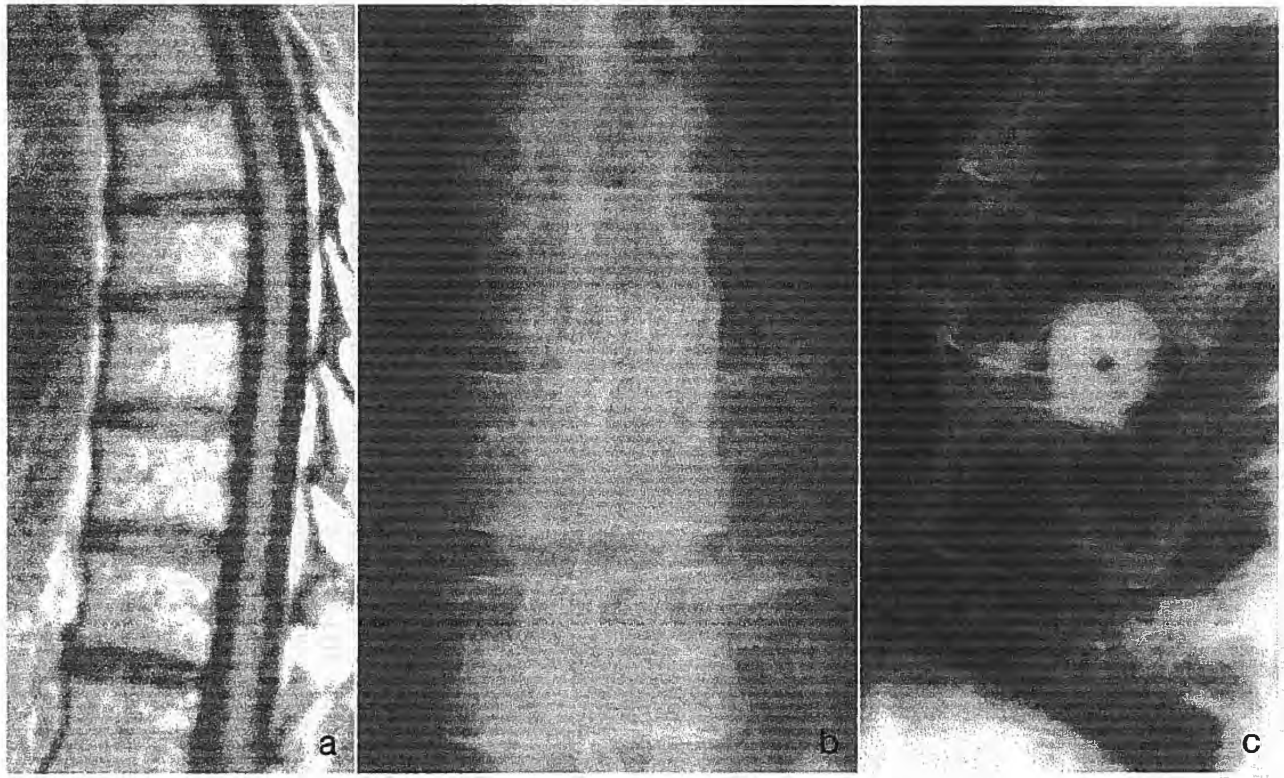
The introduction of the pedicle screw system for vertebral fixation has certainly provided an excellent method for spinal stabilization in selected cases. Complications resulting from the use of these devices have tended to run at an unacceptably high level, Esses *et al.* (1991).

These authors presented a careful review of 617 surgical cases in which various designs of implants had been used. They recorded the following complications:

Unrecognized screw misplacement	5.0%
Post-operative deep infection	4.2%
Pedicle fracture and CSF leakage	4.0%
Aortic perforation and death occurred in one case.	
Transient neuropraxia	2.4%
Permanent nerve root injury	2.3%
Screw breakage	2.9%
Overall they reported *a complication rate of*	*27.4%*

6.8. Wound Closure

Using the conservative method of bilateral foraminal and nerve root canal decompression combined with enlargement of the central portion of the spinal canal where indicated by removing the upper attachments of the ligamentum flavum at each level, and thinning the laminal bone on its deep surface, followed by reattachment of the lumbo-dorsal fascia on both sides to the mid-line supra-spinous and inter-spinous ligaments, the post-operative results have been superior to the older method of extensive lumbar canal decompression involving excision of the spinous processes and central portions of the laminae. In the first instance, reconstitution of the normal anatomical relationships between the spinous processes and related ligaments and lumbo-dorsal fascia has obviated the necessity for wound drainage even after multi-level decompressions. The paraspinal muscles no longer bow-string across the decompressed segment of the vertebral column. Spinal stability appears to be enhanced and the necessity for using internal fixation devices with spinal fusion has been greatly restricted.



Figures 6.24a–c. **a** A mid-sagittal MR T2 weighted image of the thoracic spine of a female aged 56 showing a sequestrated disc fragment at the T8/9 level. **b** An antero-posterior photograph of this patient's spine taken six months after interbody fusion. Note the separate discs of bone cut from the rib removed at the time of thoracotomy. **c** A lateral view of the same spine showing the proximity of the grafts to the spinal canal. Before inserting the grafts the disc prolapse was easily removed

6.9. *Thoracic Canal Decompression*

Stenotic lesions producing spinal cord compression are rare. Ossification of the posterior longitudinal ligament is sometimes associated with ossification of the ligamentum flavum. Ossification of this ligament may also occur following trauma. Intra-dural lesions, other than tumours, which may compress the cord, such as post-traumatic arachnoid cysts (Fig. 6.13a–c) or localized ossific arachnoiditis may all respond to simple thoracic laminectomy.

The major lesions which cause thoracic canal stenosis and impairment of cord function are usually found in the anterior wall of its canal. Thoracic disc prolapse, ossification of the posterior longitudinal ligament, and calcific disc prolapses are all dealt with most safely by a trans-thoracic approach to the thoracic spine. Localization of these lesions is often difficult and very careful radiological and MRI studies are needed for that purpose. Depending on the siting of the lesion, the chest may be opened either from the right or left side excising portion of the rib proximal to the vertebral level of the lesion. Sometimes these approaches can be accomplished by an extra-pleural approach though often in healthy people the parietal pleura is very thin and easily ruptured, so that the operation is performed transpleurally and post-operative chest drainage is then necessary.

Providing appropriately long instruments are available, many of these lesions can be dealt with through quite limited approaches following removal of the middle third of a rib, retracting the anterior margin of the latissimus dorsi muscle without dividing it.

Once the chest has been opened, the parietal pleura should be incised along the mid-lateral line of the vertebrae. Most of the pathological processes that require surgical treatment involve only one or occasionally two intervertebral discs. These can be dealt with without dividing the overlying sympathetic nerve fibres and without division of any of the regional intercostal vessels. However, if extensive exposure is required when dealing with inflammatory lesions of the spine or with neoplastic lesions, then several intercostal arteries may need to be divided. This can be safely done without damage to the spinal cord circulation providing the vessels are divided at about the mid-point between their aortic origins medially and the intervertebral foramina laterally.

Thoracic disc prolapse can usually be satisfactorily removed by incising the peripheral annular fibres and removing the disc in toto with long fine straight pituitary rongeurs.

For the removal of large sequestrated fragments or calcified nuclear material, it is wiser to construct a dowel cavity from one side of the vertebral column to within a few millimetres of the other.Ellipses of bone and intervening disc are then removed and through this large cavity the remaining disc tissues posterior to the dowel can be removed from the front of the spinal canal itself.

To determine the actual level of the posterior vertebral margins, it is often necessary to excise the head and neck of the rib and to work across the floor of the canal with the aid either of a high speed drill or fine angled curettes until the anterior surface of the dural sac has been completely decompressed.

With this method, using a cutter one size larger than that used to prepare the dowel cavity, a series of discs can be cut from the excised rib fragment and these are then impacted into the dowel cavity from one side of the vertebral bodies to the other (Figs. 6.24, 25).

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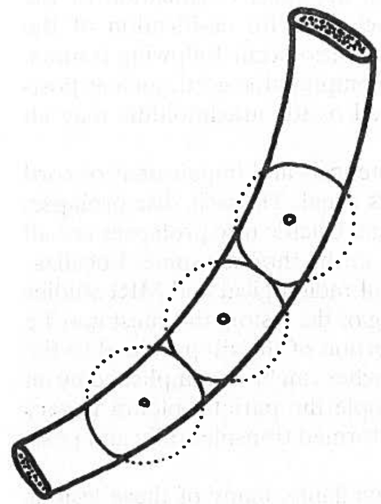


Figure 6.25. A schematic drawing showing the methods of preparation of rib grafts for interbody fusion when the dowel technique is used

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.

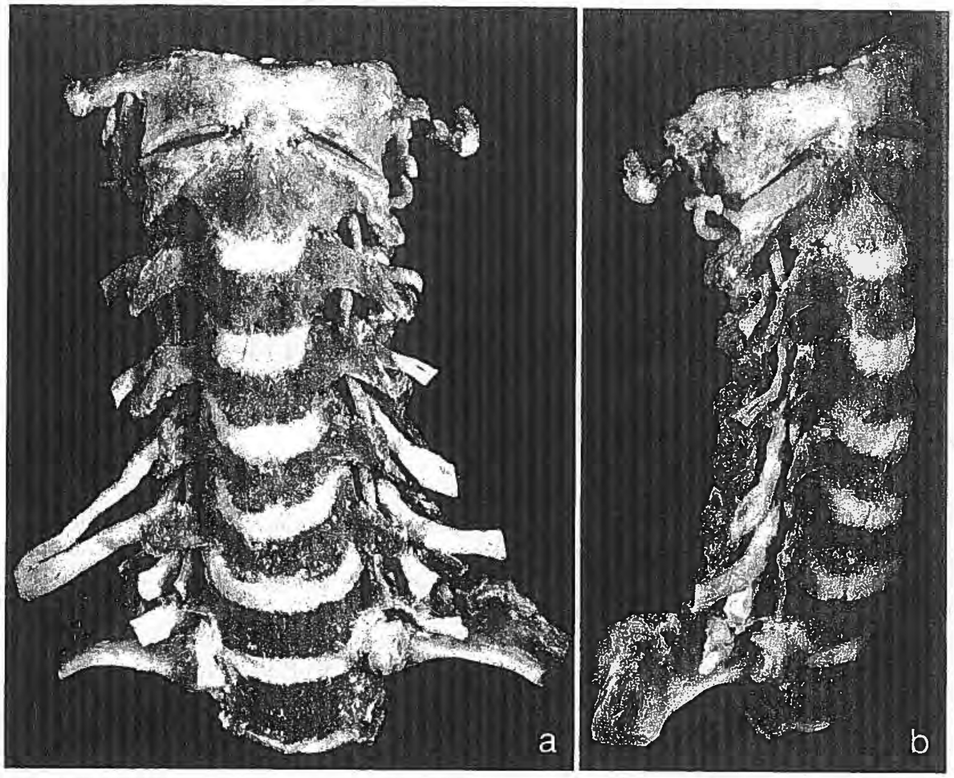
In the course of performing anterior cervical interbody fusion operations a wide range of pathological lesions can be dealt with safely and effectively. For example, some of the space-occupying lesions which project into the anterior wall of the cervical canal can be removed before the grafts are inserted, 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:

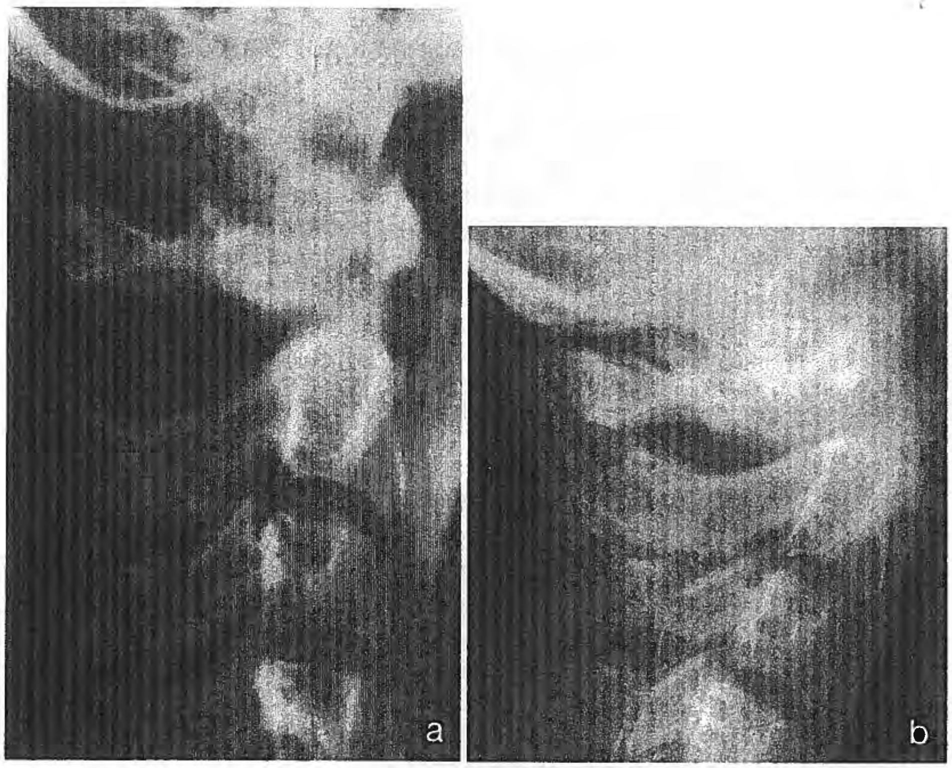
1. For decompression of the spinal canal in cases of multi-level stenosis.
2. For the relief of persistent stenosis of the canal after anterior interbody fusion operations, rarely.
3. For drainage of epidural abscesses.
4. For the treatment of spinal cord tumours.

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 (Figs. 7.2a,b).



Figures 7.1a,b. **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 right side showing the relationships of the vertebral artery and the emerging cervical nerve roots



Figures 7.2a,b. a 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. **b** 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

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, twenty-five 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 (Figs. 7.3–5).

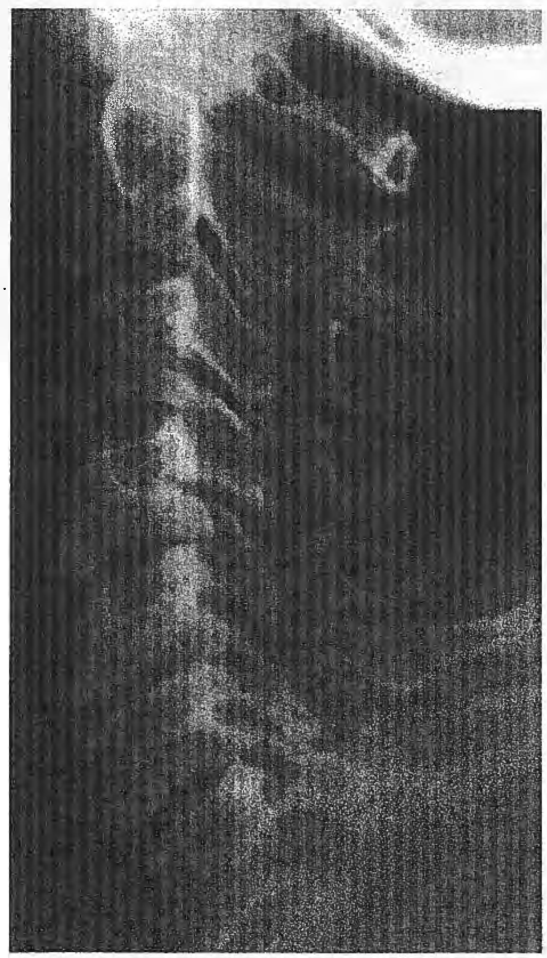
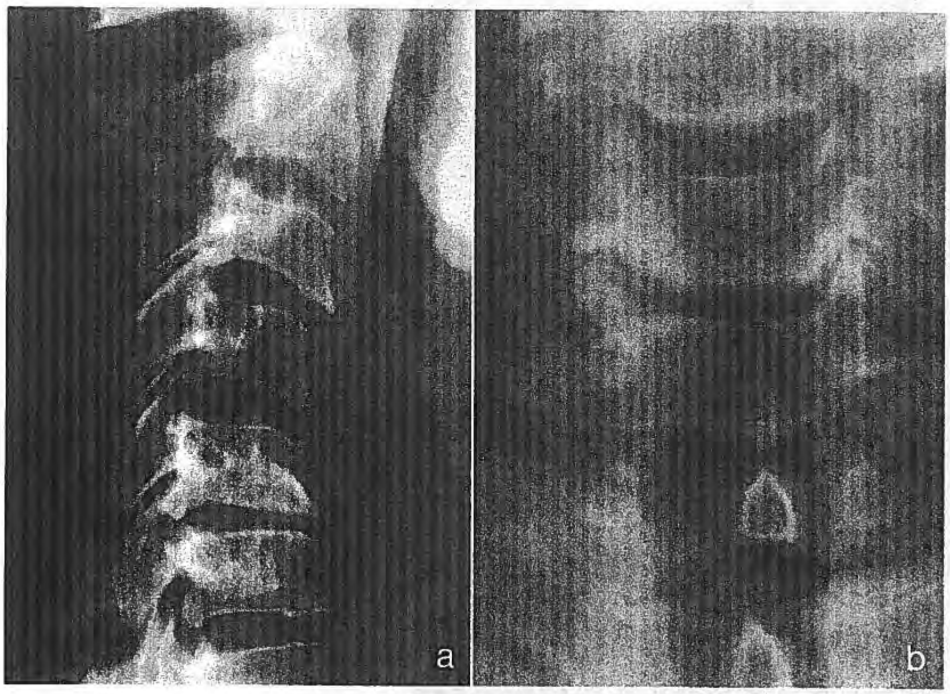


Figure 7.3



Figures 7.4a,b. **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

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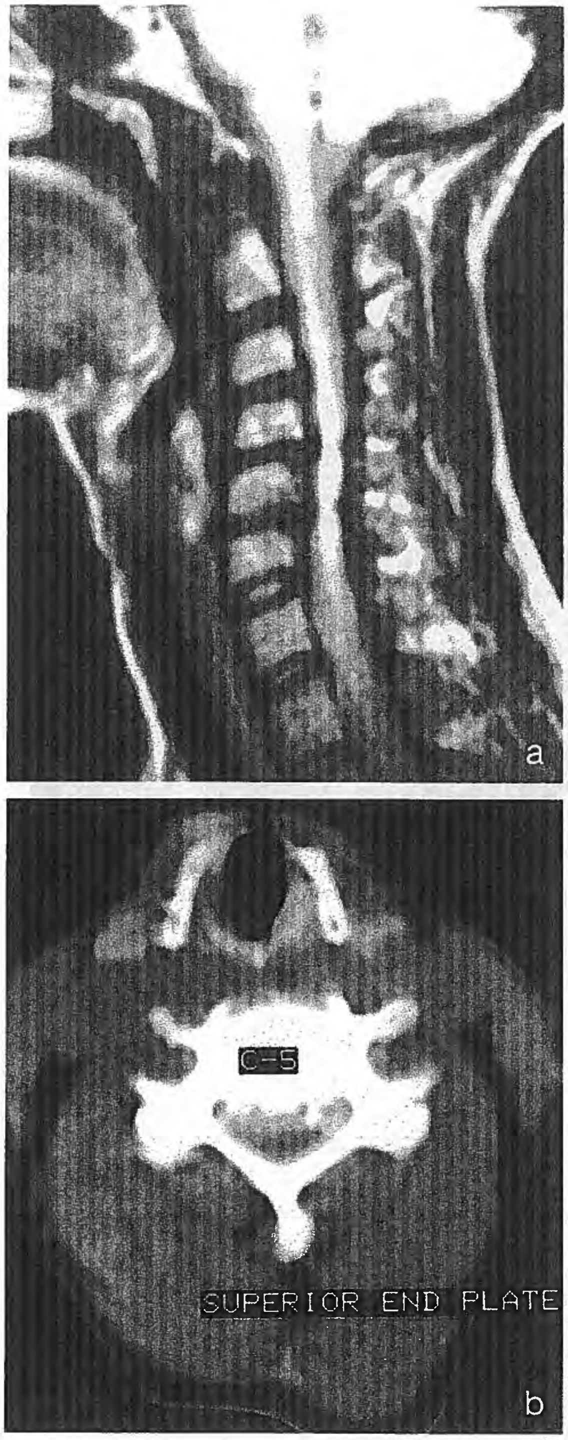
Figure 7.3. A lateral radiograph of the cervical spine of a woman aged 45 years showing advanced cervical spondylosis affecting the discs between the vertebral bodies of C4/5, C5/6 and C6/7. Large osteophytes project backwards into the spinal canal. This is an example of post-traumatic disc degeneration 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 7.5a,b. **a** A central sagittal view of the cervical spine in a female patient aged 41 years, T2 weighted sequence MRI. Note the hour-glass shaped deformations of the spinal cord commencing at the C3/4 disc level and increasing in degree at C4/5 and C5/6 levels. The bony components of the tissues indenting the anterior surface of the dural sac are not defined in this MRI sequence **b** An axial image from the CT radiculogram in the same patient. The dense irregular osteophytes that form a bar projecting backwards into the spinal canal can be clearly seen. This patient presented with increasing weakness of her arms and legs, with severe neck pain and occipital headache. Symptoms had commenced insidiously two years previously

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

a) For the relief of persistent 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

i) *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. 120, for the management of lumbar and thoracic disc prolapses (Fig. 7.6).

ii) *Post traumatic internal disc disruption.* 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 these injuries which often cause protracted disability. Opinions among doctors vary widely, not only on the question of the causes of persisting symptoms in these patients, but also on the methods of treatment which should be used to treat them.

Figure 7.6. A sagittal MRI of the cervical spine of a female patient aged 36 years, showing a large disc lesion at C6/7 indenting the spinal cord

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 the patients 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-five 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.
   b) Normal spinal radiographs.
   c) Normal myelogram.
8. The most 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.
   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. It is time then to order cervical discograms (Figs. 7.8 a, b).

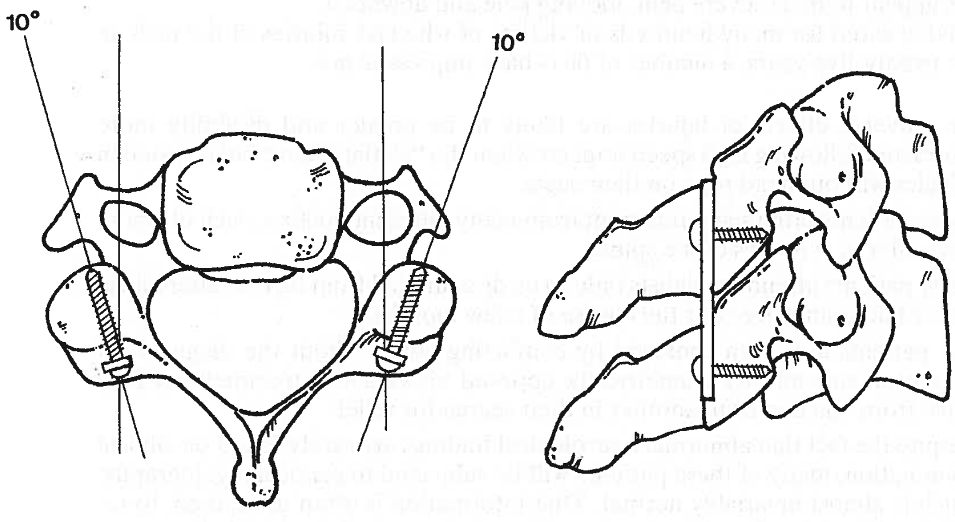


Figure 7.7. Drawings to illustrate the orientation of screws and a plate for cervical vertebral fixation

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Figures 7.8 a, b. 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

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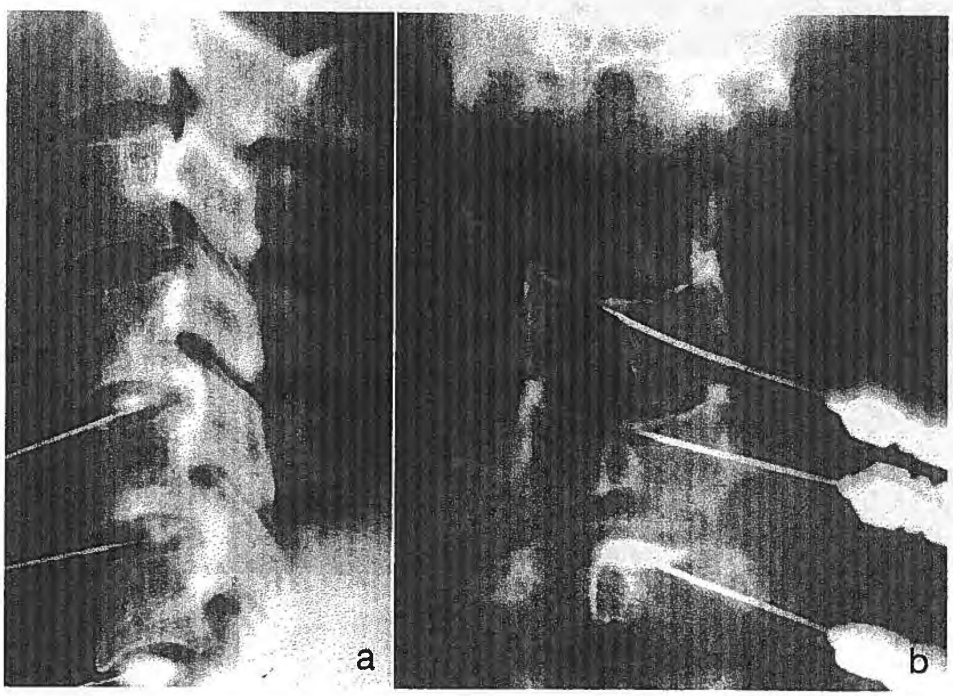
c) Spinal Injuries

Indications for surgery following cervical fractures and dislocations have been expanded considerably in the past ten years. European surgeons (Magerl, Grob, Roy-Camille and Böhler) have introduced innovative fixation techniques and devices which can be applied to the cranio-cervical junction and to lower regions of the neck for the treatment of many of these lesions, shortening hospital stay and speeding rehabilitation (Fig. 7.7). The use of screw fixation for odontoid fractures, either introduced from in front, as recommended by Böhler, or from behind, using trans-articular screws and C1-C2 grafts as described by Magerl and reported by Grob *et al.* (1991), has revolutionised the care of this injury (Figs. 7.9 a, b).

The management of burst fractures and fracture dislocations with cord involvement, formerly treated with rigid conservatism, has also changed. Emphasis in many centres now focuses on urgent anterior decompression of the cervical canal with interbody fusion and if necessary plate and screw fixation.

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 (Fig. 7.10).
b) For the treatment of non-union of fractures of the odontoid.
c) For post-surgical deformity of the cervical spine, a difficult problem which often follows extensive laminectomies for spinal cord tumours (Fig. 7.11).



Figures 7.8 a, b

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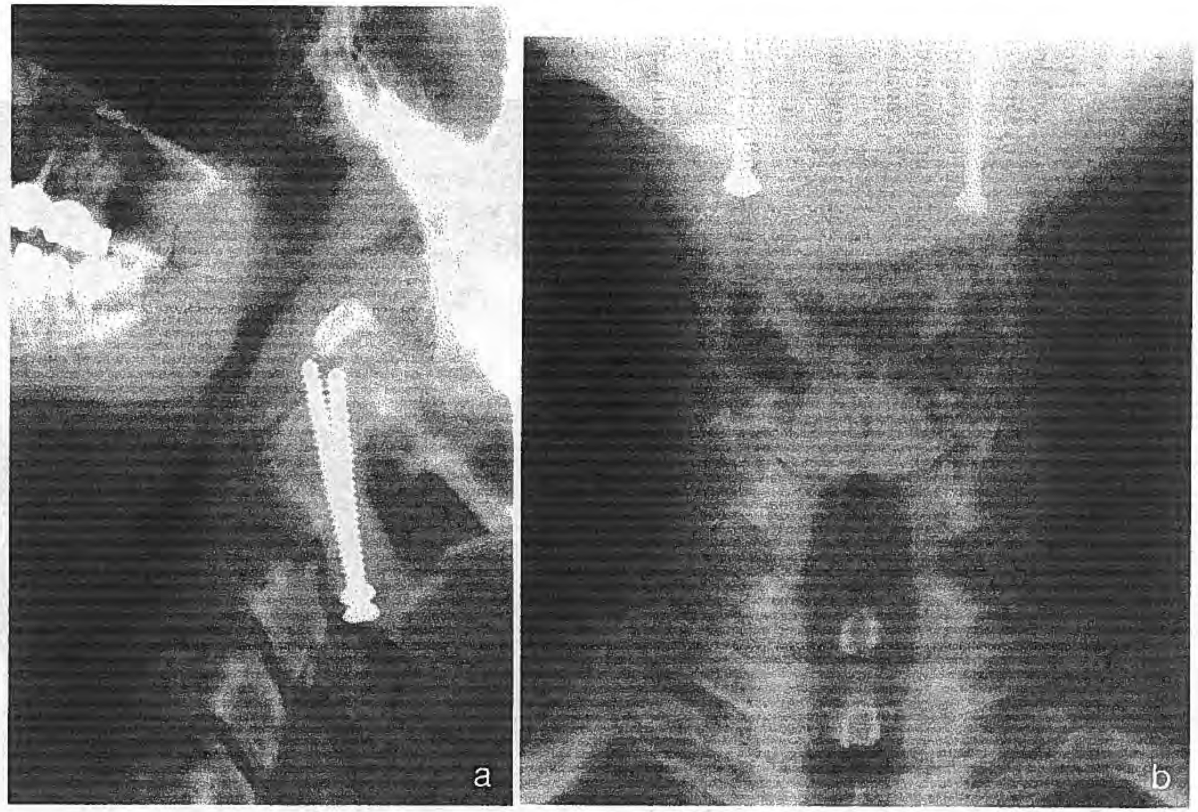

Figures 7.9 a, b. **a** A lateral radiograph of the upper cervical spine in a male patient showing the Magerl, Grob method of trans-articular screw fixation of C1/C2 vertebrae with an inter-laminar graft between C1 and C2. **b** An antero-posterior view of the same spine. This operation was kindly performed on this patient in London by Dr. Dieter Grob, orthopaedic surgeon, Schulthess Clinic, Zurich, Switzerland, for post traumatic rotatory subluxation of C1 on C2

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Figure 7.10. 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