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C H A P T E R 12

RADIOLOGICAL DIAGNOSIS OF SPINAL STENOSIS

INTRODUCTION

This chapter traces the development of radiological diagnosis of spinal stenosis from the first observation of reduced lumbo-sacral disc height and oil-based contrast myelography to water-soluble contrast myelography, and radiculography in patients with central and lateral canal stenosis. Finally, the contrast radiographic features of stenosis in spondylolisthesis and post-fusion stenosis are described.

The term "myelography" is often loosely applied to contrast visualisation of the cauda equina, but strictly speaking this is incorrect since myelography can only apply above the L1-2 level where the spinal cord terminates, and below that the correct terminology is radiculography. The term "radiculography" is also more appropriate now that more accurate visualisation of the nerve root sleeves is possible using water-soluble contrast media.

PLAIN RADIOLOGICAL FEATURES

(a) General Features

In 1932 Paul Williams observed a correlation between a reduction in the lumbo-sacral joint space and sciatic irritation. He described a lesion consisting of a narrowing or a complete loss of the intervertebral disc, between the fifth lumbar and first sacral vertebra in the majority of patients suffering symptoms of sciatic irritation (Williams 1932). He considered that

"the frequent occurrence of this and its clinical significance are unappreciated by the medical profession as a whole".

He concluded that narrowing or complete loss of the lumbo-sacral intervertebral disc with localised arthritic reaction is found in the majority of cases of sciatica, and frequently in cases of "lumbago". Secondly, continued physiological trauma to an intrinsically weak lumbo-sacral region afforded a favourable site for traumatic disease. Thirdly, rupture of the nucleus pulposus of the lumbo-sacral disc would produce the same clinical and radiological findings which are observed in those cases with reduced lumbo-sacral joint space. Fourthly, sciatic irritation was probably due to motion at the lumbo-sacral joint plus constriction of the intervertebral

foramen and arthritic lipping which follows loss of joint space. He went on to conclude that the appropriate treatment was fixation of the lumbo-sacral joint.

Although this final conclusion is questionable, his description of the pathogenesis of sciatica remains essentially unchanged to date, and subsequent advances have been only in improved imaging and more accurate descriptions of the same process.

Subsequent authors described complete blockage of the myodil column in the absence of gross narrowing of the affected disc (Blau 1961). Swelling of the nerve roots was also described as early as 1957 by Lewtas and Diment in two cases, and he considered this to be a "hypertrophic interstitial polyneuritis" of the cauda equina (Lewtas 1957), but Blau and Logue noted similar features of thickened nerve roots superimposed upon the obstruction to the myodil column in 1961 (Blau 1961).

(b) Reduced Disc Height

More recently, progressive loss of disc height was described as associated with root canal stenosis (Crock 1976). In the lower lumbar region the disc height between adjacent vertebral end plates ranges from 15 mm. to 20 mm. This may be reduced to 3 mm. The vacuum phenomenon of Knuttson may be another prominent radiological feature, which may only become evident if a film is taken with the patient standing with the spine hyperextended. A black gas shadow will then appear in the disc space. Sclerosis of the adjacent vertebral bodies was also found to be a prominent feature of disc resorption causing root canal stenosis. Although marginal osteophyte formation was minimal in many patients a ridge of bone was found on myelography to be covered by a thin layer of annular fibre remnants which may project into the spinal canal. End plate settling is seen to be parallel on an antero-posterior radiograph. When root canal stenosis is present in such patients with loss of disc height, it is usually bilateral.

The plain radiographs were reviewed in a series of two hundred and twenty-one patients with spinal stenosis treated at the Nuffield Orthopaedic Centre between 1976 and 1986. No absolute measurement of loss of disc height was made, since this was considered unreliable and unrepeatable and subject to the usual errors of magnification and projection. Instead an opinion was expressed by one of two consultant radiologists and then

re-checked by the author (Fig. 12:1). Two types of reduction of disc height were noted, the commonest type involving a solitary level at which stenosis occurred (eighty-two per cent) and the less common form when multiple levels were involved (eighteen per cent). Thirty-five per cent of patients managed conservatively were found to have reduced disc height at one or more levels and fifty-two per cent of patients managed surgically had significant reduction of disc height. These figures are shown in more detail in Table 12:1 and 12:2.

	FEMALES MANAGED CONSERVATIVELY	MALES MANAGED CONSERVATIVELY
LUMBAR 1-2	3	16
LUMBAR 2-3	10	16
LUMBAR 3-4	12	12
LUMBAR 4-5	29	16
LUMBO-SACRAL	46	40

Table 12:1. The proportion of conservatively treated patients with significant reduction of disc height according to level involved as a percentage of the total number with loss of disc height.

	FEMALES MANAGED SURGICALLY	MALES MANAGED SURGICALLY
LUMBAR 1-2	0	6
LUMBAR 2-3	0	6
LUMBAR 3-4	20	13
LUMBAR 4-5	20	25
LUMBO-SACRAL	60	50

Table 12:2. The proportion of surgical patients with reduced disc height as a percentage of the total number of patients with loss of disc height.



Figure 12:1. Isolated disc resorption may be progressive and associated with root canal stenosis. Central and lateral recess stenosis may develop later from degenerative change of the facet joints and shingling of the lamina.

Nachemson considered it important to distinguish between patients with narrowing of a single disc as with spondylosis, and those with marked multiple disc narrowing. He considered single disc narrowing and spondylosis to be much less important than marked multiple disc narrowing (Nachemson 1976). He did however, also consider facet joint arthrosis, subluxation, and tropism of the facet joints, presence of transitional vertebra, and mild to moderate scoliosis, as well as calcification of the disc to be of dubious significance whilst spondylolisthesis, lumbar osteochondrosis, and congenital and traumatic kyphosis were of much more significance in a review of two thousand five hundred radiographic examinations. Verbiest considered facet joint arthritic change which occurred late in life was always secondary to degenerative change in the discs, and that the facet joints are probably a source of pain in older patients with spinal stenosis (Verbiest 1973).

(c) Spondylolisthesis

Thick, heavy convergent laminae and enlarged pedicles are characteristic of degenerative spinal stenosis. The spinous processes also become thickened and sometimes are approximated. Articular facets become thickened and in some fibrous ankylosis of the joints as well as close approximation of the two lamina may occur. Spondylolisthesis is fairly frequent in patients with localised stenosis usually at the L4-5 level and with an intact neural arch.

Degenerative spondylolisthesis was present in fifty per cent of the female patients in the surgical group at the Nuffield Orthopaedic Centre. Over half of these occurred at the L4-5 level and an equal number occurred at the L3-4 level as at the L5-S1 level in this group (Table 12:3). Spondylolisthesis was noted in only eighteen per cent of males treated conservatively, but in thirty per cent of these it was spondylolytic in type. In ten per cent of the patients managed conservatively, spondylolisthesis was present at two levels. The level most frequently involved was L4-5 in all groups of patients, and in particular in females managed conservatively in whom seventy-eight per cent of spondylolisthesis occurred at this level (Table 12:3).

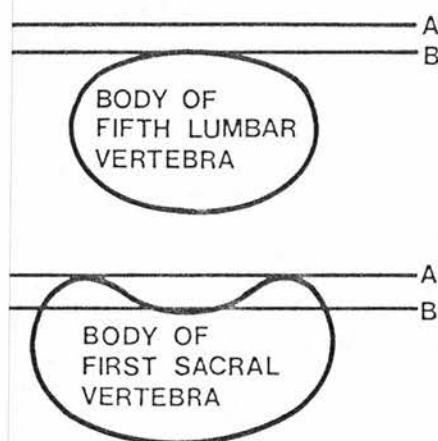
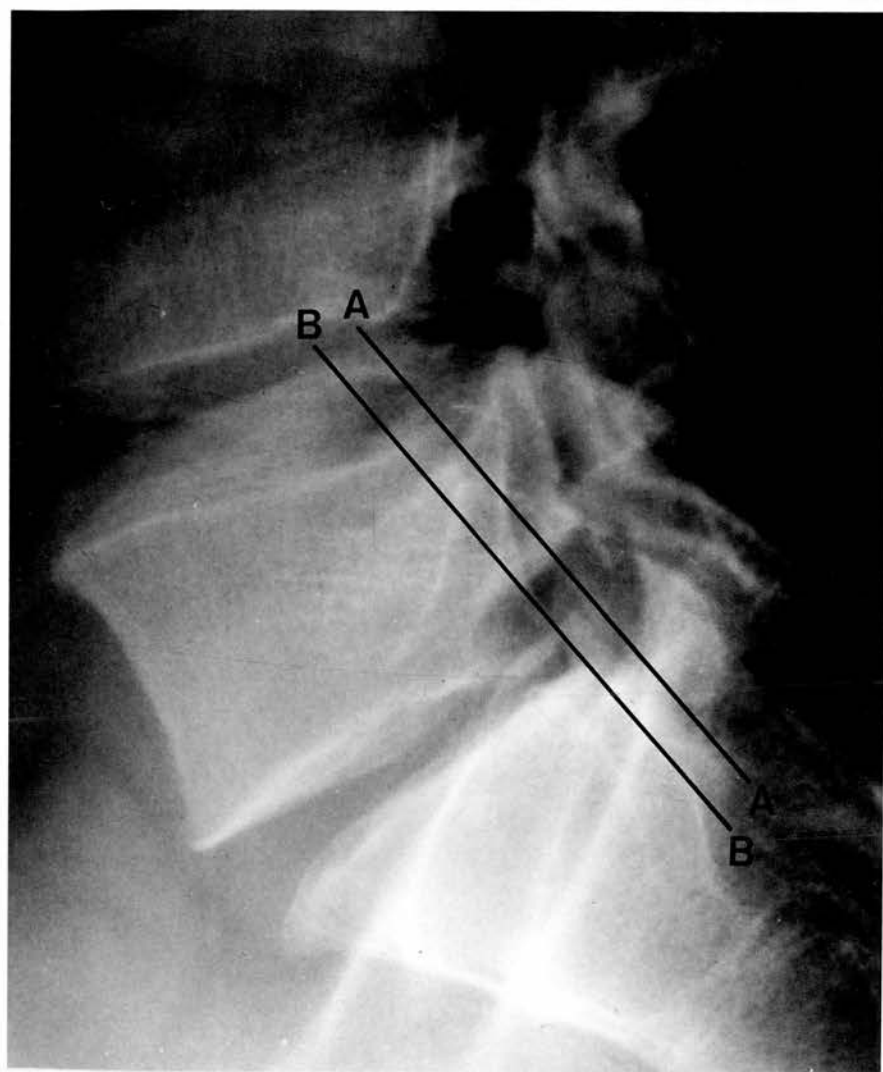
LEVEL	CONSERVATIVE		SURGICAL	
	FEMALE N = 18	MALE N=18	FEMALE N = 50	MALE N = 9
L1-2	0	0	0	0
L2-3	0	0	0	0
L3-4	11	20	22	25
L4-5	78	60	56	50
L5-S1	11	20	22	25

Table 12:3. The frequency of spondylolisthesis in the four sex/management groups as a percentage of the total number in each group (N), and according to the level involved expressed as a percentage of each spondylolisthetic group. In both conservative groups the spondylolisthesis involved two levels in ten per cent of patients.

It should be noted that it is possible to over-diagnose spondylolisthesis at the L5-S1 level through misinterpretation of the plain radiographs. This occurs because the posterior aspect of the body of the first sacral vertebra is scalloped or concave in the transverse plane such that the postero-lateral segments of the body are more noticeable on the lateral projection and create the false impression of a more posteriorly situated body (Fig. 12:2).

(d) Retrolisthesis

Retrolisthesis was present less frequently but again was considerably more common in the female groups. It was noted four times more often in females than in males, and was present in twelve per cent and eleven per cent of females in the conservative and surgical groups respectively (Table 12:4). Unlike spondylolisthesis, the L3-4 level was most frequently involved, but levels L1-2 and L2-3 were also affected. The lumbo-sacral level was only rarely the site of retrolisthesis.



(a) Lateral radiograph of the lumbo-sacral junction suggesting a spondylolisthesis

(b) Transverse section of body of sacrum to illustrate the location of lines A and B

Figure 12:2 (a) & (b) Diagrams to illustrate a radiological artefact which, when not appreciated, may result in the diagnosis of a lumbo-sacral spondylolisthesis. It should be noted that the anterior part of the body of the fifth lumbar vertebra is not displaced forwards.

LEVEL	CONSERVATIVE		SURGICAL	
	FEMALE N = 12	MALE N = 5	FEMALE N = 11	MALE N = 0
L1-2	17	0	0	0
L2-3	33	0	50	0
L3-4	50	33	50	0
L4-5	0	33	0	0
L5-S1	0	33	0	0

Table 12:4. The frequency of retrolisthesis in the four sex/management groups expressed initially as a percentage of the total group (N) and secondly according to the level involved as a percentage of each retrolisthetic group.

Spondylolisthesis, particularly at the L4-5 level, usually indicates the level of stenosis demonstrated myelographically. This is not invariably the case, however (Fig. 12:3). Retrolisthesis on the other hand seldom is severe enough to result in central canal stenosis. It may, however, affect the intervertebral foramina by diminishing the available space for the nerve roots.

Flexion and extension lateral films are useful in identifying abnormal mobility but this examination unfortunately was not performed in this series.

(e) Facet Joint Osteo-arthritis

Osteo-arthritis of the lumbar facet joints is extremely common in patients with and without spinal stenosis. The changes of facet joint degeneration are evident at autopsy as early as the third decade of life, and appear to begin in the upper lumbar segments, extending to the lower lumbar segments where degeneration often progresses more rapidly. The presence of facet joint arthritis is evident radiologically as:

- (i) Reduction of joint space (sometimes not well visualised because of the rotational alignment of the joint)
- (ii) Sub-chondral sclerosis
- (iii) Marginal osteophytes
- (iv) Sub-chondral cyst formation
- (v) Subluxation of the facet joint.



Figure 12:3. (a) The lateral radiograph of a patient (B.G.) with neurogenic claudication, demonstrating spondylolisthesis at the L4-5 level. This one would suspect to be the level of stenosis. (b) A radiculogram of the same patient (B.G.). It is clear that stenosis is present at level above the spondylolisthesis. The radiculogram continues to provide a most useful screening examination for firstly the localisation of the level of stenosis and secondly to exclude any intrathecal or extradural space-occupying lesion in the upper lumbar and lower thoracic spinal canal.



Figure **12:3b** The A.P. and lateral views of the myelogram of the fifty-five year old patient (B.G.) whose plain radiographs are shown in Figure **12:3a** . There is no evidence of stenosis at the lumbo-sacral or L4-5 levels at the sites of maximum plain X-Ray findings, but at the L2-3 and L3-4 levels there is severe combined degenerative and disc stenosis with almost complete "spinal block". Stenosis at this level can account for L5 and S1 root signs.

Facet joint tropism predisposes to advanced degenerative change in the contralateral facet joint by displacing the axis of rotation of the intervertebral joint and essentially blocking or reducing movement at the tropic joint (Chapter 9).

The radiological changes of facet joint osteo-arthritis are usually symmetrical involving predominantly one level or multiple levels. The lumbar 4-5 segment is, however, most frequently affected (Table 12:5). Unilateral changes occur in association with

- (i) Facet joint tropism
- (ii) Asymmetrical transitional lumbo-sacral vertebrae
- (iii) Developmental anomalies of the facet joint (Chapter 5) (Fig. 12:4)
- (iv) Trauma.

Enlargement of the inferior articular facet tends to encroach upon the central part of the spinal canal and enlargement of the superior articular facet tends to restrict the nerve root canal. Clearly the two articular facets are usually both enlarged, but the degree of stenosis thereby produced is dependent upon a number of factors, including

- (i) Associated loss of disc height
- (ii) Pre-existing shape and volume of the spinal canal and nerve root canals
- (iii) Degree of mobility particularly extension and axial rotation permitted at the involved level.

On review of the plain radiographs taken at the time of presentation of two hundred and twenty-one patients with spinal stenosis at the Nuffield Orthopaedic Centre, the frequency of severe facet joint osteo-arthritis as defined above was obtained. This is shown in Table 12:5.

	CONSERVATIVE (N = 149)	SURGICAL (N = 72)
FEMALE (N=88)	72	45
MALE (N=133)	76	58

Table 12:5. The incidence of severe osteo-arthritic change of one or more facet joints in a population presenting to hospital with spinal stenosis, expressed as a percentage of this population according to sex and treatment group.



Figure 12:4. Antero-posterior radiograph of the lower lumbar spine of a fifty-five year old patient (E.T.) with combined developmental-degenerative stenosis. Note the shingling of the laminae. The facet joints also are very close to the midline.

The unexpectedly low incidence in both surgical groups when compared with the conservative groups may be explained by a number of factors: firstly the high incidence of degenerative spondylolisthesis (forty per cent) as the cause of stenosis in the female surgical group; secondly the high incidence of a combination of degenerative and disc disease (twenty-three per cent) in the male surgical group; and thirdly by the incidence of developmental stenosis in ten per cent of the male surgical and five per cent of the female surgical groups. In these conditions, severe stenosis may be present with minimal radiological evidence of facet joint degeneration.

The levels at which severe facet joint osteo-arthritis was evident are shown in Table 12:6.

LEVEL	FEMALE MEDICAL (N=63)	MALE MEDICAL (N=86)	FEMALE SURGICAL (N=25)	MALE SURGICAL (N=47)
L1-2	0	17	0	6
L2-3	19	17	0	6
L3-4	22	21	12	19
L4-5	39	23	50	38
L5-S1	20	22	38	31

Table 12:6. The levels of severe facet joint osteo-arthritis according to sex/management groups expressed as a percentage of each group.

In approximately ten per cent of patients in each group multiple levels were severe affected. It is clear from Table 12:6 that the L4-5 level is most frequently involved followed closely by the lumbo-sacral level. It should be noted that the level of facet joint osteo-arthritis as observed on plain radiographs was not always the level of maximum spinal canal stenosis. This applies particularly at the lumbo-sacral level.

(f) Transitional Vertebrae

The presence of transitional vertebrae is said not to increase the incidence of low back pain (Timmi 1977). However, since eighty per cent of people experience back pain at some time in their life, and the prevalence of transitional lumbo-sacral vertebrae in the general population

is unknown, it seems difficult to substantiate this statement. In this series, there was no difference between the incidence of transitional vertebrae in the conservatively or surgically treated groups (Table 12:7).

	CONSERVATIVE	SURGICAL
FEMALE	8	5
MALE	4	5

Table 12:7. The incidence of transitional vertebrae at the lumbo-sacral junction in a series of two hundred and twenty-one patients with spinal stenosis according to sex and management groups, expressed as a percentage of each group. There is no difference between the four groups.

MEASUREMENT OF THE SPINAL CANAL IN SPINAL STENOSIS

Verbiest reported that the interpedicular distance which can clearly be measured from radiographs is normal in patients with spinal stenosis (Verbiest 1955). He found however measurement of the antero-posterior diameter from routine radiographs impossible, and even sagittal tomographs were of little help because of scoliosis of the lumbar spine in many patients. Because of this difficulty he went so far as to design an instrument for measuring the antero-posterior distance in the midline perpendicular from the arch to the body. He considered that the thickness of the ligament opposite the body and the thickness of the epidural vein overlying this did not amount to more than 0.75 mm., and therefore having measured several times he considered his accuracy to be within 1 mm.

On the basis of a considerable number of measurements and on the figures produced by Huizinga in 1952 using cadaver spines (Huizinga 1952) he concluded that:

1. Developmental narrowing of the lumbar canal caused by an abnormally short antero-posterior diameter does exist
2. In the presence of a narrow although not abnormally narrow lumbar vertebral canal, additional slight deformities such as posterior lipping or posterior disc protrusion can cause symptoms of compression. Neurological signs were few in the patients described by Verbiest, but myelography did show an almost complete block at the level of the protrusion.

3. In the presence of an abnormally narrow lumbar canal, a small disc protrusion may cause considerable damage to the caudal nerve roots. He also considered that the ligamentum flavum showed no abnormal thickness or hypertrophy, and he raised the possibility of the medico-legal implications of narrowness of the spinal canal being the main determining factor in working men who developed sciatica or spinal stenosis whilst at work.

Difficulties in measurement of the antero-posterior spinal canal diameter on plain radiographs have continued (Fig. 12:5). Even sagittal tomography does not permit measurement of the mid-sagittal diameter. This finding has been confirmed by many authors (Verbiest 1975).

In the cervical spine, the antero-posterior measurement of the spinal canal is easily assessed on the lateral radiograph, and absolute values have been defined for normal individuals (Wolf 1956; Paine 1957; Burrows 1963) so that when the cervical spine has a small canal this can be readily appreciated. This is because the cervical spinal canal is oval in shape: the lumbar spinal canal however is trefoil (Fig. 12:6).

In the lumbar region however normal maximum and minimum antero-posterior measurements have been established for the spinal canal using human skeletons (Huizinga 1952), but this is clearly of little relevance in establishing a clinical diagnosis. Jones and Thomson attempted to relate the antero-posterior diameter of the spinal canal and interpedicular distance to the size of the vertebral body (Jones 1968). They found this method useful in thirteen patients with narrow lumbar canals and spondylosis, of whom ten came to surgery.

This method subsequently became known as the "spinal index". The antero-posterior diameter of the spinal canal on the lateral radiograph was measured from the middle of the back of the vertebral body to the base of the spinous process. The interpedicular distance was measured on the antero-posterior radiograph. These two values were multiplied together to obtain the product AB. The antero-posterior and transverse diameters at the middle of the same vertebral body were then measured, and multiplied to give a product CD (Fig. 12:7).

Jones and Thomson referred to this as the "canal-body ratio", and they considered that most ratios should lie within the range of 1:2 to 1:4.5, the former indicating a large canal and the latter a small canal. Patients with spinal stenosis therefore have a ratio above 1:4.5. Clearly this method abolishes the need for correction of the magnification factor of the

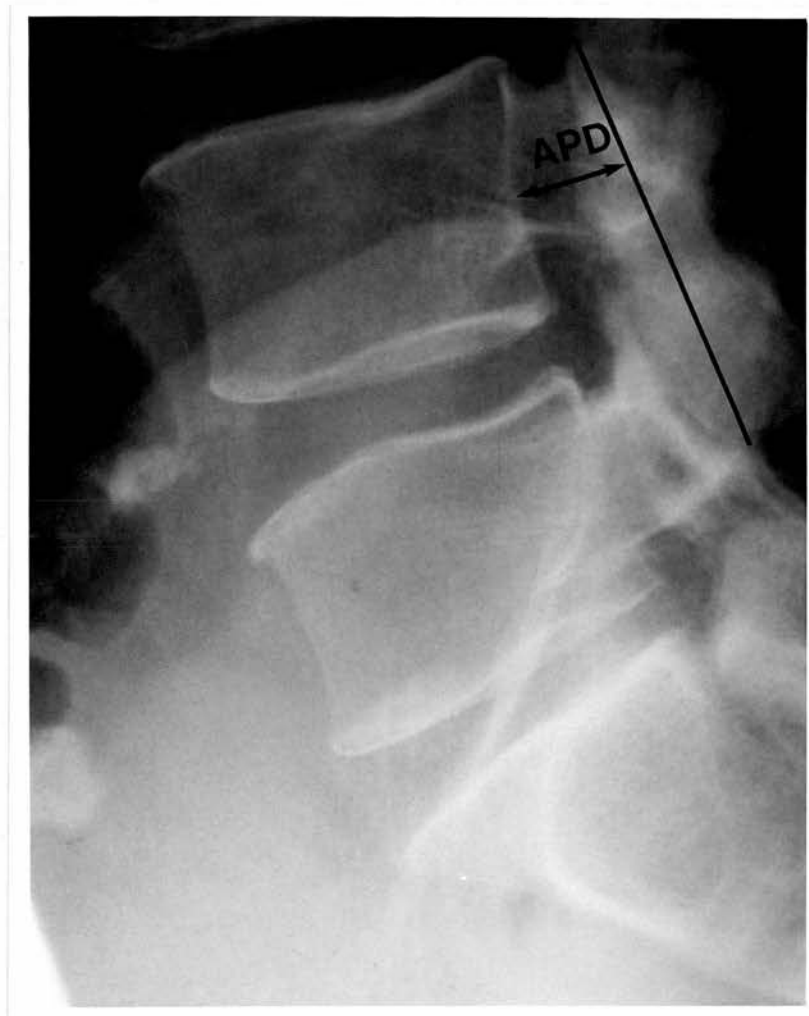
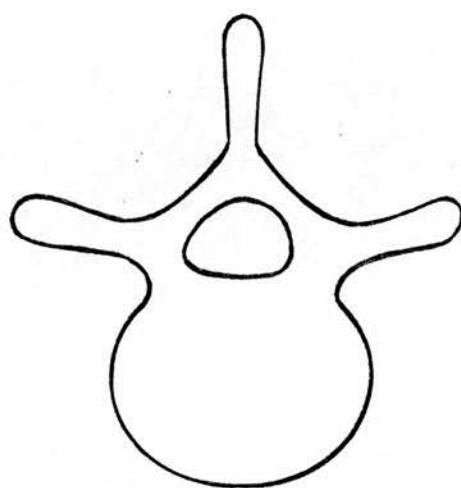
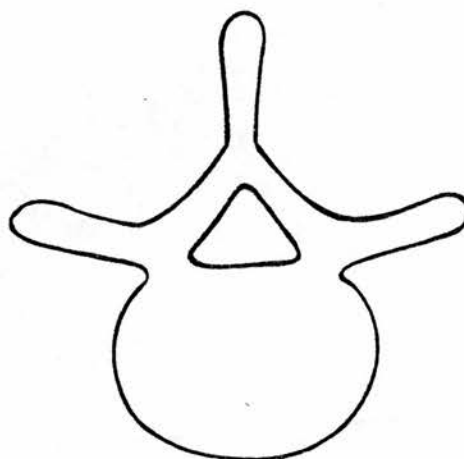


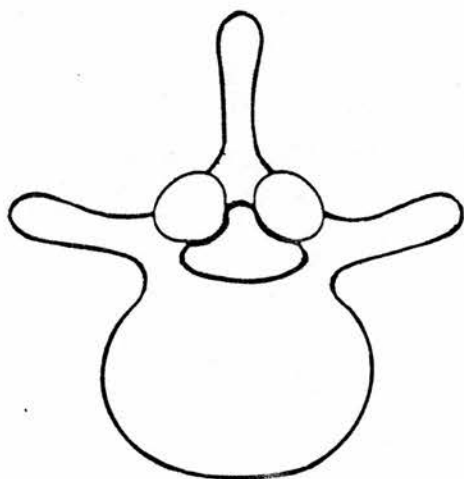
Figure 12:5. Measurement of the antero-posterior diameter of the spinal canal is unreliable on plain radiographs but in this example (E.T.) of developmental stenosis there is obvious failure of the L5 pedicle to attain its full height which is strongly suggestive of developmental spinal stenosis.



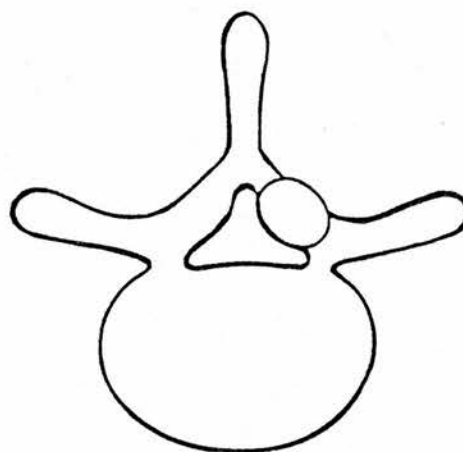
OVAL
Long pedicles
Coronal lamina



TRIANGULAR
Short pedicles
Lamina more sagittally
orientated

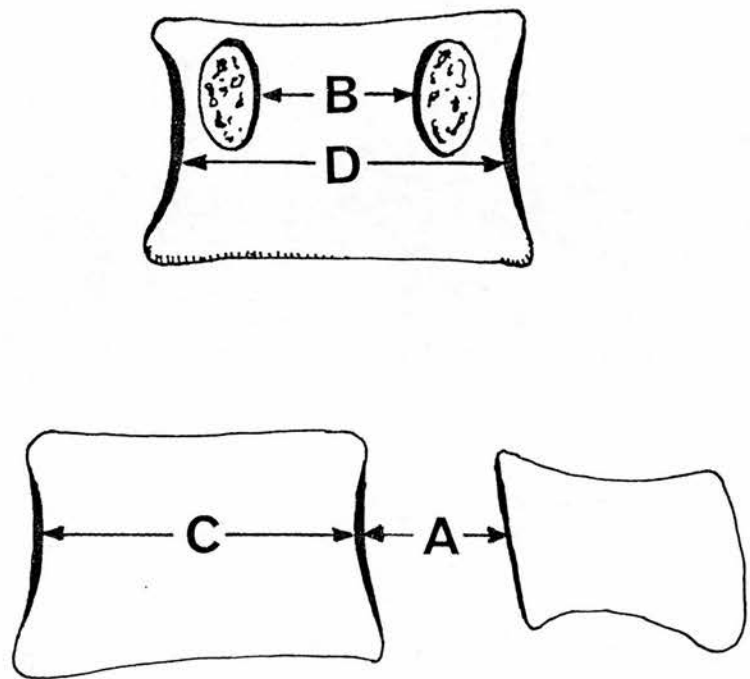


DELTOID
Long pedicles
Intrusion by thickened
lamina or facet joints



TREFOIL
Short pedicles and minimal
facet joint intrusion or
long pedicles and major facet
joint intrusion

Figure 12:6. The shape and cross-sectional area of the spinal canal is more important than its absolute sagittal or coronal dimensions. The spinal canal may be oval at one level and trefoil at another.



AB : CD	Canal - body ratio
Normal Range	1 : 2 to 1 : 4.5
Spinal Stenosis	> 1 : 4.5

Figure 12:7. The "canal - body ratio" or "spinal index" of Jones and Thomson overcomes the problem of radiological magnification by comparing absolute radiological measurements and expressing the result as a ratio. The error in measurement A (antero-posterior canal diameter) however, remains large

radiograph. Getty reported that seventy-four per cent of the patients with spinal stenosis who came to surgery (twenty-three patients), had an abnormal spinal index, whilst the remainder were within normal limits.

Eisenstein however considered the spinal index of Jones and Thomson not to be a valid indicator of stenosis (Eisenstein 1977). He preferred an absolute measurement and stated that the lower limit of normal of the antero-posterior diameter of the lumbar canal is 15 mm. The antero-posterior diameter of the lumbar canal is variable however and is narrowest at the second to fourth segments. The posterior limit of the spinal canal can most easily be determined by drawing a line joining the apex of the superior articular facet to the inverted apex of the inferior articular facet. Using this measurement it appears that an antero-posterior diameter of less than 12 mm. is pathological. Eisenstein however confirmed that the shape of the canal was considerably more important than either the sagittal or transverse diameters (Fig. 12:8).

Larsen and Smith measured the size of the vertebral body in patients with and without myelographically demonstrable spinal stenosis (Larsen 1980). The following measurements of the vertebral bodies were made:

- (a) the intermediate width of the vertebral body assessed as the shortest transverse diameter measured half way between the upper and lower vertebral surfaces;
- (b) the intermediate depth (or sagittal diameter) defined as the shortest antero-posterior diameter measured in the mid-sagittal plane half way between the upper and lower vertebral body surfaces.

These points of reference were chosen in order to avoid as far as possible the effect of degenerative lesions, especially common at the edges of the vertebra. They found no difference at all in the mid-sagittal or mid-transverse diameters of the vertebral bodies in those patients with spinal stenosis compared with those patients who did not have spinal stenosis. There was a slight increase in the diameter from the first to the third lumbar vertebra, but hardly any difference between the fourth and fifth lumbar vertebra in the sagittal body diameter.

Larsen and Smith also confirmed the findings of Huizinga and colleagues, that the sagittal diameter of the spinal canal gradually decreases from L1 to L3, but that there is no significant difference between L3 and L4 and it increases again from L4 to L5 (Huizinga 1952). This is compatible with the predilection of spinal stenosis of the lumbar canal for the L3-4 and L4-5 levels despite the high incidence of degenerative change at the lumbo-sacral junction.

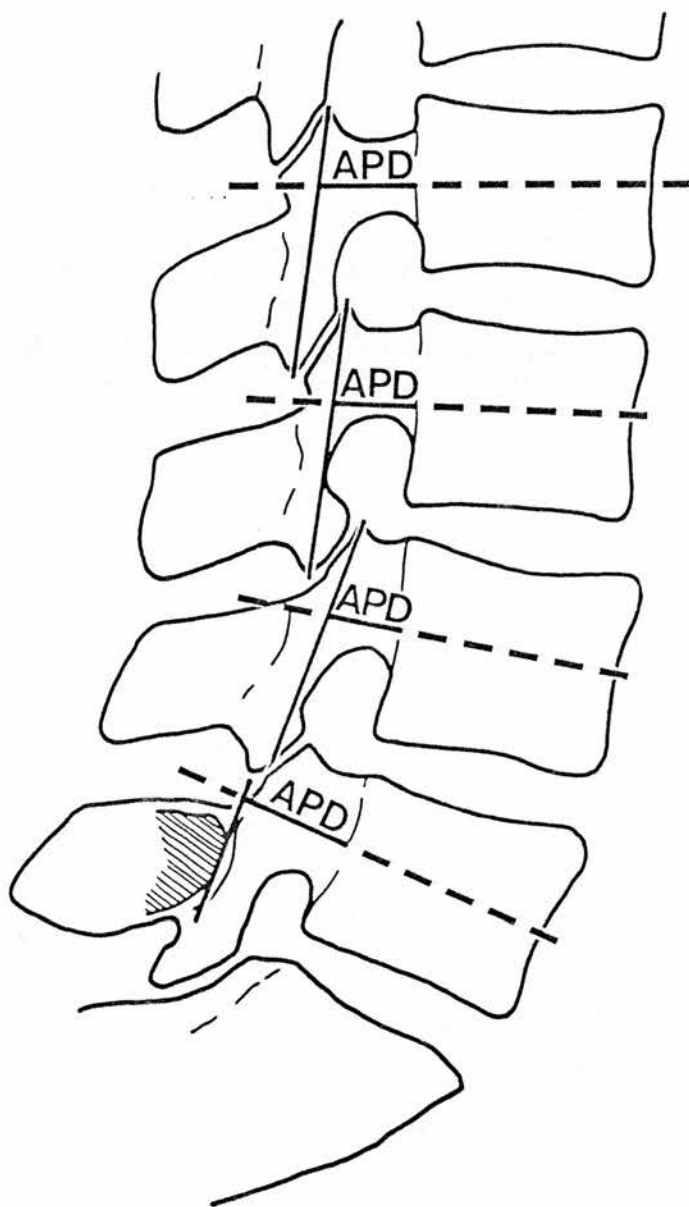


Figure 12:8. The antero-posterior diameter (APD) of the upper four lumbar vertebrae was measured by Eisenstein from the back of the vertebral body to a line joining the apices of the superior and inferior articular processes. An APD of less than 12 mm. is pathological.

Any increase in size of the vertebral body in its horizontal diameter beyond the age when growth usually ceases is dependent upon periosteal bone growth, whilst vertical height of the vertebral body is dependent upon enchondral bone apposition which terminates at the end of puberty. Ramani in 1976 pointed out that patients with prolapsed lumbar intervertebral discs coming to surgery tended to have spinal canals which were narrower than normal (Ramani 1976).

Elliot pointed out that the cross-sectional area of the spinal cord is dependent upon sex, height and weight (Elliot 1945), and the same holds true for the dural sac and the included subarachnoid space at least in the antero-posterior diameter (De Villiers 1976). Larsen's and Smith's work confirms the supposition that lumbar canal stenosis is based upon developmental or degenerative lesions in the posterior part of the vertebral canal, and not in the vertebral bodies.

RADICULOGRAPHY IN SPINAL STENOSIS

Teng observed in 1962 that osteophytes may not be revealed on the plain radiograph of the lumbar spine, due to inadequate calcium deposition, but they are well demonstrated on myelography (Teng 1963). A solitary defect of this type may resemble a centrally displaced disc on myelography, but multiple defects can be considered to be characteristic of spondylosis. He described the myelographic findings of spondylosis as:

1. Calcified osteophytes indenting the anterior margin of the Pantopaque column
2. Posterior defects caused by the hypertrophic posterior wall of the spinal canal
3. Multiple defects at different lumbar interspaces
4. Multiple constricting defects, hour-glass or wasp-waist in appearance, at different interspaces above a complete obstruction in a lateral projection
5. A general narrowing of the antero-posterior diameter of the lumbar spinal canal at the interspace levels. He found that the most frequently involved areas in order of frequency are L4-5, L3-4, and L2-3, whereas in herniation of the nucleus pulposus they were quite clearly L4-5 and L5-S1. These findings have subsequently been confirmed by other authors.

The first reports of the use of a contrast material with a lower osmolarity than myodil appeared in 1969 (Metzger 1969). By 1976 extensive

experience had accumulated of its use in Great Britain and Western Europe (Gonsette 1971; Grainger 1971). They indicated clearly the additional benefit of the use of water-soluble contrast myelography in the demonstration of the nerve roots and their sheaths. There was no doubt that a water-soluble contrast material could extend further along the root sheaths than an oil-based medium, and could therefore give a more accurate estimate of non-filling of the root sheaths which indirectly indicated nerve root entrapment (Fig. 12:9).

Subsequently the use of oil-based media was banned in Scandinavian countries because of the risk of late arachnoiditis (Nachemson 1976). Metrizamide however was found to be slightly epileptogenic, and so patients with a history of seizures or alcoholism should be avoided. Also Metrizamide should be avoided in those patients using tricyclic anti-depressive drugs and analeptic drugs and other agents known to have an effect on the convulsive threshold. Earlier reports indicated that Metrizamide improved nerve root imaging providing a ninety-five per cent correct diagnosis rate in three hundred surgically verified cases of nerve root involvement, with no serious complications (Irtam 1974). These were cases not only of spinal stenosis, but also of disc prolapse. In patients with severe spinal stenosis the cerebro-spinal fluid protein is very often elevated up to 0.9 g/l. In such patients with shingling of the laminae considerable difficulty may be experienced in performing a lumbar puncture because of the narrowed interlaminar space (Martens 1984).

The use of contrast material has been used to give some idea of the size of the thecal sac, by measuring the quantity of contrast material required to fill the thecal sac up to the middle of the body of L3 with the patient almost erect. Usually between 10 ml. and 15 ml. is sufficient (Epstein 1977). When this level is attained with less than 8 ml., the dural sac is very likely to be constricted in a small spinal canal, but this is not invariably so. Another cause of difficulty in performing a lumbar puncture is the marked thinning of the dural sac which may occur when the patient is not relaxed or is straining. At times the volume of the dural sac is so diminished that there is hardly room for the tip of the needle. In such patients care is required to make sure that the patient is quietly at rest during lumbar puncture. The extent of the myelographic defect is sometimes increased during hyperextension of the lumbar spine and relieved in flexion. Thickening of the nerve roots of the cauda equina is frequently seen especially in those patients with severe obstructions of



Figure 12:9. Details of the radiculogram of the fifty-three year old fitter (W.K.) demonstrating that maximal stenosis occurs at the motion segment and not the bony arch. At the cephalad edge of the L5 lamina the dural sac fills well with contrast, but the under-filling proximal to this extends beyond the level of the disc alone and in fact extends under the caudal part of the L4 lamina as far as the proximal insertion of the ligamentum flavum. Clearly, the stenosis is not purely antero-posterior, but is concentric to produce a "Napkin Ring" appearance, with the degenerate facet joints contributing to the narrowing. A combined degenerative-disc type of stenosis

long duration. In some patients the nerve roots are elongated, and tortuous and resemble venous varicosities (Fig. 12:10).

Verbiest measured the antero-posterior mid-sagittal diameter of the contrast column at both the cephalad and caudal borders of the laminae. He reported "absolute stenosis" as that which may produce compression of the caudal nerve roots in the absence of other compressive agents, occurring in association with a mid-sagittal diameter of 10 mm. or less. He also coined the term "relative stenosis", in which small spondylotic ridges or central soft protrusions or hypertrophy of the ligamentum flavum would produce compression of the caudal nerve roots, with a mid-sagittal diameter varying from 10 mm. to 12 mm. (Verbiest 1975). Epstein attached little significance to measurements greater than 13 mm. (Epstein 1962), and Davatchi considered a mid-sagittal diameter smaller than 11.5 mm. to be definitely pathological (Davatchi 1969).

The use of water-soluble contrast material improved the reliability of diagnosis of lumbar root compression, from eighty-three per cent using myodil (Hakelius 1972), to ninety-five per cent correct diagnosis using Metrizamide (Irstam 1974) in three hundred surgically verified cases.

Getty used myelography to classify a group of thirty-one patients (Getty 1980) into three broad groups of degenerative, mixed, and developmental spinal stenosis according to the criteria of Kirkaldy-Willis (Kirkaldy-Willis 1974). In this series myelography demonstrated that twenty patients (sixty-five per cent) had degenerative lumbar spinal stenosis. There were eight patients (twenty-five per cent) with degenerative stenosis in a developmentally narrow canal - that of mixed stenosis. The antero-posterior dimension of the canal at myelography was uniformly less than 14 mm. over most of the lumbar spine. Three patients (ten per cent) had idiopathic developmental lumbar spinal stenosis with uniform narrowing over almost the whole length of the lumbar bony canal. The antero-posterior dimension of the canal as determined by direct measurement of the lateral myelogram was less than 14 mm. throughout the lumbar spine (Getty 1980).

DISC PROLAPSE COMPARED MYELOGRAPHICALLY WITH COMBINED DISC-DEGENERATIVE SPINAL STENOSIS

One of the most important myelographic distinctions to make is whether the filling defect represents a simple disc prolapse in a normal spinal canal or whether it represents a disc prolapse (or osteophytic ridge)



Figure 12:10 (a)



Figure 12:10 (b)

Figure 12:10 (a). The radiculogram of a fifty-three year old fitter (W.K.) with generalised spinal stenosis most prominent at the L4-5 level where there is almost a complete block. The irregularity adjacent to the L3 vertebra is more likely due to distended epidural veins than a redundant nerve root.

Figure 12:10 (b). The lateral radiculogram of the same patient (W.K.) with generalised stenosis. Reduced antero-posterior and lateral dimensions of the spinal canal in a young man with only minor degenerative change would suggest the presence of developmental stenosis. Note, however, that the narrowing is most prominent at the motion segment and not at the cranial part of the lamina arch as one would anticipate in a purely bony stenosis.

in a combined disc-degenerate stenotic (Fig. 12:11). A number of facts may assist in making this distinction:

- (i) The age of the patient: in patients over forty there should be a high index of suspicion that many of the changes are degenerative. However a patient under forty may present with severe stenosis when the spinal canal is developmentally small.
- (ii) A localised concentric constriction of the contrast column clearly evident on the antero-posterior film as reduced density at the motion segment of the spine: the "napkin ring" sign (Fig. 12:12). This is usually degenerative in origin, but may be the result of a large central disc prolapse. If the defect is not at the motion segment, this may represent a sequestered nucleus pulposus or an extradural (or intrathecal) space-occupying lesion.
- (iii) The oblique radiculograph is usually obtained to provide a detailed projection of the nerve root. It also, however, provides information on the postero-lateral aspect of the spinal canal and is a useful guide to indentation of the contrast column by the ligamentum flavum (Fig. 12:13a, 12:13b, 12:14, 12:15).
- (iv) Functional myelography: the myelographic pattern of spinal stenosis is frequently misinterpreted as a disc herniation. Functional myelography is based on the observation that myelographic blocks can be reduced by flexion of the spine and worsened by extension. A close correlation appears to exist between the complaints considered to be caused by lumbar spinal stenosis and the degree of stenosis demonstrated on a functional myelographic examination (Grabias 1980). A minimum antero-posterior diameter in extension of approximately 15 mm. (true value 10.5 mm.) is probably the lower limit of normal.

The difference between the antero-posterior diameter of the contrast column in flexion and extension is normally small. In patients with spinal stenosis, however, there is a considerable difference with the volume of the dural sac opening up in flexion and significantly reduced in extension. This difference appears to be characteristic of this condition.

Wilmink performed myelographic flexion/extension studies in four groups each containing ten patients. The groups were patients with (a) normal myelograms, (b) bilateral nerve root compression at L4-5, (c) unilateral nerve root compression at L4-5, and (d) nerve root compression at L5-S1 (Wilmink 1984). The aim of the investigation was to use the flexion/extension radiograph to assess the part played by spinal stenosis in nerve



Figure 12:11. Lateral view of the radiculogram of the fifty-three year old fitter (W.K.) demonstrating the part played by disc bulging in the precipitation of symptoms of spinal stenosis. Note the lack of dorsal indentation of the contrast column at this level. Dorsal indentation is usually most noticeable on the oblique film since the sagittal antero-posterior diameter of the canal is not compromised, but oblique diameter is.

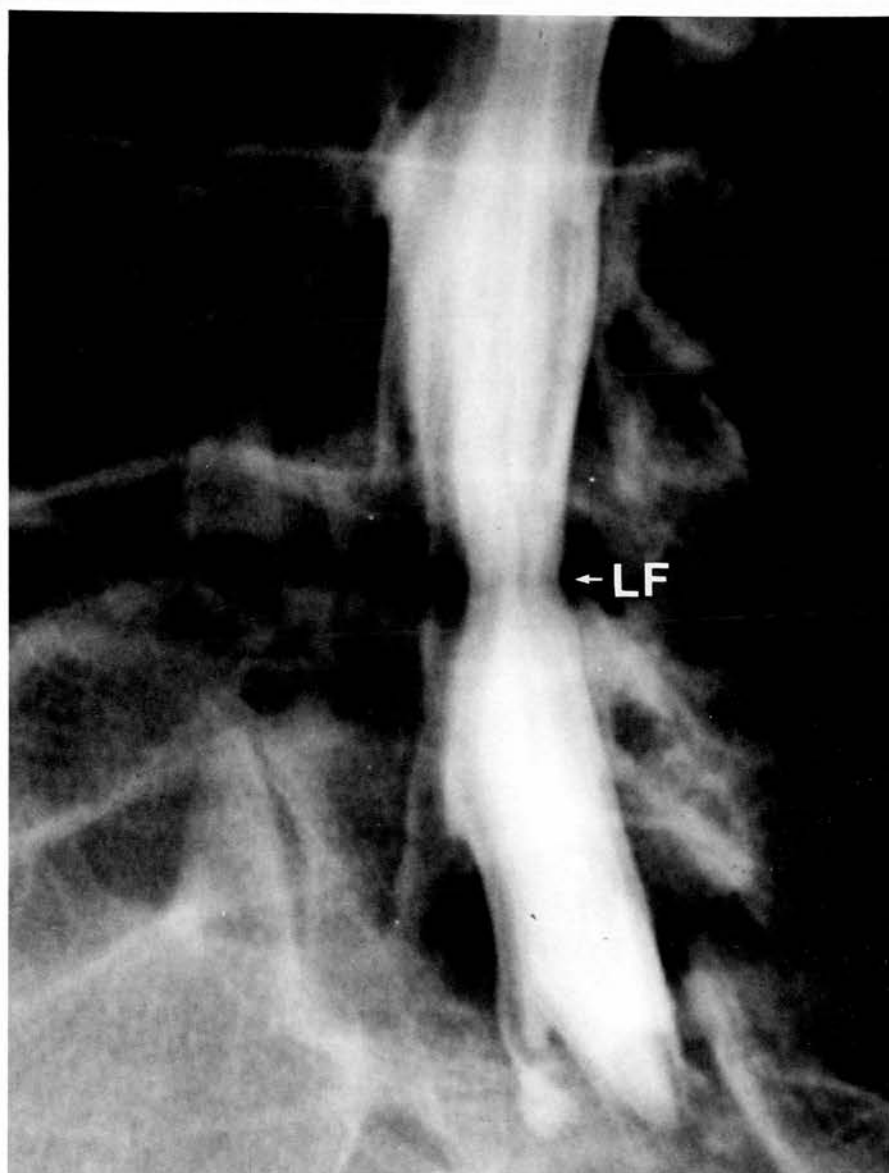


Figure 12: 12. The right oblique view of the radiculogram of a patient who at first glance may be thought to have simply a prolapsed intervertebral disc causing cut off of the L5 nerve root. It should however be noted that the contrast column is less dense at this disc level across its entire width and that there is ligamentum flavum indentation (LF) of the postero-lateral aspect of the column of contrast. This patient would respond poorly to a simple fenestration and discectomy and requires more extensive decompression. If in doubt, a CT scan will clarify the cause of stenosis.

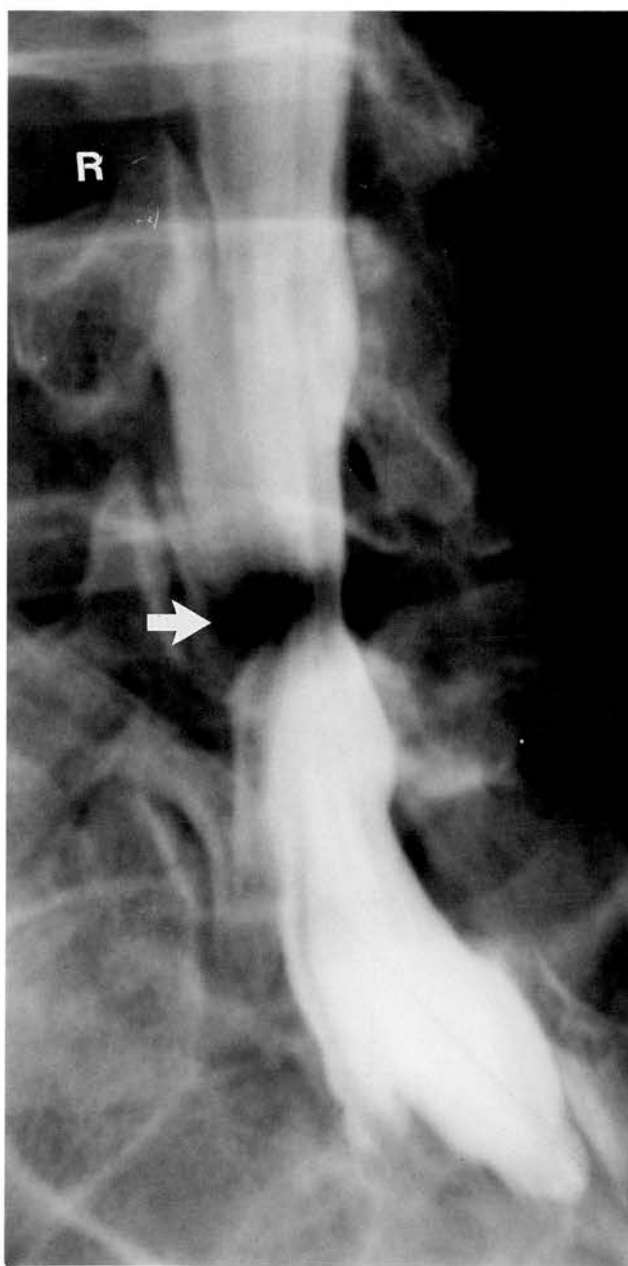


Figure 12: 13a.

The radiculogram of a sixty-year old ex-policeman (D.S.) who presented with acute onset of right sided sciatica. A disc prolapse is indicated by the arrow and was surgically removed. He made an excellent recovery and returned to climbing in the Scottish Highlands. It was not appreciated at the time however that he also had the radiological features of spinal stenosis.



Figure 12: 13b. The patient D.S. returned nine months later with further numbness and weakness in both legs on exercise and with recurrence of right sided sciatica. A repeat radiculogram (sides reversed) shows persistence of spinal stenosis with ligamentum flavum indentation as described above, despite a satisfactory result from discectomy. He responded well to a formal spinal decompression, which he should have undergone at the first operation.

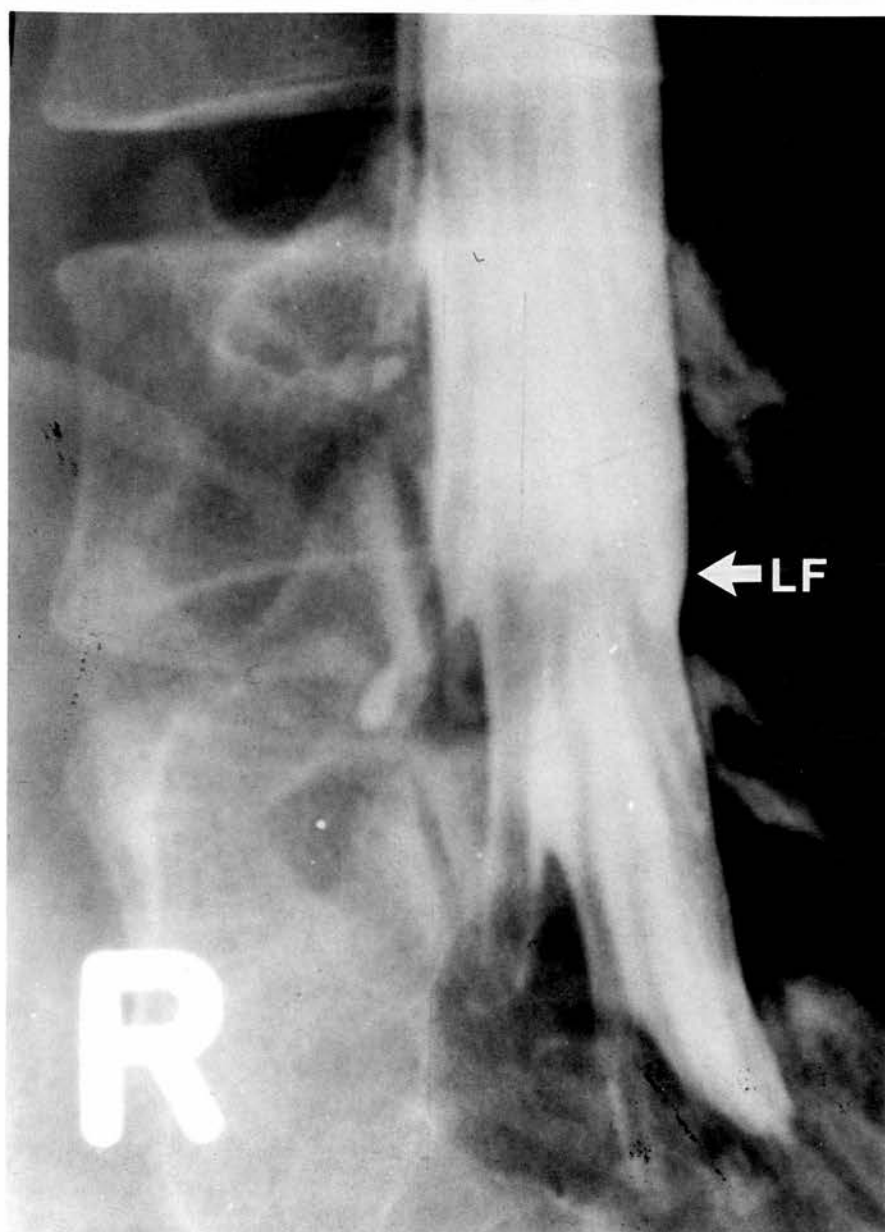


Figure 12:14. The right oblique view of the radiculogram of a forty-five year old male with right sided sciatica. Failure of the right L5 nerve root to fill at disc level is clearly associated with facet joint degeneration, but it is also important to note tha the ligamentum flavum on the left side at the L4-5 level is not causing any indentation of the contrast column and is in fact allowing full expansion of the dural sac at this interspace (LF).

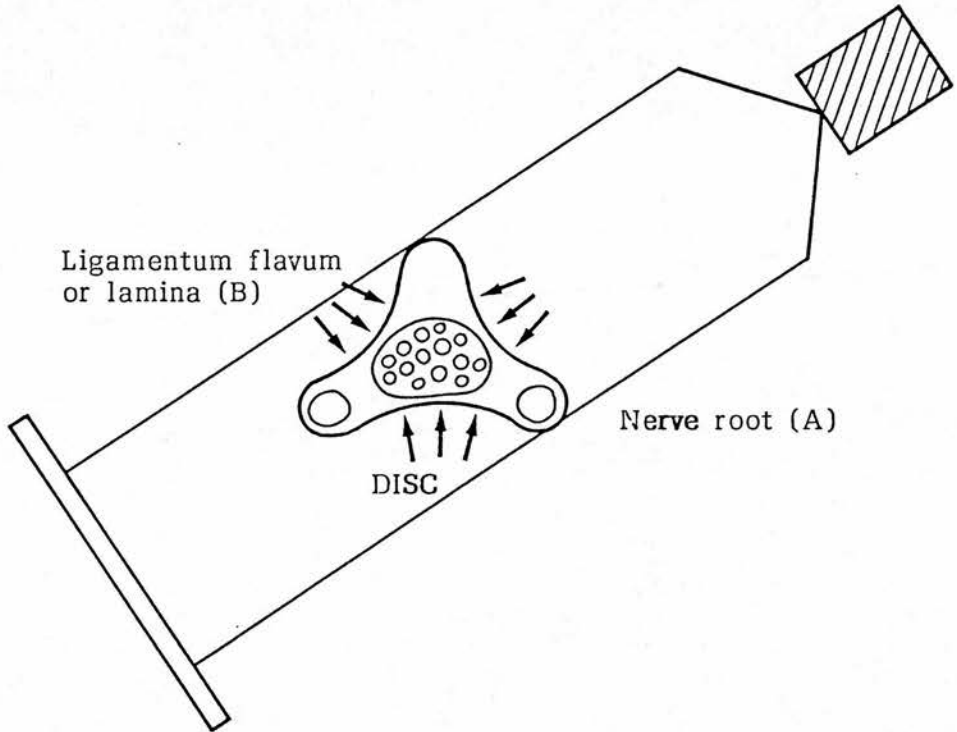


Figure 12: 15. The oblique projection of the radiculogram demonstrates not only details of nerve root compression (A) but also indentation of the contrast column from lamina hypertrophy, ligamentum flavum thickening, or both (B)

root compression . The results suggested that spinal stenosis did contribute significantly to bilateral nerve root compression at the L4-5 level and to a lesser extent in unilateral nerve root compression at the L4-5 level. The flexion/extension films were of little value in assessing compression at the L5-S1 level however when stenosis was more often involving the lateral recess. Wilmink recommended that in myelographic L4-5 nerve root compression additional flexion/extension studies should be performed to evaluate the possible role of stenosis in contributing to this compression. It is important to be aware that in nerve root compression caused by disc extrusion, concomitant spinal stenosis may necessitate a decompressive laminectomy rather than simple fenestration and discectomy.

Examination techniques performed in extension (prone lumbar myelography) tend to enhance abnormalities, while techniques in which the spine is more or less flexed (epidural phlebography, computed tomography) tend to mask them. In addition there may be a discrepancy between the picture during surgery (usually in lumbar flexion) and the situation in which a patient experiences symptoms (usually in lumbar extension in spinal stenosis) (Fig. 12:16).

Wilmink routinely includes in every lumbar myelogram sitting flexion/extension films in lateral projection and, if considered necessary, also in oblique projections. This positional comparison is quickly and easily performed during myelography, but difficult to achieve accurately with CT and virtually impossible with epidural phlebography (Wilmink 1983).

Radiculography was performed on ninety-two of the two hundred and twenty-one patients with clinical features of spinal stenosis at the Nuffield Orthopaedic Centre. Clearly all patients considered for surgery underwent radiculography but only twenty-six per cent of females in the conservative group and only thirty-five per cent of males in the conservative group were subjected to this investigation. Ninety-two per cent of those females in the conservative group had a partial block and eight per cent a complete block of the contrast column. Of the males examined in the conservative group, eighty-eight per cent had a partial block and twelve per cent a complete block. These figures are shown in more detail in Table 12:8, which indicates the levels involved.

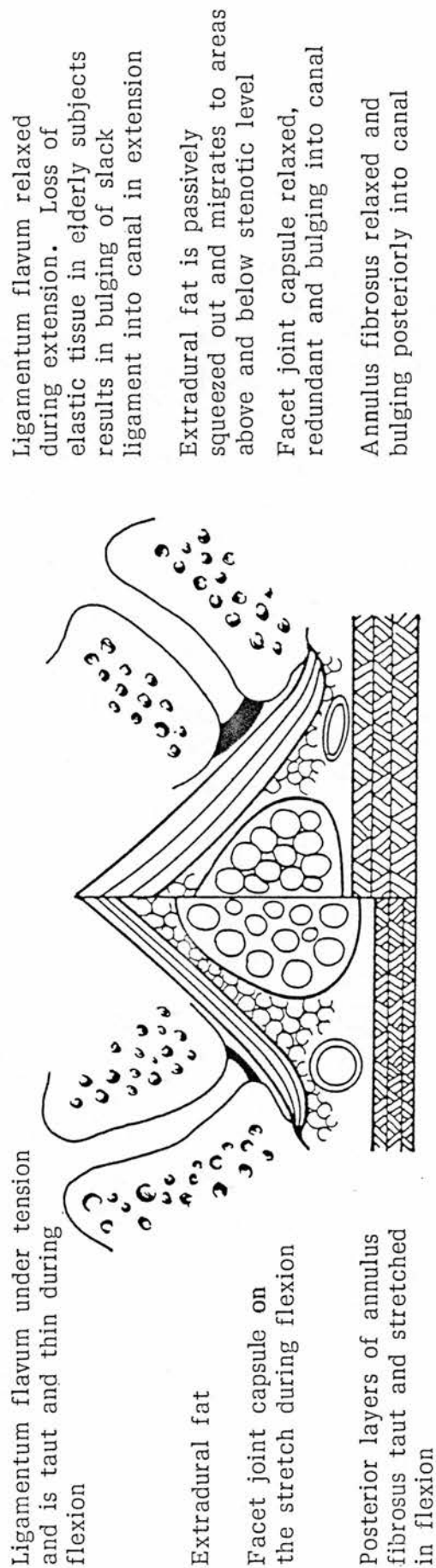


Figure 12:16. Schematic cross-section of spinal canal to illustrate changes which occur in the soft tissues during flexion and extension of the spinal canal, and how extension reduces the volume of the spinal canal.

LEVELS INVOLVED	FEMALES (N=13)		MALES (N=18)	
	PARTIAL BLOCK	COMPLETE BLOCK	PARTIAL BLOCK	COMPLETE BLOCK
L1-2	0	0	0	0
L2-3	15	8	22	0
L3-4	15	0	5	12
L4-5	38	0	45	0
L5-S1	24	0	16	0
MULTIPLE	25	0	28	0

Table 12:8. The results of radiculography in the group of patients managed conservatively (N=31) according to sex and level of involvement, and the degree of block demonstrated, either partial or complete, expressed as a percentage of patients undergoing myelography in the conservative group. Twenty-five per cent of females and twenty-eight per cent of males had partial blocks at more than one level.

Patients with complete blocks remained in the conservative group either because they were considered unsuitable for surgery, or the block was merely postural, or the symptoms were considered not severe enough to justify surgery, or in two patients the symptoms resolved following radiculography. This latter is not a new observation, but the explanation for it remains speculative and unclear.

All patients in the surgical group were examined by radiculography. This was considered essential to identify precisely the level of maximum involvement, and also to exclude a space-occupying lesion in the thoracolumbar spinal canal, either extradural or intrathecal. Only two patients were identified with space-occupying lesions, one with an ependymoma and the other a lipoma. Both were excluded from this series. The results of radiculography in the surgical group of patients are shown in Table 12:9.

LEVELS INVOLVED	FEMALES (N=25)		MALES (N=47)	
	PARTIAL BLOCK	COMPLETE BLOCK	PARTIAL BLOCK	COMPLETE BLOCK
L1-2	0	0	2	0
L2-3	0	0	2	0
L3-4	24	6	12	10
L4-5	24	24	37	16
L5-S1	11	11	19	2
MULTIPLE	18	6	16	7

Table 12:9. The results of radiculography in the surgical group of patients (N=72) according to sex and level of involvement, and the degree of block demonstrated either partial or complete, expressed as a percentage of patients undergoing radiculography in the surgical group.

The level at which either partial or total block occurs in the contrast column correlates well with the levels of maximum involvement seen on the plain radiograph. Approximately twenty per cent of patients had multiple level involvement. When a single level was affected this was most frequently the lumbar 4-5 level. In some patients with a partial block or when the myelographic findings were unimpressive, CT scanning often revealed stenosis particularly involving the nerve root canals, which was not well seen on radiculography. In these instances, the patient underwent CT scanning within hours of radiculography so that the scan was enhanced by residual intrathecal contrast.

The findings of bulging annulus fibrosus, sequestered nucleus pulposus, lateral recess stenosis, and arachnoiditis will not be discussed at this point, except that in each group, particularly the surgical groups, these findings were not uncommon. A more detailed discussion of these findings will be presented in Chapter 20.

RADICULOGRAPHY IN THE ELDERLY PATIENT

In the elderly, loss of disc height and thickening of the lamina and ligamentum flavum may result in abnormal myelograms. The spinal canal of asymptomatic elderly patients when examined myelographically has impressions and filling defects which may be misinterpreted as spinal stenosis (Hitselberger 1968). Of the ninety-one patients over fifty-nine

studied by Uden using myelography, sixty-six had symptomatic spinal stenosis and twenty-five were asymptomatic (Uden 1985). Thirty-one of the sixty-six (forty-seven per cent) symptomatic patients had a sagittal diameter of the spinal canal of less than 11 mm., but three of the twenty-five asymptomatic patients also had a spinal canal diameter less than 11 mm. (twelve per cent). A more reliable myelographic sign is the complete block which was seen in five patients in this series, all of whom were symptomatic.

It is therefore clear that in the elderly, spinal canal narrowing occurs and can be demonstrated myelographically, but this is not always equivalent to a clinical diagnosis of spinal stenosis.

REDUNDANT NERVE ROOTS

Redundant nerve roots have been regarded as a rare pathological state. However redundancy of the cauda equina was found in approximately forty-five per cent of the fixed cadavers in one series although the magnitude of the redundancy was slight compared with those in clinical experience (Sorensen 1975).

Tsuji found that in forty-four cases with positive evidence of redundancy the main location of the redundant nerve configuration was on the cranial side of the level of spinal stenosis that is mainly at the level of the first and second lumbar vertebrae (Tsuji 1985). In two cases, the redundant root configuration occurred at the level of the fourth to fifth lumbar vertebra immediately below the segment that severely gripped the caudal sac. Hypertrophic changes in the redundant nerve roots were confirmed in at least eight of the twelve patients who underwent dural incision.

Degenerative disease of the lumbar spine causes a gradual increase in the cauda equina/spinal canal length discrepancy. The slackened cauda equina may be squeezed and gripped at the stenotic level due to the spondylotic changes producing redundancy of the nerve roots in the cranial region of the lumbar spinal canal. Here the nerve root may coil as reported by Ehni (Ehni 1970). This process may take many years (Fig. 12:10a).

What changes occur in redundant nerve roots? Changes in action potential wave form and diminished conduction velocities observed in redundant nerve roots during surgery indicate that neuronal loss has occurred.

This may be irreversible. In patients with typical cauda equina claudication, the amplitude of the spinal evoked potential recorded during walking decreases in conjunction with the appearance of claudication and recovers rapidly after rest. This suggests intermittent ischaemia in the nerve roots caused by walking, and is compatible with the postural changes noted in the cauda equina during radiculography.

RADIOLOGICAL FEATURES OF DEGENERATIVE SPONDYLOLISTHESIS

In the majority of patients, spondylolisthesis occurs between L4 and L5. A combined slip however may occur between L4 and L5 and also L5 on S1. Degenerative spondylolisthesis may also occur at the L3-4 level and more rarely at higher levels. The frequently used classification for spondylolytic spondylolisthesis of Meyerding (Meyerding 1931 and Meyerding 1934) is as follows: first degree is a slip of less than one-third of the antero-posterior diameter of the vertebral body, second degree is a slip of between one-third and two-thirds, third degree is over a two-thirds slip, and fourth degree is a spondyloptosis. A degenerative spondylolisthesis is usually only a first degree slip, and only rarely becomes a second degree slip.

On myelography the frequency of a complete block is roughly the same as the frequency of an incomplete block (Cauchoix 1976). Other findings are failure of nerve root sleeves to fill. This involves the L5 nerve root more frequently than the S1 nerve root. An interesting feature is the lack of any correlation between the degree of slip and the severity of the myelographic changes.

The level of the spondylolisthesis on the plain radiograph does not always correlate with the level of stenosis demonstrated by radiculography (Fig. 12:3).

THE RADIOLOGICAL FEATURES OF POST-FUSION SPINAL STENOSIS

In this group of patients the symptoms may be protean and non-specific, and the patients are at risk of being dismissed as neurotic. Features observed on the radiculogram can often be misinterpreted. These patients may nonetheless suffer recurrent nerve root entrapment and/or recurrent disc herniation.

It is possible to misinterpret the radiographic findings as follows:

1. Interpreting the longitudinal streaking of the dye column under a thickened fusion mass as "arachnoiditis", and not recognising it as bony hypertrophy.
2. Symmetrical narrowing of the column at a joint: the "napkin ring defect" may frequently be referred to as a "bilateral disc herniation" thus ignoring the posterior portion of the constriction.
3. Small posterior indentations are easily overlooked because attention is directed to the anterior wall of the spinal canal.
4. Post-operative irregularity of the column may be interpreted as due to adhesions.
5. Complete or almost complete block is more often due to the stenotic syndrome than to arachnoid adhesions or to extruded fragments (Brodsky 1976).

The radiological diagnosis of post-fusion stenosis therefore represents one of the most complex areas of interpretation, and one of the fields in which CT myelography has been of most assistance in establishing a firm diagnosis.

THE LUMBAR SPINAL CANAL IN CHILDREN

It has been postulated that the dimensions of the spinal canal increase rapidly from birth up to the age of five years, and then more slowly between the ages of five and ten (Epstein 1976). The canal has almost attained its final shape when the neurocentral synchondroses fuse between the third and tenth year (Fig. 5:1). It must be realised however that this postulate is based upon the work of Knutsson (Knutsson 1961), which states:

"the dimensions of the spinal canal increase fairly rapidly from birth up to the age of five years, and considerably more slowly between the ages of five and ten".

The work of Knutsson however is based purely on measurements of radiographic material.

One of the problems with such radiological studies, including those of Knutsson, is that radiological magnification is not taken into account. It is clear that magnification will be more pronounced in larger children than in smaller children. Consequently the observations of the spinal canal made during growth do not necessarily accurately reflect changes in anatomical size.

Larsen in 1981 measured the lumbar interpedicular distance of one hundred children aged three to fifteen years radiologically before and after correction for magnification in the different age groups (Larsen 1981). The increased magnification in the older children resulted in an inaccuracy of approximately 2.5 mm. in the upper four lumbar vertebra, and approximately 3.3 mm. at L5 in the older children. He also noted a rather weak correlation between the interpedicular distance and the sagittal diameter of the spinal canal. This correlation was strongest at the fourth lumbar level. He also found no clear correlation between the interpedicular distance and the height of the pedicles.

A clear understanding of the growth of the lumbar spinal canal is not easily obtained by radiographic measurements of the spinal canals of children. This is for three main reasons. Firstly, as already pointed out, measurement of the antero-posterior diameter of the spinal canal from plain radiographs poses many problems. Secondly, myelography fails to demonstrate the presence or absence of the epidural fat space. Thirdly, CT myelography which offers the greatest accuracy is seldom indicated in children. These points are clearly of great importance and relevance when considering congenital and developmental stenosis of the lumbar spinal canal.

An experimental model was developed to determine the influence of sublaminae wiring on growth and development of the spinal canal. The results of this are presented in Chapter 8.

C H A P T E R 13

COMPUTERISED TOMOGRAPHY (C.T.) IN SPINAL STENOSIS

INTRODUCTION

Improved imaging techniques have enhanced considerably our understanding of the exact anatomical changes of spinal stenosis, and have greatly assisted careful planning of surgical decompression. The third generation of CT scanners has supplied more detailed information of nerve root anatomy and pathology such as oedema, as well as demonstrating the important space around the nerve roots and thecal sac. Sagittal reconstruction of the image and the introduction of small quantities of contrast material into the thecal sac or intravenously for enhancement provide yet further information.

This chapter describes the anatomical structures which can be demonstrated by computerised tomography and describes the CT features of spinal stenosis. The concept of "the spinal reserve capacity" is outlined and the scope and limitations of computerised tomography are described.

ANATOMY OF THE NORMAL LUMBAR AND SACRAL SPINE DEMONSTRATED BY COMPUTERISED TOMOGRAPHY

The superior and inferior articular facets of the apophyseal joints are readily visible: this represents the most cephalad portion of lateral recess. The lateral recess is an area bordered laterally by the pedicle, posteriorly by the superior articular facet and anteriorly by the posterolateral surface of the vertebral body. The ligamentum flavum is demonstrated at this level extending medially from the lumbar facet joints, and attached posteriorly to the medial aspects of the laminae.

Proceeding caudally the inferior articular facets become smaller and are no longer seen, whereas the lateral recesses become larger. At the mid-pedicle level a lucent vascular groove extending anteriorly from the posterior aspect of the vertebral body in the mid-line for a variable distance marks the termination of the basivertebral vein, occupying a vascular groove in the vertebral body, as it enters the retro-vertebral venous plexus. A calcified cap of cortical bone is frequently seen at this site (Chafetz 1983).

At the level of the inferior aspect of the pedicles, the lateral

recesses are visualised at their greatest dimension. The nerve roots coursing along the lateral aspect of the lateral recess are often visualised, and can be seen to be separated by epidural fat from the thecal sac. At the level just inferior to the pedicles (the level of the nerve root foramina), these same roots can be seen to exit laterally. Occasionally the anterior internal vertebral veins can be visualised antero-lateral to the thecal sac and medial to the existing nerve. The nerve roots exit just below the pedicle.

The annulus fibrosus and nucleus pulposus of the disc are of slightly higher density than the thecal sac, which enables the interface between the disc and the thecal sac to be distinguished on the CT scan in most cases. The normal configuration of the posterior aspect of the intervertebral disc at the L3-4 or L4-5 level is slightly concave and with increasing age (beyond forty years) becomes flattened. In older patients it is common to see mild degrees of convexity representing a minor diffuse annular bulge which if not associated with obliteration of the epidural fat is of no clinical significance.

At the L5-S1 level, the posterior aspect of the intervertebral disc is normally convex. Usually there is abundant epidural fat at this level and the thecal sac and S1 roots (which are often well demonstrated) are not impinged upon. Figure 13:1 lists the anatomical structures which were studied using CT scanning in the surgical group of patients with spinal stenosis at the Nuffield Orthopaedic Centre.

THE PATHOLOGICAL CHANGES OF LUMBAR SPINAL STENOSIS DEMONSTRATED BY COMPUTERISED TOMOGRAPHY

As described above, the bony structures of the spinal canal are well seen. The dorsal arch is distorted by thickened vertically orientated sclerotic laminae. The ligamentous inter-laminar space is often lost, and as a consequence the enclosed lumbo-sacral nerve roots and cauda equina are compressed. The articular processes especially the inferior ones that form the lateral and dorsal walls of the caudal part of each segment of lumbar canal also become sclerotic and bulbous. If the inferior articular process is more involved than the superior process a pathological gutter develops ventral to the overhanging inferior facet (Fig. 13:2). When the superior articular process is also distorted and hypertrophied, the entire lateral wall is constricted medially with encroachment on the lateral gutter and deformation of the lateral wall of the spinal canal (Fig. 13:3). The

BONY STRUCTURES

Central canal
 Lateral recess
 Nerve root canals
 Pedicle height
 Inter-pedicular distance
 Marginal body osteophytes
 Facet joint hypertrophy
 Paget's disease
 Neoplastic invasion

INTERVERTEBRAL DISC

Normal
 Bulging degenerate
 Lateral disc prolapse
 Sequestered nuclear fragments

SOFT TISSUES

Ligamentum flavum
 Facet joint capsule
 Epidural fat
 Arachnoiditis (contrast enhancement)
 Paraspinal abscess
 Epidural and retroperitoneal tumour

NERVE ROOTS

Normal
 Oedematous
 Deviated
 Compressed
 Obliterated

Figure 13:1. CT scanning of the surgical group of patients at the Nuffield Orthopaedic Centre provided information, often detailed, on the anatomical structures listed. CT scanning was of most value in patients with degenerative and developmental stenosis and was less helpful in patients with spondylolisthesis or scoliosis.

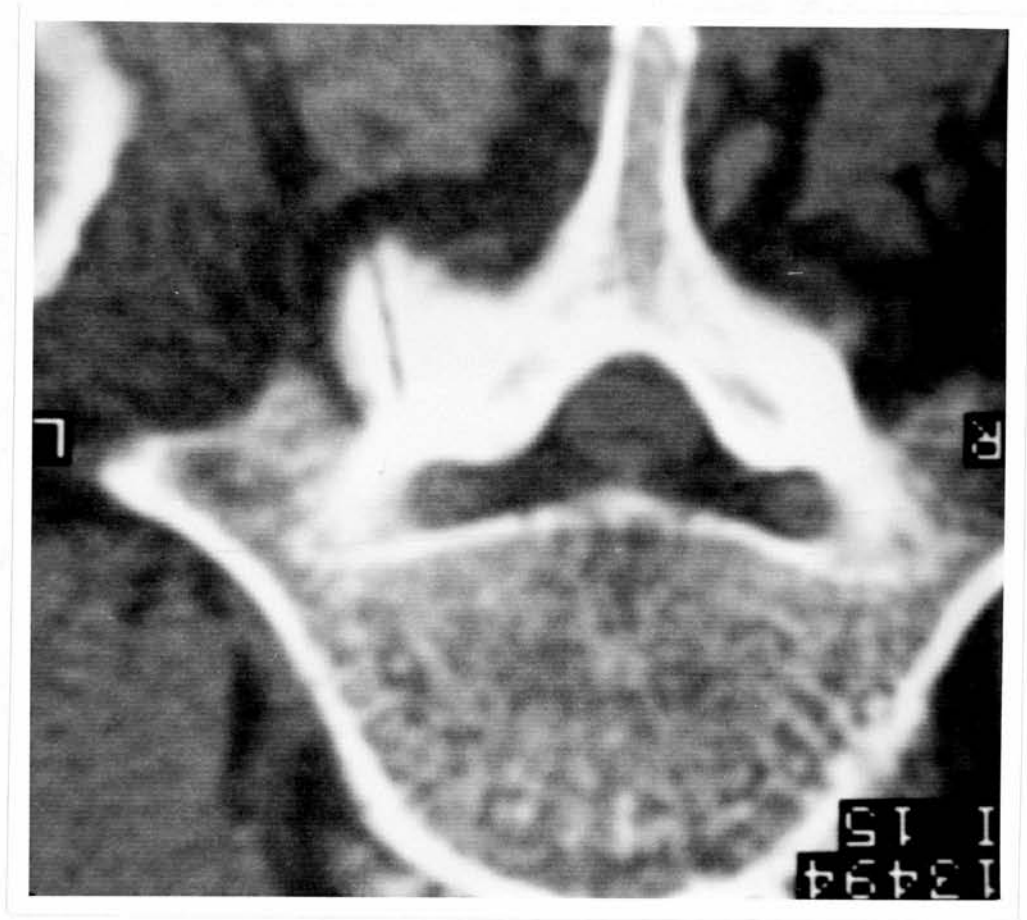


Figure 13:2. CT scan of a fifty-three year old fitter (W.T.) with degenerative stenosis. The upper part of the first sacral facet has been sectioned on the left. Enlargement of the inferior facet of L5 encroaches upon the central part of the canal. Compare this with the influence of the superior facet shown in Figure 13:3.



Figure 13:3. CT scan of the L4-5 level of a fifty-three year old fitter (W.T.) with degenerative stenosis, taken two two sections above that of Figure 13:2. Note that the superior facet of L5 causes most narrowing to the lateral recess of the spinal canal. Not only is there overgrowth of facetal bone but also of the medial edge of normally placed pedicles.

canal may then appear as a markedly flattened tube (Helms 1982). This may be misinterpreted as resulting from medial placement of the pedicles, and is actually caused by steady overgrowth of facet bone into the canal from the medial edge of normally placed pedicles.

Osteophyte formation in the lumbo-sacral facet joints has been defined by Carrera as excrescent new bone lacking a medullary space arising from the margin of the joint (Carrera 1980). Hypertrophy is defined as an enlargement of an articular process with normal proportions of medullary cavity and cortex.

CONGENITAL OR DEVELOPMENTAL STENOSIS

In general, narrowing of the canal is more marked within the articular segment regardless of the level involved. The dorsal aspect of the spinal canal is narrowed due to enlargement of the inferior articular facets. This occurs at multiple levels, but is most prominent at the lower lumbar region. The normal ligamentum flavum is interposed between successive laminae in the interlaminar space. In developmental stenosis apposition of the laminar arches to the articular processes causes the entire dorsal wall of the canal to become bony. Superimposed enlargement of the inferior articular facets results in a distorted central canal and elongated lateral recesses (Jacobson 1975; Sheldon 1976). In achondroplasia nerve root canals are flattened in the antero-posterior direction and elongated vertically. The fifth lumbar vertebra is recessed deeply between the iliac wings (Sheldon 1976).

COMPUTERISED TOMOGRAPHY OF LATERAL RECESS STENOSIS

The superior aspect of the pedicle marks the level where the lateral recess is at its narrowest. Polytomography has been suggested as the most accurate technique, but no study using CT with sections measuring 5 mm. rather than 10 mm. has been reported. A lateral recess of less than 3 mm. is considered evidence of stenosis, whereas one greater than 5 mm. excludes the possibility of lateral recess stenosis. A lateral recess measuring between 3 mm. and 5 mm. although highly suggestive of stenosis, should be implicated only if the patient's symptoms indicate lateral recess stenosis. Here again, the configuration and obliteration of epidural fat should be considered when determining what is and what is not a significant finding. This is necessary because spinal stenosis is often

a dynamic rather than static condition. It is probable that intermittent compression of an entrapped nerve root from lateral recess stenosis which occurs during standing or walking is the result of a slight forward shift of the superior articular facet on accentuation of the lumbar lordosis (Helms 1982).

The narrowest part of the lateral recess is at the superior border of the pedicle due to the anterior slanting of the superior articular facet. Therefore hypertrophy of the superior articular facet is more likely to cause nerve root compression at the superior border of the pedicle. It is therefore at this point that the height of the lateral recess should be measured.

COMPUTERISED TOMOGRAPHY OF NERVE ROOT CANAL STENOSIS

Anatomically the nerve root canal has the shape of an inverted tear drop. Superior and inferior borders are formed by the pedicles, while the anterior wall is formed by the posterior portion of the vertebral body and the disc. The posterior wall or roof is formed by the pars interarticularis. The nerve root typically exits directly beneath the pedicle, therefore narrowing of the inferior portion of the nerve root foramen is less likely to cause clinical symptomatology than narrowing in the superior portion (Helms 1982).

The finding of a narrow nerve root canal at the level of the vertebral end plate and disc does not by itself indicate significant encroachment with nerve root compression, because the nerve has generally exited slightly superior to the level of the disc. Bone encroachment may be caused by an osteophyte from the postero-inferior aspect of the vertebral body (Fig. 13:4), or the antero-superior aspect of the superior articular facet.

Occasionally one encounters the important observation of a lateral bulging or herniated disc that encroaches upon the exiting nerve root laterally in the nerve root canal (Fig. 13:5). The encroachment is often undetected by conventional myelography (Fig. 13:6), but is readily depicted by computerised tomography (Fig. 13:7). In the evaluation of osseous nerve root canal encroachment, sagittal and oblique reconstructions occasionally provide additional useful information.

When there are transitional or additional vertebra which may present difficulties in the terminology of involved nerve roots, the segmental distribution of the nerve roots remains appropriate for the vertebral body

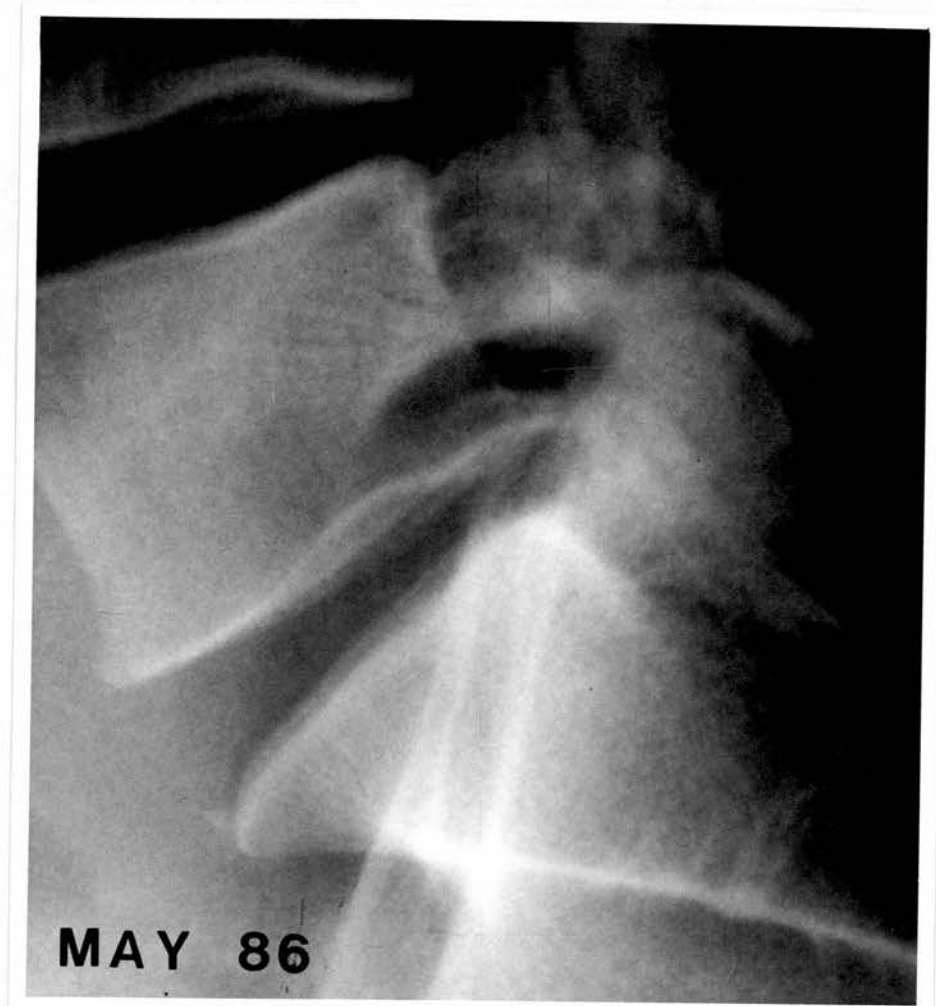


Figure 13:4. Lateral radiograph of the lumbo-sacral junction of a forty-five year old male (A.C.) with a past history of left sided sciatica which was managed conservatively. He presented five years later with neurogenic claudication on exercise in the left leg. This radiograph demonstrated osteophyte formation of the posteroinferior margin of the body of the fifth lumbar vertebra.

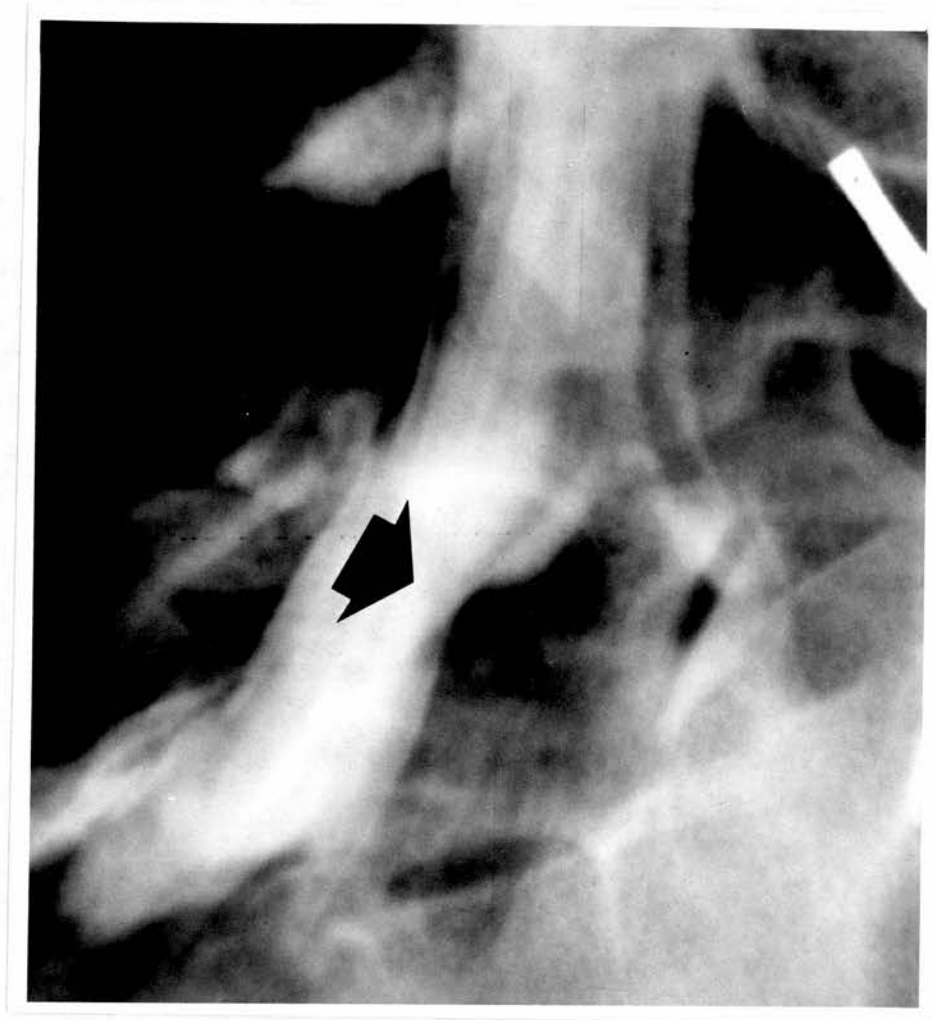


Figure 13:5. The radiculogram of A.C. demonstrated on the oblique film what appeared to be a straightforward disc prolapse, but the history was more of stenosis than a simple disc prolapse.

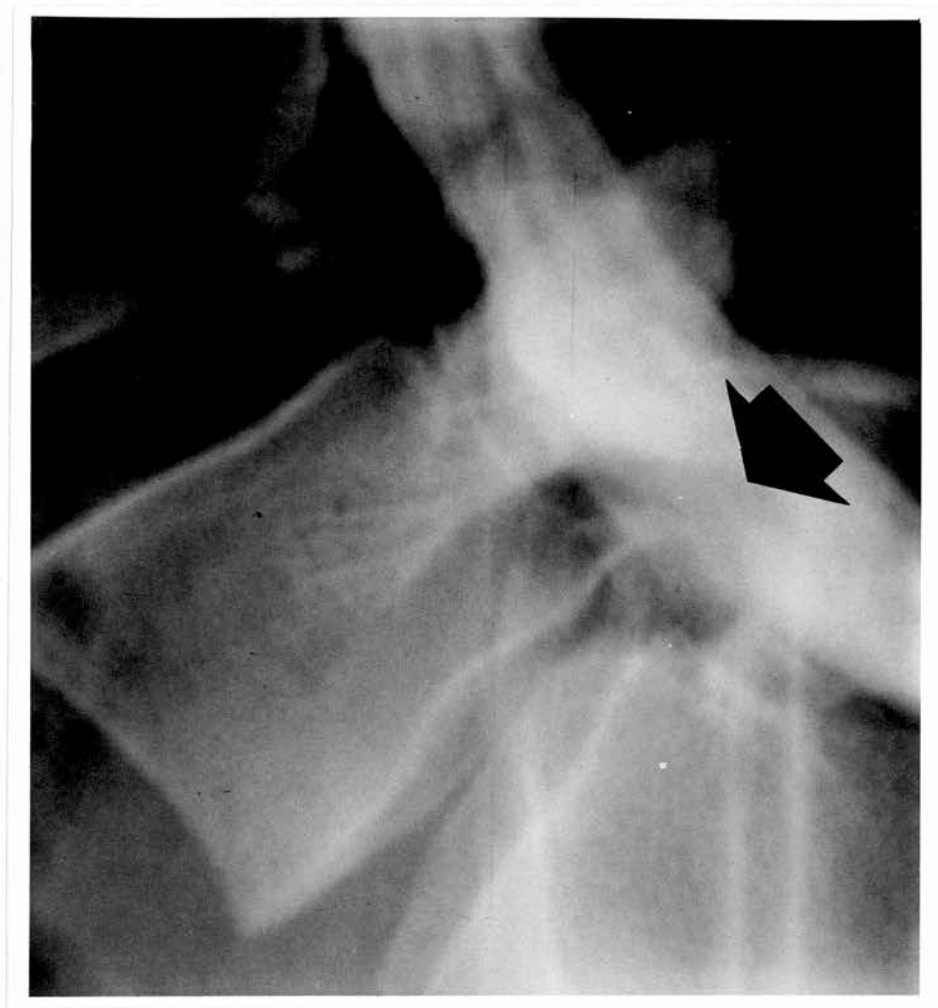


Figure 13:6. On the lateral view of the radiculogram of A.C., the filling defect was clearly seen to be associated with the osteophyte noted on the plain radiograph (Fig. 13:4), and so a CT scan was requested in view of this and the atypical history (see Figure 13:7).

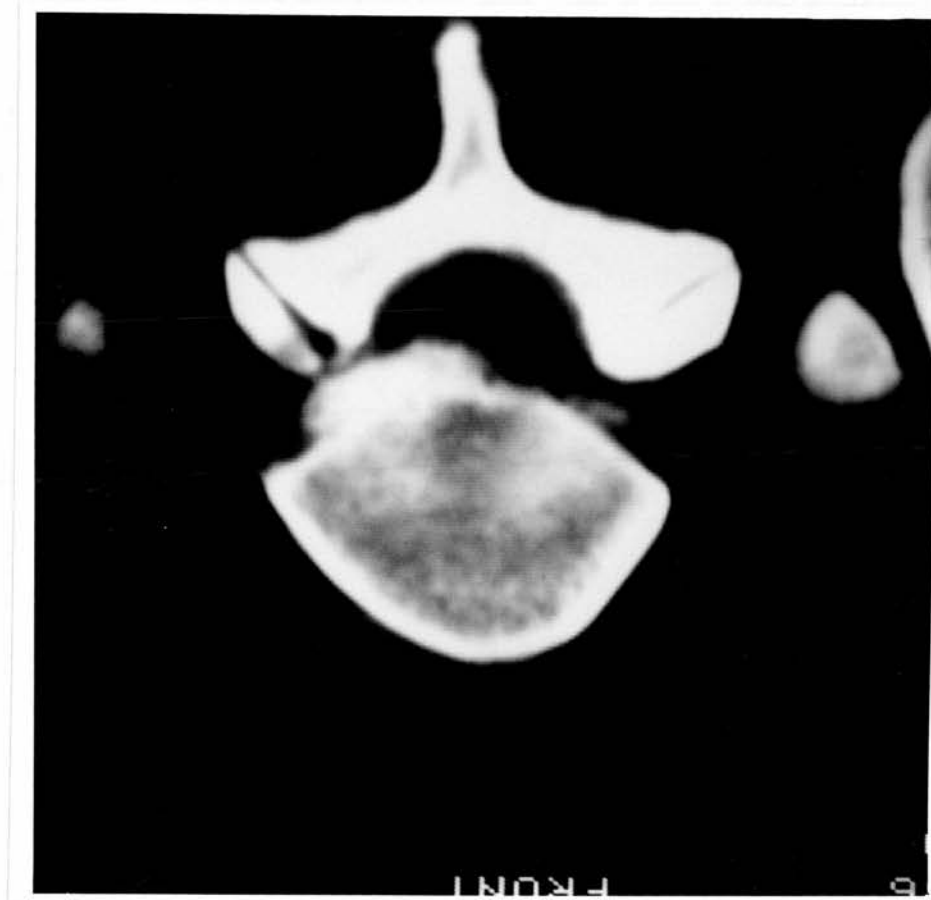


Figure 13:7. CT scan of the lumbo-sacral level of the same patient (A.C.). The history was of lateral recess stenosis, whilst the oblique radiculogram demonstrated what appeared to be a disc prolapse (Fig. 13:5). The CT scan resolved the dilemma by demonstrating an old disc prolapse which had now calcified with an overlying osteophytic ridge to produce lateral recess and nerve root canal stenosis.

when counted and identified starting from the first cervical segment. For example, if there are four vertebrae having a lumbar configuration, the fourth lumbar nerve exits from the intervertebral foramen between L4 and the sacrum. If there are six lumbar vertebrae, the first sacral nerve will exit between L6 and the sacrum (Sheldon 1976). This is useful in correlating clinical and radiological appearances in patients with four or six lumbar vertebrae who have nerve root canal stenosis.

MEASUREMENT OF THE SPINAL CANAL USING COMPUTERISED TOMOGRAPHY

Although measurements of the antero-posterior, transverse and cross-sectional dimensions of the lumbar canal by computed tomography have been published, the application and interpretation of such measurements can be difficult. There is wide biological variation in these measurements which makes discrimination between a given patient and the normal population difficult in many cases. In addition, as the window settings of a given CT scanner can affect both linear and area measurements, the scanner should be calibrated with a phantom of known dimensions (Chafetz 1983).

In the lumbar spine antero-posterior diameters of less than 11.5 mm., inter-pedicular distances of less than 16 mm., and a canal cross-sectional area of less than 1.45 square centimetres are considered abnormal. If however a measurably small osseous canal is present but epidural fat is preserved at the level of the pedicle and lamina, spinal stenosis is not present.

In general, widespread loss of epidural fat is the hallmark in spinal stenosis. Ligamentum flavum hypertrophy with consequent encroachment upon the dural sac may itself produce spinal stenosis with normal linear and area measurements of the bony canal.

Measurements by Eisenstein of two thousand three hundred and seventy-three complete lumbar cadaver vertebrae both by computerised tomography and direct measurement was a significant attempt to establish the normal range of spinal canal dimensions in three racial groups. The study revealed that the mid-sagittal diameter of the spinal canal was significantly smaller than the transverse (Eisenstein 1983). This study confirmed the findings of Newman that the mid-sagittal diameter is smaller in the middle three lumbar vertebrae (Newman 1975). The transverse diameter on the other hand increases from first to fifth lumbar

vertebra in both caucasoid "whites" and South African negroes.

Quantitative assessment of the fifth lumbar vertebral canal using computed tomography was recently reported in eighty-one patients (Kornberg 1985). Twenty-nine of these patients were diagnosed clinically and on the CT scan as prolapsed intervertebral disc at L4-5 but did not come to surgery. The cross-sectional area and the mid-sagittal diameter of the spinal canal of these patients were smaller ($p < 0.05$) than the control group of twenty-five subjects. Twenty-four patients who came to L4-5 discectomy had yet smaller canals at the L5 level than the non-operative group ($p < 0.001$); and in three other patients who underwent discectomy but with a poor result the mid-sagittal diameters, inter-facet distance, inter-pedicular distance, and cross-sectional area were all significantly smaller than these twenty-four patients who had a good post-operative result ($p < 0.001$).

Patients likely to undergo surgical discectomy have a mid-sagittal diameter less than 16 mm. and a cross-sectional area less than 2.5 sq. cm. The cross-sectional area is most accurate at detecting congenitally small spinal canals (Kornberg 1985). A cross-sectional area of the spinal canal at L5 of less than 2 sq. cm. can be taken to represent congenital spinal stenosis, given the limitations of such measurements discussed above.

DURAL SAC CROSS-SECTIONAL AREA

When measurements of the bony spinal canal are made using computerised tomography to establish the presence or absence of spinal stenosis, two important assumptions are made. Firstly that there is a linear correlation between the size of the bony canal and the size of the dural sac, and secondly that epidural soft tissue including facet joint capsule, ligamentum flavum and fibrous tissue play no part in the pathogenesis of spinal stenosis. There is certainly no evidence to support the first assumption, and abundant evidence to totally refute the second assumption. Schonstrom found no correlation between the transverse cross-sectional area of the dural sac and either the antero-posterior diameter of the spinal canal, the inter-facet distance, or the transverse area of the bony spinal canal (Schonstrom 1985). In fact he demonstrated several patients with a very narrow dural sac but a normal bony canal. Out of the twenty-four patients studied, the main cause of stenosis was identified as soft tissue in seventeen. Enlargement of the facet joints

displacing a thickened ligamentum flavum towards the central part of the spinal canal was implicated most often. Lamina encroachment on the spinal canal was the main cause of stenosis in only two of the twenty-four patients (Schonstrom 1985).

It is hardly surprising therefore that the cross-sectional area of the dural sac is the most reliable indicator of spinal stenosis. Contrast enhancement can assist in the measurement which Schonstrom considered became critical below 100 sq. mm.

COMPUTERISED TOMOGRAPHY AND SPINAL RESERVE CAPACITY

Computerised tomography of the spine reveals a free space which normally contains fat and epidural veins between the outer layer (bony wall and ligamentous lining), and the inner layer (dura, peridural fat, and areolar tissue). This space is required for tension-free movement of the neural contents. This space within the spinal canal is therefore functional and represents the spinal reserve capacity. The term implies a physiological space.

When measuring this capacity by computerised tomography, the space is expressed as the difference between the sagittal diameter of the canal (c1), (this represents the distance from the posterior margin of the centre of the vertebra to the junction of the lamina or to the intruding hypertrophied ligamentum flavum), and the sagittal diameter of the contents (c2), (the dural sac and surrounding soft tissues). The spinal reserve capacity (C) = $c1 - c2$ (Weisz 1983). It is either by decrease in the size of the container or increase in the volume of the contents that attenuation or obliteration of the space is achieved.

It is possible that the reduced mobility of the lumbar spine in elderly patients may be linked with a decreased neural tissue mobility in the lumbar spinal canal, and possibly reduced spinal reserve capacity.

Weisz measured the spinal reserve capacity in seventy-five patients with spinal stenosis and noted the following findings.

1. The spinal reserve capacity is positively correlated with clinical and myelographic findings, and is therefore useful in the diagnosis of significant stenosis in the presence of a developmentally narrow spinal canal, and in ligamentous hypertrophy.
2. The spinal reserve capacity is positively correlated and useful in the diagnosis of acquired lumbar stenosis (Paget's disease, Forestier's disease, post-fusion and post-arachnoiditis fibrosis).

3. The spinal reserve capacity is negatively correlated, and therefore does not lead to a diagnosis of stenosis in cases of spondylolisthesis, ankylosing spondylitis, and post-surgical scarring.
4. The spinal reserve capacity is negatively correlated, and therefore does not indicate the presence of stenosis in the majority of younger patients, except those with developmental bony stenosis.

The usefulness of the spinal reserve capacity declines in those conditions which may be classified as "restrictive stenosis". In these conditions the symptoms result from a reduction of the mobility of neural tissue, rather than a decrease in the reserve capacity.

A COMPARISON OF COMPUTERISED TOMOGRAPHY WITH MYELOGRAPHY IN THE DIAGNOSIS OF LUMBAR STENOSIS

It may be difficult at operation to detect with certainty a relatively mild degree of narrowing of the spinal canal or lateral recesses. It is essential therefore that prior to surgical exploration of the spine the anatomy and pathology of the level to be explored is well understood, and the specific pathology dealt with, without the need for unnecessary exploratory procedures.

Most series confirm that computerised tomography is more accurate in the diagnosis of spinal stenosis and in particular lateral recess and nerve root canal encroachment, than conventional water-soluble myelography. Postacchini however considered that in developmental stenosis computerised tomography was less accurate than water-soluble myelography, due to the fact that a short mid-sagittal diameter may not produce myelographic changes in the absence of additional compressive agents, such as bulging discs or hypertrophy of the articular facets (Postacchini 1981).

Water-soluble myelography however does clearly demonstrate the extent of narrowing of the thecal sac, and if this is extensive throughout the lumbar spine and the constriction is uniform and not segmental, then in this instance water-soluble myelography clearly indicates strongly the presence of developmental rather than degenerative stenosis.

The highest index of correlation between computerised tomographic findings and myelographic patterns is found in degenerative stenosis of the spinal canal, in most cases of which computerised tomography not only detected the stenotic levels, but also enabled the severity of bony encroachment to be assessed at the various levels involved with a view to planning surgery.

THE VALUE OF COMPUTERISED TOMOGRAPHY IN DETECTING UNEXPECTED LESIONS OF THE SPINE

It is clear that in many patients with lumbo-sacral radicular symptoms plain films and myelography may fail to define the nature or extent of the underlying disease process.

Computerised tomography can detect bony destructive lesions not apparent on plain films, largely due to its superior density resolution. It is therefore useful in detecting destructive lesions in those locations that are relative blind spots on plain radiography, and often on geometric tomography, primarily lesions of the sacrum and spinal column.

Computerised tomography is the only modality in common use that effectively displays both the bony and soft tissue components of spinal stenosis and may unexpectedly reveal the presence of neoplastic or inflammatory lesions causing a paraspinal mass not evident on plain radiographs or myelography. The myelogram may suggest that extradural compression is due to spinal stenosis or an extruded nucleus pulposus, but the computerised tomogram may indicate that this is an extension possibly from the vertebral body or disc space or retroperitoneal abdominal space.

Computerised tomography will demonstrate extra-osseous tumour spread into adjacent paravertebral tissues, or into the spinal canal itself. When utilised in conjunction with metrizamide myelography it permits the visualisation of the spinal cord and extradural intraspinal soft tissues (Federle 1980). Computerised tomography helps to characterise lesions as cystic/solid, vascular/avascular, and infiltrated/sharply demarcated.

Computerised tomography is therefore a vital tool which has added significantly to our understanding of spinal stenosis. When combined with plain radiographs and water-soluble contrast myelography, computerised tomography assists in planning accurately the extent of surgical decompression thereby avoiding the need for unnecessary surgical exploration. It has become an essential key to the understanding of spinal stenosis and has thereby improved the results of surgery and consequently the prognosis for patients with spinal stenosis.

THE LIMITATIONS OF SPINAL COMPUTED TOMOGRAPHY

Computed tomography of the spinal canal and its contents is a non-invasive technique which does not subject the patient to any discomfort. It does, however, involve a significant dose of radiation to the patient

particularly if extensive areas of the spine are to be scanned, and it is therefore advisable to select areas of interest from plain radiographs or water-soluble contrast myelograms, and to tailor the computerised tomographic examination to specific areas of interest. This results in better characterisation of spinal stenosis which leads in turn to improved surgical management. (Fig. 13:8 to 13:10)

Secondly, the distinction between the spinal cord and the sub-arachnoid space, and the definition of nerve root pouches may be difficult and misleading due to artefacts and limitations of computer programming related to the encircling bone. Precise reproducible positioning of the patient is necessary and may often be difficult to achieve.

Thirdly, the computerised tomographic section may not always be perpendicular to the plane of the spine. The section through the disc particularly at the lumbo-sacral junction may not be achieved on the other hand because the gantry of the scanning machine cannot be inclined to a sufficient angle to achieve a true transverse section.

Fourthly, the introduction of intrathecal contrast material greatly enhances the morphologic capabilities of spinal computerised tomography, in particular when there is difficulty in determining the interface between disc material and the spinal theca, when there is no intervening fat layer or where there is sequestered disc material.

Conventional screening procedures such as plain films of the spine and myelography should be obtained prior to spinal computerised tomography in most cases, because of their value in defining the location and longitudinal extent of the pathological process to be examined by computerised tomography (Roub 1979).

Using High Resolution CT (HRCT) Scanning nerve root displacement, compression, swelling, and anatomic variants (such as conjoint nerve roots) can be appreciated by direct visualisation. HRCT is perhaps at its best in the presentation and understanding of central and lateral degenerative spinal stenosis. The ability to visualise nerve roots, ganglia, epidural fat, epidural fibrous tissue, and epidural veins may sometimes be enhanced by the subarachnoid or intravenous injection of a water-soluble contrast agent.

CONCLUSION

Although CT was introduced in 1972, it is estimated that only sixty per cent of hospitals in the United Kingdom have ready access to this

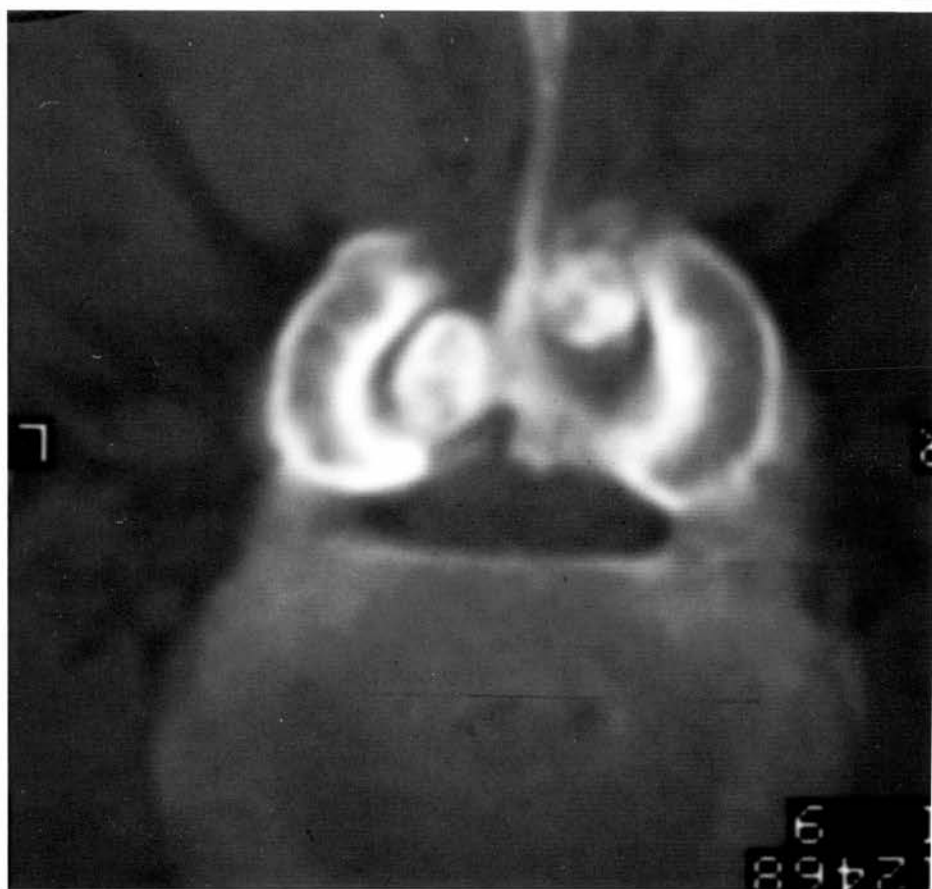


Figure 13:8. The grey scale of the CT scan can be adjusted to illustrate different features of the spinal canal. These two scans are of the same level at different grey scale intensities, the top illustrating the spinal canal and the lower ones details of the facet joints.

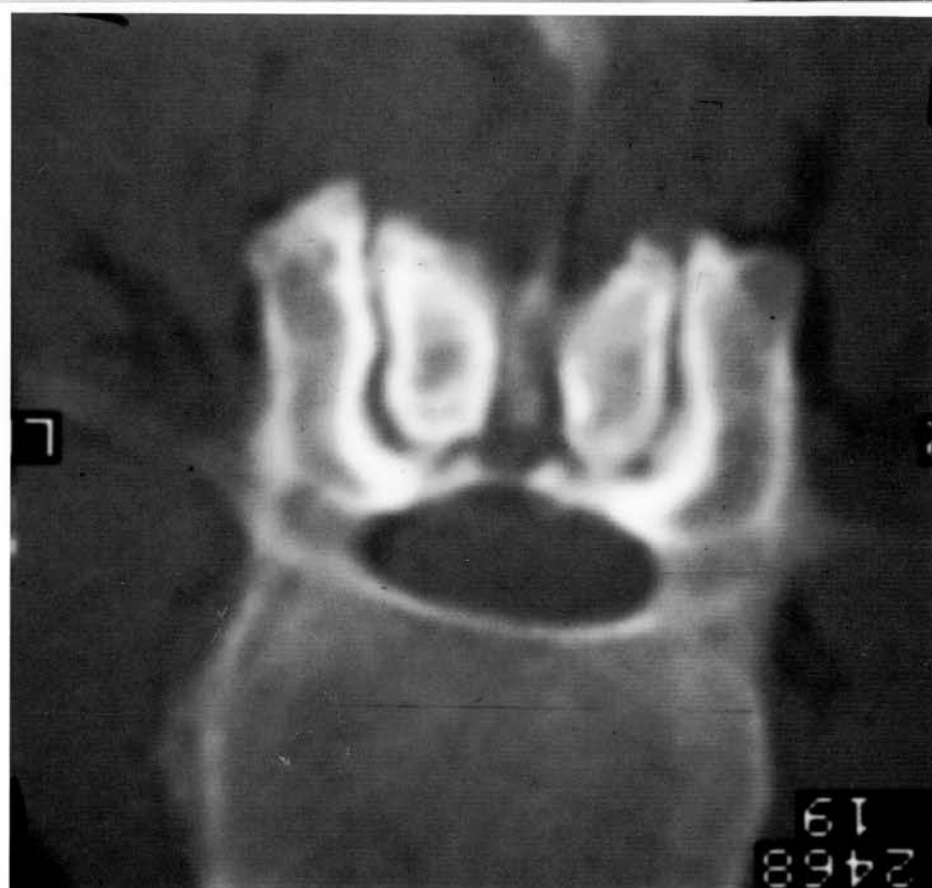


Figure 13:9. Articular facet degeneration with enlargement. Minimal space exists between spinous process and facet joints. Also note the contribution of the superior facet to the roof of the spinal canal.

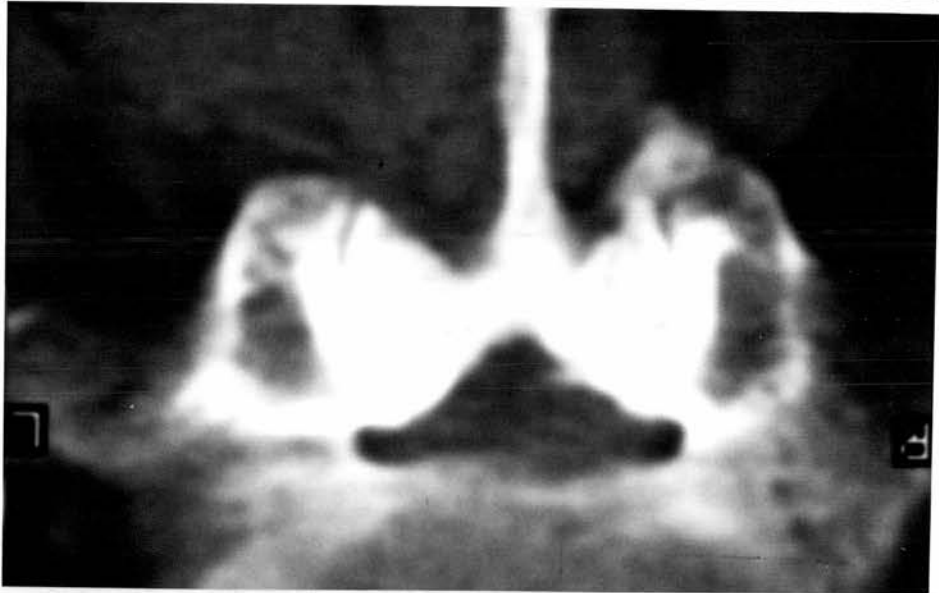
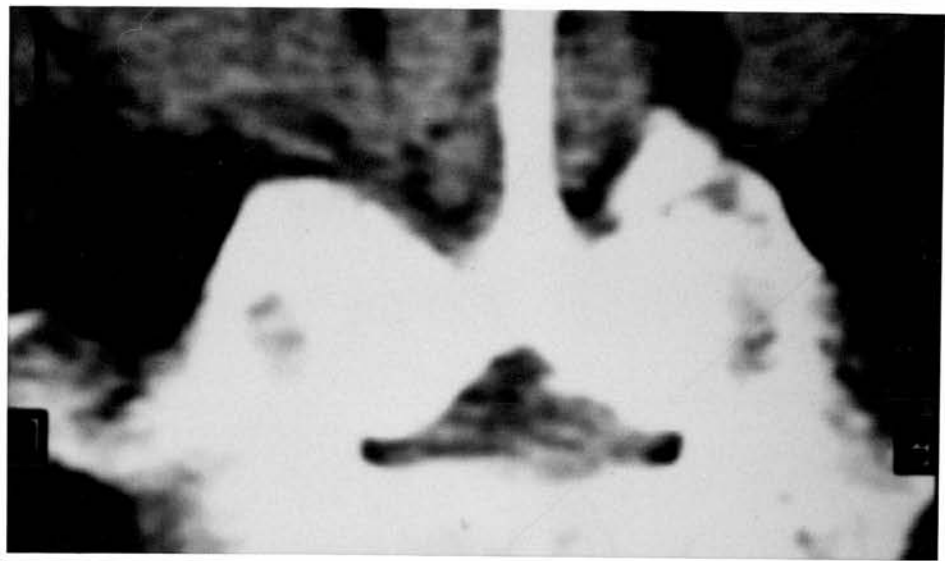


Figure 13:10. Three different grey scale intensities of the same CT section to illustrate one of the difficulties in making accurate measurements of the spinal canal using CT.

technology as it presently exists. For lumbar CT scanning this figure is probably less than five per cent (Burton 1983). CT scanning with continued advances in software programmes is likely to remain the diagnostic leader for the next decade at least with regard to lumbar spine imaging.

The possibility exists now for tomographic imaging using radiation sources (Crawshaw 1984). Over the past seven years nuclear physicists have been attempting to use radio-pharmaceuticals with half lives in the order of seconds as positron emitters. Two forms of such "emission computed tomography (ECT)" have emerged dependent firstly on the radioactive material used and secondly the detection method employed. These systems include Single Photon ECT (SPECT) and positron emission computed tomography, which may well be suitable for monitoring blood, cerebrospinal fluid and lymph flow. The most significant practical limitation of ECT remains the need for immediate isotope injection requiring the presence of a multi-million pound cyclotron on site.

CHAPTER 14

MAGNETIC RESONANCE IMAGING IN SPINAL STENOSIS

INTRODUCTION

In 1983 nuclear magnetic resonance (NMR) scanning became a commercially available technique. Unlike CT in which the integration of computers with conventional X-Ray tomography has been able to produce highly detailed electron maps of body tissues, NMR maps elements having odd numbers of protons or neutrons. Essentially the current generation of NMR imaging systems are limited to mapping hydrogen since this is the only element abundant enough in the human body to produce signals measurable by present NMR technology.

The use of nuclear magnetic resonance (NMR) in the diagnosis of radicular pain due to lateral canal stenosis in twenty-one patients was reported by Crawshaw (Crawshaw 1984). NMR was able to distinguish normal intervertebral discs from degenerate discs, and Crawshaw found that NMR evidence of reduction of epidural fat was found to be more reliable than radiculography in identifying lateral recess nerve root entrapment. NMR is an important advance in the investigation of lumbar radiculopathies but the normal-abnormal boundary has still to be defined.

Computerised tomography (CT) has greatly improved imaging of the lateral canal, and made imaging of soft tissues within the canal possible (Haughton 1980, and Isherwood 1980) and has been considered the procedure of choice in the investigation of lumbar radicular pain. However, some authors suggest that the diagnosis of radiculopathy by CT scanning remains no better than by electro-myography (Getty 1981a; Heithoff 1984).

THE ADVANTAGES OF MAGNETIC RESONANCE IMAGING

A detailed examination of the lumbar spine using CT may result in a radiation dose per patient of between 4.8 and 7 rads (Isherwood 1980). Nuclear magnetic resonance is a harmless, non-invasive method of imaging (Steiner 1982; Saunders 1983). The aim of Crawshaw's study was to evaluate multi-planar NMR as a method of investigating the lumbar spine, with particular reference to the lateral recess, and to compare its diagnostic precision with that of more conventional methods such as radiculography and computerised tomography (Crawshaw 1984).

Nuclear magnetic resonance is a non-invasive multi-planar method of

imaging which makes it possible to identify degenerative discs, as predicted by Hawkes (Hawkes 1981). The coronal view is capable of demonstrating reduction of epidural fat in the lateral recess, and the parasagittal views even more so. Crawshaw considered that this reduction correlated well with both the CT scan and clinical findings of lateral recess stenosis (Crawshaw 1984). NMR essentially examines the physiological or pathological function rather than anatomy and therefore avoids the problem often encountered in correlating the canal measurements obtained by computerised tomography with the clinical signs of nerve compression.

Comparison with radiographs, high resolution CT scans, and myelograms showed that NMR was the most sensitive for identification of disc degeneration and disc space infection, distinguishing between the normal nucleus pulposus and annulus and the degenerate disc (Modic 1984). Herniation, stenosis of the canal, and scarring can be identified as accurately with NMR as with CT or myelography.

In patients with stenosis of the spinal canal, NMR with a 120 msec. TE and 3 sec. TR was as accurate as myelography and CT in quantifying narrowing of the subarachnoid space, however CT was more accurate in separating bony from soft tissue impingement due to the faint MR signal from cortical bone. In most cases the level of stenosis was associated with disc degeneration and both bone and ligamentous over-growth. In one patient, MR showed that the disc itself was not involved in the stenotic process because its signal intensity was unchanged, indicating normal hydration.

Magnetic resonance can also be used to evaluate the effects of surgery on the patency of the neural canal and may be helpful in identifying scarring, though the number of cases in Modic's series of post-operative scarring was too small to permit a definitive statement. In three cases, signal intensity was increased in the region of the neural canal and inter-vertebral disc space and was found at surgery to represent scar tissue. By comparison a recurrent disc prolapse should have a decreased signal intensity. Signal intensity can also increase in the end plates of the vertebral body following chymopapain injection, suggesting inflammation or scarring. Such injections are followed by rapid dehydration, collapse, fibrosis, and rigidity of the disc and the success of treatment may be due to destruction of the cartilaginous plates with subsequent ingrowth of granulation tissue and rapid scarring of the disc space.

DISADVANTAGE OF MAGNETIC RESONANCE IMAGING

Major limitations of MR include the section thickness, spatial resolution, examination time and lack of clear signal from cortical bone. Also, the MR scanning apparatus appears to induce claustrophobia more frequently than the CT scanner. Because the information provided by NMR is different and relates more to the quality and nature of tissue than its structural dimensions, it seems more likely that hybrid CT-NMR systems will be developed.

MAGNETIC RESONANCE SPECTROSCOPY

In Oxford magnetic resonance spectroscopy has been used by courtesy of Professor Radda to look for evidence of denervation in the muscles of the lower limb of patients with spinal stenosis. Magnetic resonance spectroscopy is extremely sensitive and effective in detecting the very earliest changes of muscle denervation as it affects phosphorus metabolism in the muscle. It appears however to have little advantage over electrophysiological testing by conventional means, which also is most sensitive. The principal drawback to the use of magnetic resonance spectroscopy in this field however is myotomal variability, so that if denervation is detected, the finding remains non-specific and further investigations are required to define exactly the site of nerve compression.

A further study is in progress using magnetic resonance spectroscopy pre- and post-surgical decompression of the stenotic spine to define the degree of nerve root recovery more precisely. Clearly if nerve root infarction has occurred with intraneural fibrosis and scarring, there is little prospect of post-operative nerve root recovery; but it is probable that most nerve roots have some potential for recovery following decompression.

C H A P T E R 15

ULTRASONIC DIAGNOSIS OF SPINAL STENOSIS

INTRODUCTION

Diagnostic ultrasound remains a simple, safe, and non-invasive method of examining a small portion of the spinal canal via an "acoustic window". Improved imaging techniques and equipment however have not resolved the discussion on exactly which anatomical structures reflect the ultrasound.

MEASUREMENT OF THE SPINAL CANAL USING DIAGNOSTIC ULTRASOUND

Porter measured the lumbar spinal canal in over eight hundred subjects including one hundred mining recruits, and fifty nurses between the ages of fifteen and eighteen years using pulsed echo ultrasound (Porter 1978). Three major echoes were demonstrated from the posterior and anterior surfaces of the lamina and from the posterior surface of the vertebral body at any one vertebral level. The accuracy of measurement of the oblique sagittal diameter of the lumbar spinal canal was indicated by an inter-observer and intra-observer error of 0.02 cms.

The "acoustic window" was identified 15° to the sagittal plane, and the ultrasound echo was lost if the transducer was moved medially because of the high absorption of sound by the spinous processes, or laterally from absorption by the facet joints and thickened lamina. The "window" was entirely covered by a 2 cm. diameter beam of ultrasound, and Porter found this to be constant for each individual vertebra. Three major echoes were obtained using the A-scan.

The mean oblique sagittal diameter measured by ultrasound was found by Porter to be similar to the mid-sagittal diameter measurements reported by Eisenstein in 1977 (Eisenstein 1977). The mean values for the female canal were slightly greater than those for the male. Porter considered that ultrasound offered a non-invasive technique which permitted accurate measurement of the spinal canal but appreciated that computed axial tomography demonstrated the detailed anatomy of the trefoil canal. However he considered the technique useful in preventative medicine for identifying subjects at risk, and in deciding the segmental level which required further examination and subsequent decompression.

Forsberg failed to visualise the spinal canal using a modified "B-scan" technique in certain patients who continued to have symptoms following

removal of a herniated lumbar disc (Forsberg 1982). These failures of visualisation were related to skeletal changes which might block the "acoustic window". This gave rise to the assumption that skeletal changes including bony hypertrophy of some magnitude would prevent visualisation of the spinal canal and in these patients computerised axial tomography was more appropriate.

Forsberg suggested that pre-operative ultrasound investigation might be appropriate in patients with sciatica to indicate the general narrowness of the spinal canal, thereby indicating which patients required a simple discectomy for sciatica and which required a more formal decompression.

It must be said however that the pre-operative decision concerning the extent of surgical decompression required clearly demands more accurate anatomical visualisation than can be achieved by current day ultrasound techniques.

Forsberg found the oblique sagittal diameter of the lumbar canal in patients who responded well to simple disc surgery to be 12.7 ± 1.9 mm. (20/24 sites visualised) at the lowest level, proceeding upwards 13.7 ± 2.1 mm. (24/24), 14.7 ± 2.1 mm. (23/24), 16 ± 1.9 mm. (24/24), and 16.5 ± 1.9 mm. (24/24) at the highest of the five discs.

In patients who continued to have symptoms following simple disc removal, the measurements were as follows: 10 ± 0.7 mm. (5/20 sites visualised) at the lowest level, 11.6 ± 3.4 mm. (14/20), 12.9 ± 2.3 mm. (15/20), 14.4 ± 1.8 mm. (16/20), and 15.2 ± 2 mm. (16/20) at the highest of the five disc levels.

This would indicate that ultrasound is of more value as a screening procedure than in planning surgery.

ULTRASOUND COMPARED WITH MYELOGRAPHY IN SPINAL STENOSIS

Porter used pulsed echo ultrasound to measure the spinal canal in the 15° oblique plane in one hundred and thirty-eight patients with a history of neurogenic claudication. Their average age was forty-nine. He found that seventy per cent had measurements below the tenth percentile for the fifty to sixty-five year old subjects (Porter 1980). Asztely found a poor correlation in fifty-nine patients between the antero-posterior measurement of the subarachnoid space using myelography and ultrasound (Asztely 1983). The correlation between the measurement was low and the distribution of the regression coefficient was considerable. The non-invasive ultrasound method could be used he considered in selecting patients

for myelography. An ultrasound measurement of 14 mm. or more excluded a corresponding antero-posterior measurement using myelography of 8 mm. or below.

Of the fifty-nine patients in this study, thirty-three were male and twenty-six were female, with a mean age of forty-three years, with a range of eighteen to seventy-one years. The "acoustic window" was again identified 15° oblique to the sagittal plane, and ultrasound measurements and myelographic measurements were made at one hundred and seventy different levels in the fifty-nine patients. The mean predicted ultrasound measurement for a given myelographic measurement of 10 mm. was 13.7 mm., when the myelography measurement was 8 mm. the corresponding mean ultrasound measurement was 13.2 mm.

Kadziolka reported a good correlation between measurements obtained at ultrasound examination and measurements of casts from the spinal subarachnoid space (myelogram) using cadaver specimens immersed in saline (Kadziolka 1981). However the poor correlation obtained by Asztely between myelography and ultrasound measurements is clearly the result of these two examinations being performed in different planes. There is simply no relationship between the midline ventro-dorsal sagittal measurement at myelography and the 15° oblique measurement made via the "acoustic window" at ultrasound particularly for a trefoil canal. The relationship between these measurements is a factor of the shape of the spinal canal, and this varies between oval, triangular and trefoil.

GRAY-SCALE SCANNING

Using a gray-scale technique, Engel reported that he was able to visualise a "triple density" formed by the visualisation of soft tissue in the extradural space between the two bony landmarks of the anterior lamina and the posterior vertebral body (Engel 1985). Myelography and surgery confirmed that these were in fact herniated discs. Engel reviewed the ultrasound scans of sixty-seven patients with low back pain and sciatica. He noted that forty-four of these had either focal or diffuse stenosis. Porter used the A-mode scan imager to obtain precise measurements from laminar to vertebral interfaces, and found a high degree of correlation between focal stenotic levels and disc protrusion (Porter 1978b).

Gray-scale scanning allows the production of a two-dimensional image of the interior of the spinal canal from L1 to S1 on a single scan. Laminar hypertrophy or changes in alignment of the vertebral bodies causing

focal stenosis produces a gray-scale scan with a clear canal between these two echoes, but when a disc protrusion is present in the extradural space a third soft tissue interface is detected between these two bony landmarks. This "triple density" sign was found by Engel to be associated with an eighty-nine per cent sensitivity and a one hundred per cent specificity for disc herniation.

ULTRASOUND FOR SCREENING PURPOSES

Significant variation was reported by Asztely between the dimensions of the spinal canal measured using ultrasound compared with those measured on myelography. An ultrasound measurement of 14 mm. or more is needed to exclude an antero-posterior measurement at disc level of 8 mm. or less on myelography. This is before any correction is made for magnification. A large number of false positives are therefore likely to be obtained by ultrasound screening of a population. In patients with "neurogenic claudication", three out of four patients had ultrasound measurements below 14 mm. Thus, theoretically, one patient out of four could avoid myelography as a method of establishing the diagnosis. However, if surgery is proposed myelography and computerised tomography will be required to plan the extent of spinal decompression.

Porter reported that the size of the spinal canal appeared unrelated to the occupation, with miners who had worked three or four decades underground having canals slightly larger than men in sedentary occupations (Porter 1980). Heavy manual work seems not to significantly affect the diameter of the spinal canal, but it may be that localised narrowing, soft tissue thickening and excessive movement in the spine is as important as the overall shape and size of the canal as measured by ultrasound. In a further series of two hundred and forty-nine patients with root canal stenosis reported by Porter, ultrasound measurements of the central spinal canal differed little from those of the general population (Porter 1984). Figure 15:1 summarises the results of specific investigations which assist in the differential diagnosis of spinal stenosis from prolapsed intervertebral disc and peripheral vascular disease.

DIFFERENTIAL DIAGNOSIS OF INVESTIGATIONS			
	SPINAL STENOSIS	PROLAPSED INTERVERTEBRAL DISC	PERIPHERAL VASCULAR DISEASE
PLAIN RADIOGRAPHS SPINE	Degenerative change, Short pedicles, Spondylololsthesis Paget's disease etc.	Loss of normal lordosis, sclatic scoliosis, possible loss of disc Facet joint tropism on contralateral side.	Calcification of abdominal aorta; possible aneurysm.
CHEST	Normal	Normal	Cardiomegaly, Cardiac failure.
LUMBAR PUNCTURE	Difficult, CSF Block, Positive Queckenstedt's sign, Elevated CSF protein	Technically straightforward	Normal
MYELOGRAM	Diagnostic of central and lateral recess stenosis. Complete block or partial failure of filling. Localised or generalised lamina, disc, facet, ligamentum flavum indentation.	Diagnostic: local extradural filling defect usually at disc level but may demonstrate sequestered fragment of nucleus.	Normal: bulging of degenerate discs at numerous levels probable in this age group: usually disappears on flexion.
C.T. SCAN	Diagnostic: trefoli canal. Lateral recess narrowing or obliteration. Demonstrates nerve root foraminal stenosis not apparent on myelogram.	Usually non-contributory. May demonstrate very lateral disc prolapse beyond dural sleeve. Can distinguish scarring from further disc sequestration after previous surgery.	Calcification of abdominal aorta.
ULTRASOUND	Reduced spinal canal diameter	Normal or reduced spinal canal diameter.	Normal spine. Aortic aneurysm. Reduced pulse pressure.
ARTERIOGRAPHY	Normal	Normal	Diagnostic, Aortic, iliac, Femoral, Profunda or Popliteal block or stenosis.
PLEASE NOTE: SPINAL STENOSIS, PROLAPSED INTERVERTEBRAL DISC AND PERIPHERAL VASCULAR DISEASE ARE NOT MUTUALLY EXCLUSIVE AND CAN CO-EXIST			

Figure 15:1. The differential diagnosis between spinal stenosis, prolapsed intervertebral disc and peripheral vascular disease is principally on clinical grounds. The investigations outlined in this figure, however, will usually serve to resolve any clinical contention.

C H A P T E R 16

ELECTROPHYSIOLOGICAL DIAGNOSIS OF NERVE ROOT COMPRESSION

INTRODUCTION

The presence of developmental or degenerative narrowing of the spinal canal or nerve root canals is by itself of little significance until nerve root compression occurs. The presence of objective neurological abnormalities which are clinically detectable, is uncommon in the early stages of spinal stenosis. It is therefore logical to make use of electrophysiological studies to detect the very earliest neurological change. This chapter describes a number of clinical neurophysiological studies in patients with spinal stenosis mostly electromyography, and describes the electrophysiological changes which occur in nerve root compression. The value and limitations of this technique in clinical practice are described.

Abnormalities on plain radiographs of the spine increase exponentially with age. Myelography and radiculography may themselves reveal abnormalities which are incidental findings. Radiography therefore reflects structural change which does not necessarily correlate with functional abnormalities. For example, a lateral disc protrusion at the L5-S1 level may compress either the fifth lumbar nerve root laterally, or the first sacral nerve root or both.

Advances in electro-diagnostic testing in recent years has provided a more physiological assessment of spinal nerve root lesions. These techniques have included needle electromyography, F-wave response (and H-reflex) measurements, and somatosensory evoked potential. The severity of the lesion is more easily assessed than is the vertebral level of nerve root involvement.

NEEDLE ELECTROMYOGRAPHY

Electromyography localisation of a nerve root lesion is based upon abnormalities of the myotome innervated by a given nerve root, and the absence of this abnormality in other myotomes.

Evidence of active muscle denervation namely fibrillation or positive sharp waves first appears in paraspinal muscles between one to two weeks after injury (Eisen 1983). Changes do not become apparent in proximal extremity muscles until an interval of two to five weeks, and can take up to six weeks to develop in distal musculature of the involved myotome.

Although there is a high correlation between electromyographic abnormality and clinical and myelographic findings, it has the serious disadvantage of being absent in the early stages of nerve root compression. This criticism does not apply in patients with spinal stenosis where the development of compression is much slower and insidious in its onset.

As neuropraxia develops there is reduced recruitment of the number of motor units, and this is the most useful early needle electromyographic finding. Polyphasic potentials subsequently develop representing re-innervation, and become profuse about ten weeks after nerve root compression develops. These are gradually replaced by motor units of long duration and high amplitude as the reorganisation of re-innervated motor units occurs.

It is the presence of motor units of long duration and high amplitude which is the hallmark of chronic nerve root compression seen in spinal stenosis. Abnormalities detected in the paraspinal muscles are of little use in identifying a specific nerve root compression, since there is considerable segmental overlap of the nerve supply of these muscles in the superficial layers.

Jacobson considered that any combination of fibrillation and polyphasic potentials represented a positive electromyographic finding in patients with spinal stenosis (Jacobson 1976). He examined the adductor magnus and quadriceps muscles for evidence of L4 root involvement. However it is clear that the quadriceps receives additional innervation from the L2 and L3 roots, and that the L5 group muscles tested also receive innervation from L4 and S1. To detect abnormalities of the L5 nerve root, tibialis anterior, peroneus, extensor digitorum longus and brevis, and extensor hallucis muscles were tested by Jacobson, but Eisen found that gluteus medius became denervated as frequently as the more distal muscles in L5 root compression (Eisen 1983). Eisen found also that tibialis posterior was innervated mainly through the fifth lumbar root via the posterior tibial nerve, and this could be misleading. He also pointed out that extensor digitorum brevis which is purely an L5 innervated muscle becomes chronically denervated with increasing age. To examine for S1 root compression the gastrocnemius, soleus and hamstring group of muscles as well as gluteus maximus are involved. Gastrocnemius is involved more frequently than gluteus maximus in S1 radiculopathies.

It is also important to note that abnormalities of the glutei muscles localise the lesion proximally and help to rule out a peripheral neuropathy.

THE F-WAVE RESPONSE

F-waves are the late responses resulting from antidromic activation of motor neurones occurring when the axon is stimulated supramaximally. They were first recorded from the small muscles of the feet (Magladery 1950). It is not clear whether the antidromic activity affects the anterior horn cell, or does so directly through the Renshaw cell or dendritic tree excitation. F-waves give no information regarding the afferent input into the central nervous system, since they are still recorded after transverse myelotomy or dorsal root rhizotomy. Conduction times over a given segment of nerve differ by less than 0.5 of a millisecond when one compares results obtained through F-wave as opposed to direct motor response recording (M-wave). The average amplitude of the F-wave is only one per cent of the M-wave amplitude.

The F-wave latency correlates with the leg length. Prolongation of F-wave latencies has been found to be abnormal in fourteen per cent to forty-seven per cent of patients with radiculopathies. Abnormality of the F-wave response may be the sole electrophysiological abnormality encountered, particularly within the first week of acute root compression. With muscle paralysis however, the F-wave is often absent. With motor paresis the response is significantly delayed. When there is little or no motor weakness but there is a sensory deficit, comparing the F-wave latencies in comparable muscles of the two lower limbs to detect differences in the F-wave latency may be the only method of detecting the abnormality.

THE HOFFMAN REFLEX (H-REFLEX)

The H-reflex is the electric equivalent of the phasic muscle stretch reflex. Its latency is two to three milliseconds shorter than would be the case if it were mechanically induced, for example by a tendon tap. The H-reflex is a true monosynaptic reflex. Its latency gives useful information regarding conduction through proximal parts of sensory axons. The H-reflex also differs from the F-wave in that it is elicited by a sub-maximal stimulus, and its amplitude diminishes with increasing stimulus intensity. Its configuration and amplitude approximate to that of the M-wave. Unfortunately H-reflexes in the adult can only be elicited easily by stimulation of the posterior tibial nerve at the popliteal fossa with recordings made from the gastrocnemius-soleus complex. For practical purposes therefore, the H-reflex can be used only to evaluate the S1

afferent pathway.

With rare exceptions abnormalities of the H-reflex closely mirror abnormalities of the ankle reflex. Thus, inability to obtain an ankle jerk is accompanied by absence of the H-reflex. A depressed ankle jerk on one side compared with the other is usually associated with an H-reflex which is either prolonged in its absolute latency or significantly different from the latency of the response obtained on the normal side. The normal latency of the reflex is 28.5 ± 2 milliseconds (Eisen 1983). The upper limit of normal is 33.5 milliseconds, and when comparing one side with the other the difference should be no greater than 1.5 milliseconds.

An early and possibly valuable feature of the H-reflex is a fifty per cent or greater reduction in amplitude on the affected side when compared with the normal side. H-reflex studies have not proved useful in the diagnosis of L5 radiculopathies, even though the ankle jerk is mediated by fibres traversing this in addition to the S1 sensory root.

SOMATOSENSORY EVOKED POTENTIALS

Sensory symptoms or signs commonly occur in isolation in the early stages of spinal stenosis before a motor deficit develops. The electrical manifestations of the brain's reception of and response to an external stimulus be it visual, auditory or somatosensory, is referred to as an evoked response or potential. Unfortunately however because the stimulation used is inevitably multisegmental, an abnormality limited to one root is likely to be undetected because of the considerable dermatomal overlap in the lower limb, and the complexity of the evoked response or potential tending to mask any minor abnormality. Larson, however, found this examination useful. He placed recording electrodes on the scalp prior to laminectomy in patients with signs, symptoms and myelographic or computed tomographic evidence of lumbar stenosis to record the cerebral somatosensory-evoked potentials (Larson 1983).

The evoked potentials of normal persons are unaffected by walking or by flexion and extension of the spine. Larson obtained satisfactory recordings from sixty-two of sixty-six patients with lumbar stenosis. The amplitude of the initial portion of the evoked potential waveform was reduced in forty-seven patients to fifty per cent or less of control after walking, flexion or extension. These changes were reversible with return to control amplitudes occurring within several to thirty minutes. Responses to median nerve stimulation were never affected.

Thirty-six patients complained of pain associated with walking short distances, and the evoked potentials became abnormal in thirty-one patients after walking. Walking was the only stress applied to fifteen patients, and the responses became abnormal in eight of these. Evoked potentials were not affected by walking in patients who did not have claudication.

In thirty patients with spinal stenosis responses were recorded after walking, spinal flexion and spinal extension. Twenty-three out of the thirty recordings were abnormal. The changes associated with flexion and extension occurred immediately after the change in posture. The evoked potentials were reduced after walking and extension in twelve patients: walking and flexion in one patient: walking, flexion and extension in two patients: extension in six patients: flexion in two patients. Flexion and extension of the spine were the only stresses applied to seventeen patients. Response amplitude was significantly reduced in fifteen patients, six having both flexion and extension of the spine, seven extension, and two flexion.

Extension of the spine was the most frequent cause of evoked potential abnormality, reflecting the narrowing of the spinal canal and foramina which takes place during extension. The prompt reduction in response amplitude associated with extension, flexion, and even a change from sitting to standing also indicates a mechanical causation, since changes secondary to ischaemia have a latency of at least eight minutes (Flower 1972, Gilliat 1973, and Fullerton 1963).

Gonzalez examined cortical somatosensory evoked potentials (CSEP) of twenty patients with lumbar spinal stenosis a day prior to surgery and ten to twelve days after spinal decompression and bilateral lateral fusion (Gonzalez 1985).

Post-operative improvement was attributed to the immediate relief of compression with subsequent increase in available numbers of functioning large diameter myelinated fibres, conversion from conduction block to normal conduction and perhaps improved axoplasmic flow. It appears that spinal decompression partially reverses the underlying pathological process with subsequent improvement in short latency cortical somatosensory evoked potentials.

When somatosensory evoked potentials (SEP's) are combined and correlated with the myelogram and CT scan, the physiological alterations detected by SEP's can be correlated with the anatomical abnormalities

evident on the CT scan. Keim performed pre-operative SEP's on twenty patients and intra-operative SEP's on ten patients all with spinal stenosis, and found a close correlation between these SEP's, the CT scan, and operative findings when assessing the extent and laterality of the stenosis (Keim 1985). The posterior tibial nerve was abnormal in ninety-five per cent, the peroneal in ninety per cent, and the sural in sixty per cent in the symptomatic lower limb. The posterior tibial nerve was useful for screening. Bilateral lower limb SEP's can detect abnormalities on the asymptomatic side revealing unsuspected pathology, and were recommended by Keim for pre-operative evaluation. When the CT or myelogram and clinical findings are equivocal the SEP can be specifically helpful, and is probably more sensitive than conventional electro-physiological testing.

During spinal decompression SEP can be used to indicate when full spinal decompression has been accomplished or if further damage to nerve roots is occurring. The SEP monitoring equipment is extremely sensitive to the use of diathermy and other electrical equipment in the theatre and this may at present limit its usefulness in theatre.

CLINICAL STUDIES IN SPINAL STENOSIS

Knutsson in 1962 reported the results of electro-myography in one hundred and twenty-four patients with nerve root compression, and having compared the results made with the patient at rest with those during voluntary contraction, he concluded that not only was it far too time-consuming for routine clinical use, but also that it was sufficient to study the muscle at rest by examining the recordings for denervation, fibrillation and positive sharp waves (Knutsson 1962). Using this technique he reported an exact pre-operative electro-myographic diagnosis in seventy-eight point three per cent of patients which compared in his series with a clinical neurological diagnosis of seventy-seven per cent accuracy, and myelographic accuracy of seventy-five per cent. The exact diagnosis he stated was obtained at surgery, mostly for herniated discs with nerve root compression (Knutsson 1962).

Jacobson also confirmed a high index of correlation between detailed bilateral electro-myographic findings and the operative findings in ninety-seven patients with lumbar spinal stenosis (Jacobson 1976). He considered that any combination of fibrillation and polyphasic potentials was abnormal, and represented a positive electro-myographic finding.

Sixty-eight per cent of the patients had positive electro-myograms bilaterally, and also had bilateral symptoms. A third of the patients reported had bony stenosis resulting in compression of multiple nerve roots unilaterally. Electro-myography in these patients was performed bilaterally, and suggested a more diffuse pathological state than was suspected clinically.

He also examined patients with herniated discs and found an interesting electro-myographic difference between these and patients with spinal stenosis. Patients with spinal stenosis had electro-physiological evidence of diffuse root involvement. However only eight out of forty-two patients with a herniated nucleus pulposus had multi-radicular or bilateral electro-myographic abnormalities. Some difficulty arose in this study because sixty-nine per cent of these patients with herniated discs also had spondylosis or spinal stenosis. However the presence of bilateral abnormalities on the electro-myogram was present in sixty per cent of all patients with spinal stenosis, that includes those patients with only unilateral symptoms and signs, whereas bilateral abnormalities were found electro-myographically in only thirteen per cent of patients with herniated discs, and the majority of these had associated spondylosis.

Jacobson concluded that electro-myography helped to identify patterns of root involvement which distinguished a simple disc prolapse from those associated with bony stenosis. One third of the patients with surgically proven stenotic root canals and unilateral symptoms only were found to have bilateral electro-myographic abnormalities. He therefore concluded that a unilateral electro-myographic study was incomplete. He found a definite correlation between bilateral positive electro-myographs in particular and multi-radicular electro-myographs, and the findings of stenosis or spondylosis of the lumbar spinal canal. He emphasised however the importance of correlating these findings with those of myelography and radiography when surgery was contemplated.

These findings of bilateral abnormalities were confirmed by Seppalainen (Seppalainen 1981). She also noted that the electro-myographic abnormalities in lumbar spinal stenosis began at a higher level than expected in approximately thirty per cent of patients. She considered that this could possibly reflect a circulatory or nutritional abnormality which was more extensive than the area of bony hypertrophy and radiological stenosis. She noted that the discrepancies between the electro-myographic findings and the operative findings were usually minor, and in

twenty per cent of the thirty-six patients studied a good correlation was present also between the electro-myographic findings and the level of bony stenosis. She reported one anomalous finding which was of bony root compression of three nerve roots on the left, with more obvious electro-myographic abnormalities on the right where only one nerve root was involved.

ELECTRO-MYOGRAPHY IN NERVE ROOT CANAL STENOSIS

The location of the dorsal root sensory ganglion within the nerve root canal helps to indicate compression at this level, when there is no central canal involvement. Clearly compression of nerve roots within the central spinal canal compresses the root proximal to the sensory ganglion. Sensory action potentials arising from the distal sensory process will therefore be preserved in the presence of sensory loss (Yates 1981). However the more lateral the entrapment the more likely that the ganglion is to be involved, and therefore the distal sensory neurone will also be involved and the sensory action potential will be affected. In these instances sensory nerve conduction velocity and amplitude will be abnormal.

In one series of four hundred patients with spinal stenosis who came to surgery, fifteen had nerve root canal stenosis. In five of these patients electro-myographic abnormalities were noted, and this objective finding was instrumental in arriving at the decision to operate. In such patients the clinical features may be unimpressive, and the radiological findings diffuse and contrast radiculography normal. Nonetheless, the patient fails to respond to prolonged periods of conservative treatment, and in such patients carefully performed electro-myography may provide the objective evidence required for surgical decompression to be considered.

C H A P T E R 17

THE INCIDENCE OF SPINAL STENOSIS

INTRODUCTION

Previous chapters have indicated that degenerative changes occur within the lumbar spine with advancing age so frequently that they can be regarded as normal. This may be reflected in the high incidence of low back pain. Eighty per cent of people experience back pain to some extent during their active life time (Nachemson 1976). The prevalence of low back pain is well documented from many countries, with numerous reports of the epidemiological aspects of low back pain in industry (Andersson 1981).

It is surprising to note that epidemiological studies of low back pain include thousands of patients with as many as seventy-nine thousand persons chronically disabled through low back pain in Great Britain alone in 1971 (Harris 1971). Only a small proportion of these come to the attention of the hospital practitioner. In a British survey of two thousand six hundred and eighty-five men, thirty per cent had backache, and in seventy-six per cent of these it was confined to the lumbar region (twenty-three per cent of all men) (Anderson 1971). Twenty-two per cent of the low back pain sufferers were referred to hospital, and six per cent were admitted for treatment.

The epidemiology of spinal stenosis is not documented, but the majority of reported series of patients with spinal stenosis contain only small numbers of patients when compared with the total number of low back pain sufferers (see Chapter 10).

THE EPIDEMIOLOGY OF LOW BACK PAIN

Low back pain is one of the most frequent and disabling conditions affecting people in their productive years. It remains an expensive ailment when viewed socio-economically, accounting for thirty million working days lost in Britain alone in one year (DHSS 1985). Eighty per cent of persons will experience back pain to some extent during their active life. Men are afflicted as often as women, with white collar workers as often as blue collar workers. Investigations in California (Pheasant 1975) and Sweden (Dahlberg 1974) have shown that low back pain is the most expensive ailment in the thirty to sixty year old group.

In England (Dixon 1973), the United States (Leavitt 1971), Canada (White 1961), Israel (Magora 1970), and Sweden (Horal 1969) there is a striking uniformity in the annual incidence of the condition amongst industrial workers. This figure is around fifty per one thousand workers (Nachemson 1976). The number of working days lost per year varies from one thousand four hundred per one thousand workers in the United States, to about two thousand six hundred per one thousand workers in some factories in the United Kingdom (Duthie 1969). The total number of working days lost in Britain per year through low back pain alone is thirty million (DHSS 1985). By comparison, the total number of working days lost through industrial action in 1985 were six point four million, roughly twenty per cent of those lost through low back pain.

An interesting findings from Baltime, Maryland is that suburban dwellers who drive to work have twice the risk of experiencing severe back pain, compared with those who do not drive, whilst those workers who drive during most of their working days such as truck drivers, have three times the risk (Hanraets 1959). On a world-wide scale, by extending current figures, approximately two billion patients will suffer from low back pain during the next decade.

Radiographs of the lumbar spine may not be of as much assistance as one would hope in the diagnosis of low back pain. In three population surveys covering a total of one thousand seven hundred and two men and women, low back pain was found in fifty-nine per cent of those with radiological evidence of degenerative change of the lumbar spine, and in forty-seven per cent of those without any radiological abnormalities (Lawrence 1977). It is clear that low back pain is one of the most frequent and disabling conditions affecting people in their productive years.

The natural history and aetiology of back pain are still inadequately defined. This is partly the result of difficulties in classification, diagnosis and measurement methods. However epidemiological methods of assessing low back pain have not yet been used to their full potential. There remains also a need for improved application of preventative methods for dealing with low back pain, particularly in industry (Andersson 1981).

THE EPIDEMIOLOGY OF STENOSIS OF THE LUMBAR SPINAL CANAL

As noted, the epidemiology of spinal stenosis is only poorly documented at present. Although narrowing of the spinal canal may begin at an earlier age, symptoms are unusual before the third decade. The peak incidence of spinal stenosis is during the fourth to sixth decade. The symptoms may be precipitated by a fall or lifting incident which may result in a small disc herniation. Patients well over seventy are encountered quite often, usually with concomitant discal and spondylotic change. Advancing age by itself does not contra-indicate surgical decompression, and therefore accurate diagnosis is essential.

At the opposite end of the age spectrum, spinal stenosis may present in childhood. The first reported cases of painless spasticity, of flaccid paresis and enuresis and lower extremity deformities were described by Sarpyener in eight children in 1945 (Sarpyener 1945). Myelography in all these children showed focal narrowing of the lumbar spinal canal at more than one level. Only very few similar cases however have been reported in the literature since then. Dharker described in a series of sixty patients, six children aged between seventeen and nineteen who presented with progressive paraparesis, thought to be due to a congenitally narrow spinal canal (Dharker 1978). Birkenfield and Kasdon reported two patients aged fourteen and fifteen who presented with symptoms of neurogenic claudication, and who were found to have bony ridges on the posterior aspects of the vertebral bodies at the L4 and L5 levels (Birkenfield 1978). These ridges were believed to be congenital in origin and the patients improved following decompressive laminectomies. Dauser reported a patient whose symptoms began at the age of nine and by the age of fourteen developed progressive spastic paraparesis (Dauser 1982). Bladder dysfunction followed and myelography demonstrated a marked stenosis of the spinal canal at the L2 and L3 levels. Decompressive laminectomy resulted in a marked improvement in symptoms. (Fig. 17:1).

The Nuffield Orthopaedic Centre series of two hundred and twenty-one patients with spinal stenosis contained a twelve year old schoolgirl with congenital spinal stenosis. She had failure of segmentation of the first, second, third and fourth lumbar vertebrae with a hemivertebra at the second lumbar level. At the age of eleven she began to experience severe pains in both legs on exercise and a myelogram revealed narrowing of the spinal canal with the spinal cord terminating at the lower border of L2.

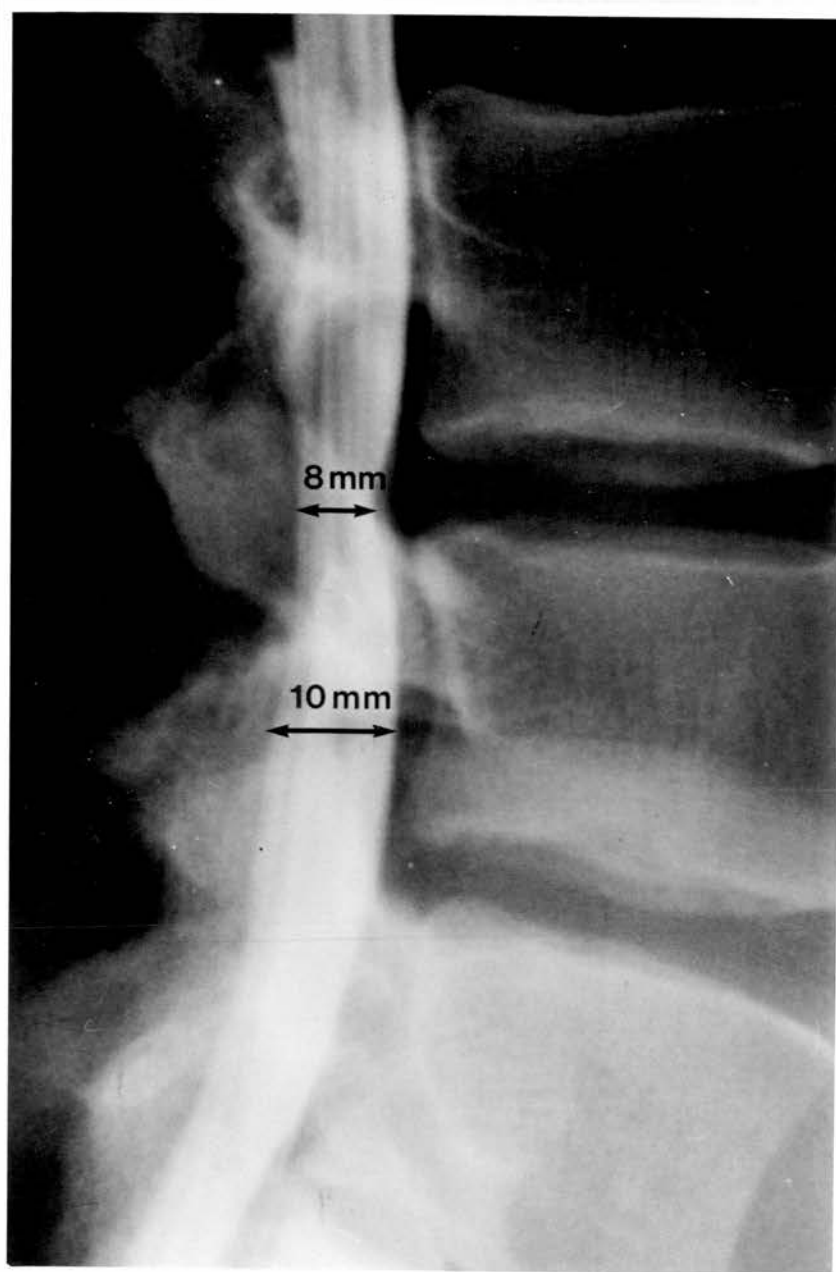


Figure 17:1. A spinal canal with developmental narrowing to 10 mm. at the osseous segment can be reduced to 8 mm. at the motion segment by minor degenerate bulging of the annulus fibrosus. This may be sufficient to precipitate symptoms of spinal stenosis.

At the age of twelve anterior spinal decompression was performed with strut grafting. Three years following surgery she had no pain after walking considerable distances.

Spinal stenosis may therefore present at any age. Males predominate in most series. Sedentary workers are as much at risk as heavy manual workers. Improved imaging techniques, in particular CT scanning, has resulted in an increased awareness of central canal, lateral recess, and nerve root canal stenosis, in patients who clinically and on the basis of myelography were previously diagnosed as having simple disc prolapse. The frequency with which the diagnosis of spinal stenosis is made is therefore bound to increase as a result of improved methods of investigation. (Fig. 17:2).

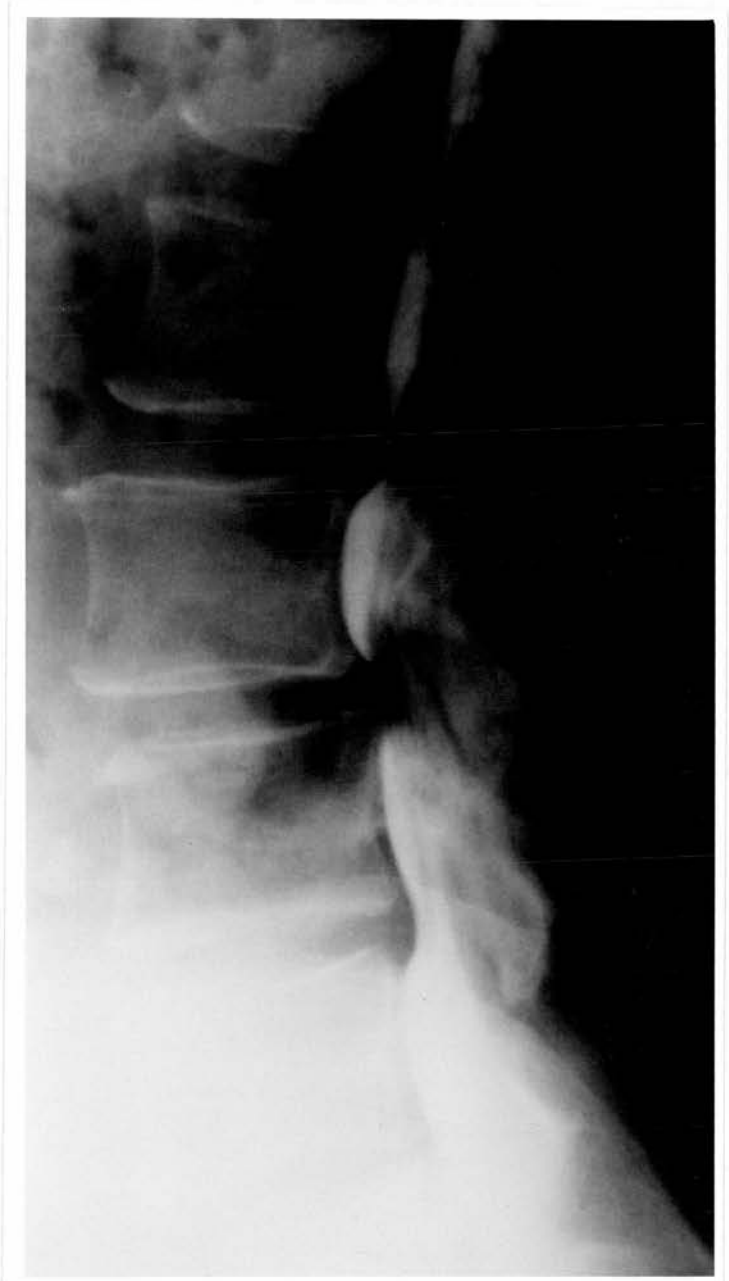


Figure 17:2. In a patient with severe developmental narrowing of the spinal canal, severe symptomatic stenosis may be precipitated by a very minor degenerative spondylolisthesis or retrolisthesis as illustrated in this lateral myelogram.

C H A P T E R 18

CONDITIONS ASSOCIATED WITH THE DEVELOPMENT OF LUMBAR SPINAL STENOSIS

INTRODUCTION

This chapter describes the development of spinal stenosis in a wide variety of conditions. These conditions include:

1. Congenital and degenerative spondylolisthesis
2. Diffuse idiopathic skeletal hyperostosis
3. Charcot spine
4. Ankylosing spondylitis
5. Achondroplasia and hypochondroplasia
6. Diastrophic dwarfism
7. Paget's disease
8. Endemic fluorosis
9. Post-traumatic.

These conditions will be considered separately and in turn.

LUMBAR SPINAL STENOSIS IN SPONDYLOLISTHESIS

Newman in 1976 reported the incidence of three common types of spondylolisthesis: first congenital (twenty-one per cent), secondly spondylo-lytic (fifty-one per cent), and thirdly degenerative (twenty-five per cent) (Newman 1976). He described the congenital spondylolisthesis of lumbo-sacral subluxation or spondyloptosis. When spinal stenosis occurs in this condition, it is difficult to estimate what proportion of the symptoms are caused by nerve root traction as the vertebrae separate, and what proportion is caused by bony or soft tissue compression.

The presenting symptom is often pain, a dull ache in the low back, buttocks and back of the thighs, increased in certain postures by standing, walking and bending, and a radicular pain radiating to the lower legs and feet, burning or lancinating in type and increased by coughing and sneezing. Paraesthesia in the lower legs and feet is common and examination often reveals marked restriction of straight leg raising, diminished reflexes and mild alteration of sensation. Newman considered that decompression by removal of the fifth and fourth neural arches was required (Newman 1976).

Spondylolytic Spondylolisthesis

The first description of a pars interarticularis "mass" in spondylolysis was provided by Schatzker in 1968 (Schatzker 1968). A "grade one" lumbar 4 on lumbar 5 spondylolisthesis was described and myelography showed that at the level of the slip a sharp angulation was present in the fluid column and oblique views disclosed postero-lateral and posterior encroachments. At surgery the dural sac was found to be compressed postero-laterally by large masses of osteo-cartilaginous tissue which pouted from the defects in the pars interarticularis. Decompression was achieved by removal of the loose lamina of lumbar 4, and wide excision of the osteo-cartilaginous tissue from the pars interarticularis, and by laminectomy of lumbar 3 and lumbar 5.

As the vertebral body slips forwards it does not carry with it the neural arch, so there is little tendency to constrict the spinal canal (Fig. 18:1). Spinal stenosis is not characteristic of this lesion, which occurs most frequently at the lumbo-sacral level and is more common in males (Newman 1976). Stenosis of the spinal or intervertebral canal is a sufficient indication for removal of the loose neural arch. The loose arch should be removed by the method described by Gill (Gill 1955). The spine should then be stabilised by postero-lateral inter-transverse fusion, or by anterior interbody fusion as a second stage procedure.

Degenerative Spondylolisthesis

This is the type of spondylolisthesis which most commonly produces the symptoms of spinal stenosis. It occurs most frequently at the L4-5 level, with the whole vertebra slipping forwards and the body carried with it the unchanged neural arch as a result of increased movement and sagittal orientation of the facet joints. Degenerative spondylolisthesis is more common in the female, but the symptoms of spinal stenosis are relatively more common in the male. The degree of slip is usually only mild averaging seventeen per cent of the antero-posterior diameter of the fifth lumbar vertebral body (Fitzgerald 1976).

Its development may be associated with osteo-arthritis of the hips and other joints. Osteo-arthritis of the hips affects seventeen per cent of these patients, and is usually severe enough to require total hip replacement. It may be that these patients are examples of the generalised polyarticular form of arthritis described by Kellgren and Moore (Kellgren 1952),

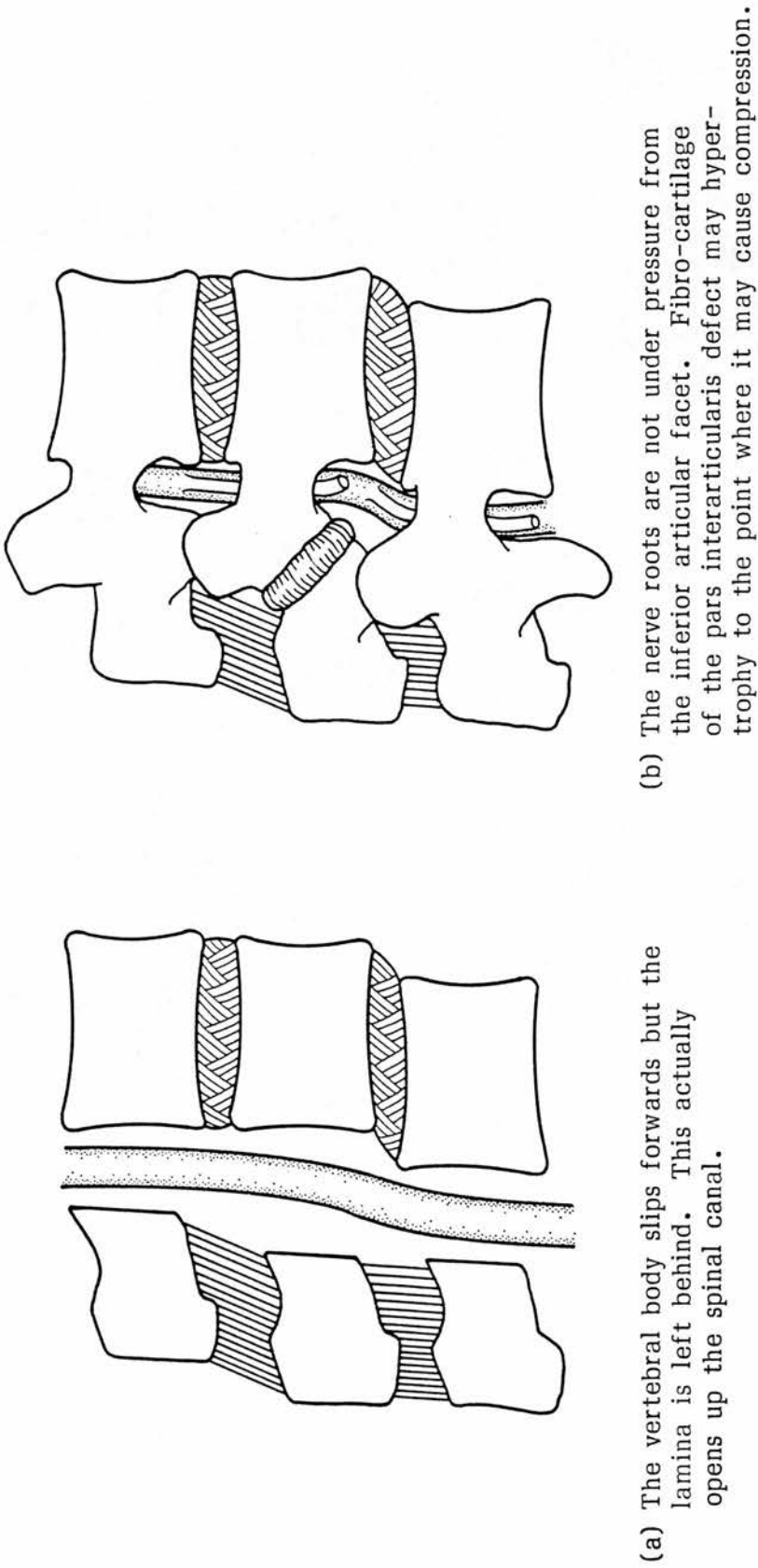


Figure 18:1. (a) Spondylolytic spondylolisthesis increases the space available within the spinal canal for the cauda equina since the vertebral body moves forwards away from its neural arch.
(b) Soft tissue and bony hypertrophy in and around the defect in the pars interarticularis may itself cause nerve root compression.

and by Lawrence, de Graaf and Laine (Lawrence 1963).

When neurological involvement occurs as a result of degenerative spondylolisthesis, the average slip is greater than in those without neurological involvement. The average slip in patients with neurological involvement is twenty per cent.

Although eighty per cent of patients with degenerative spondylolisthesis complain of backache with or without leg pain and have no objective evidence of nerve root compression, eleven per cent with sciatica have signs of nerve root compression, and nine per cent of patients with degenerative spondylolisthesis have the features of intermittent claudication of the cauda equina (Fitzgerald 1976). This condition is not generally seen before the age of forty. (Fig. 18:2).

Surgical decompression is performed by removal of the inner half of both facet joints on each side, and the lower half of the fourth neural arch. If pulsation of the dura is not then free, complete removal of the fourth neural arch is indicated. Stabilisation may be necessary and this can be performed postero-laterally or anteriorly at a second stage operation. Pressure on the fifth lumbar root will be relieved by double vertical partial facetectomy, which may leave the segment sufficiently stable to avoid the necessity for fusion. Discectomy should be avoided since this de-stabilises the spine and significantly increases the risk of further slip (see Chapter 20).

SPINAL STENOSIS IN DIFFUSE IDIOPATHIC SKELETAL HYPEROSTOSIS (D.I.S.H.)

In 1950, Forestier and Rotes-Queral described a disease involving primarily the thoraco-lumbar spine and characterised by bone out-growths from the antero-lateral aspects of the vertebral bodies (Forestier 1950). This disorder, known as "senile ankylosing hyperostosis" has since been described in the literature, with a variety of terms, including "spondylitis hyperostotica", "physiologic vertebral ligamentous calcification" and most recently, "diffuse idiopathic skeletal hyperostosis". Although the names have varied throughout the years, the clinical and radiographic findings described are similar.

The disease usually presents in middle age, with a male predominance. Patients commonly complain of mid-thoracic and lumbar pain without radiation. Occasionally cervical discomfort is described. Peripheral joint and muscular complaints are frequent, primarily involving the elbows and shoulders. Dysphagia caused by a hypertrophic anterior cervical spur may

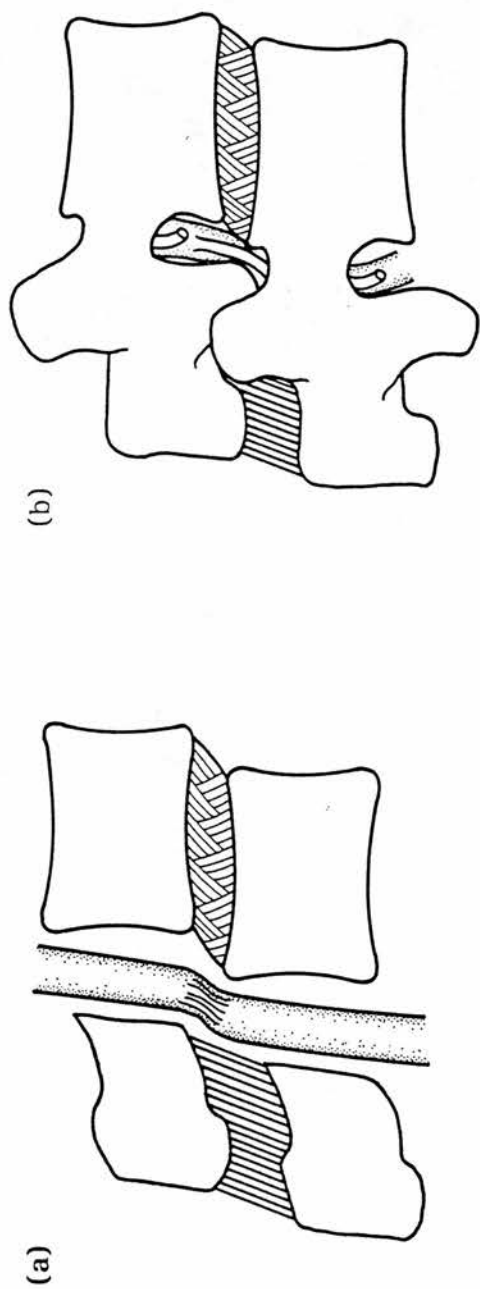


Figure 18:2. Degenerative spondylolisthesis not only significantly reduces the antero-posterior dimensions of the spinal canal (a), but also results in traction on and compression of the fifth lumbar nerve root as it prepares to exit from the level below (b).

cause the patient to consult an otorhinolaryngologist. Physical examination commonly demonstrates decreased range of motion in the spine which is not as severe as the limitation found in patients with ankylosing spondylitis. Findings in the extremities include limitation of motion in the elbow and shoulder joints, with occasional crepitation.

Radiographic findings are pathognomonic for the disease. The low thoracic and upper lumbar spine are the most frequently involved sites. The cervical spine is less often involved. The sacro-iliac joints are routinely spared. Significant calcification is found on the antero-lateral aspects of the vertebral bodies bridging the intervertebral disc spaces. The "flowing pattern of calcification" as described by Resnick, usually leads to bony ankylosis between three or more adjacent vertebral bodies (Resnick 1975).

In 1982 Karpman reported a case in which the D.I.S.H. syndrome was associated with marked hypertrophy of the ligamentum flavum leading to symptomatic lumbar spinal stenosis (Karpman 1982). Of considerable interest is the lack of involvement of the posterior longitudinal ligament in those cases of D.I.S.H. reported in the literature.

Diffuse idiopathic skeletal hyperostosis (Forestier's disease) may be mistaken for ankylosing spondylitis (Johnsson 1983). Three criteria have been proposed which help to distinguish D.I.S.H. from osteo-arthritis of the spine, intervertebral osteochondrosis, and ankylosing spondylitis. These three criteria are:

1. Flowing calcification and ossification along the antero-lateral aspect of at least four contiguous vertebral bodies;
2. Relative preservation of intervertebral disc height;
3. Absence of apophyseal bony ankylosis and sacro-iliac joint erosions, sclerosis or intra-articular osseous fusion.

The formation of new bone along the ligamentum flavum may be confirmed at surgery as a cause of spinal stenosis, and may indeed result in the sudden onset of neurological compression.

Apart from the spinal column changes, radiographic features include hypertrophic changes in joints of the extremities, primarily in the elbows and hands, and calcification of ligaments and tendons, especially sacro-tuberous ligaments and quadriceps muscle tendon just superior to the patella. Although the radiographic findings are striking in D.I.S.H., the patient's complaints are frequently minimal and they can usually be managed by anti-inflammatory medications. Surgical treatment is usually not necessary.

Other disorders which mimic D.I.S.H., i.e. ankylosing spondylitis, degenerative spondylosis or osteo-arthritis, post-traumatic or post-infectious spondylosis, acromegaly, and fluorosis can usually be excluded by radiographic examination or laboratory tests.

CHARCOT DISEASE OF THE SPINE

As long ago as 1859 Charcot first described the joint changes found in tabetic patients (Charcot 1859). Shortly afterwards in 1884 Kronig, a German physician, described also the neurological changes in the spinal cord (Alergant 1960).

Only four to ten per cent of tabetic patients developed Charcot joints, and six to twelve per cent of these involved the spine. The interval between infection with syphilis and the development of arthropathy can vary from five to forty years (McNeel 1969).

The dorso-lumbar and lumbar spine are the levels most frequently involved, and the disease may be localised to one or two vertebra. When root pain is present, it is quite often nocturnal, persistent, and distressing (Herndon 1927).

The radiological feature of Charcot spine is of dense sclerosis of the vertebral bodies, with massive osteophyte formation. At surgical exploration the laminae are found to be very thickened. Patients with stenotic symptoms generally require surgical treatment, since otherwise they steadily deteriorate (Alergant 1960). Surgical decompression of the spinal canal cannot be expected to improve the Charcot arthropathy, and in fact the increased mobility resulting from decompression may tend to hasten the destruction of the joints. Spinal decompression however should help to improve the quality of life of these patients.

This condition however is only rarely seen these days.

ANKYLOSING SPONDYLITIS

Hassan in 1976 reported that the cauda equina syndrome is a more common complication of ankylosing spondylitis than is generally appreciated (Hassan 1976). He describes six patients with ankylosing spondylitis and features of cauda equina syndrome. This occurred between seventeen and twenty-eight years after the onset of ankylosing spondylitis, during the period when the disease was relatively inactive as judged by symptoms and the erythrocyte sedimentation rate.

The initial symptoms may go unrecognised in patients with ankylosing spondylitis, with pain in the buttocks and thighs readily attributed to inflammation of the sacro-iliac joints. As symptoms progress however, pain, numbness, and weakness in the lower limbs as well as impotence and difficulties with micturition and defaecation may occur.

On myelography posteriorly situated diverticulae of the lumbar theca may be seen. These were first recognised by Matthews (Matthews 1968), and were regarded by Thomas as characteristic of the cauda equina syndrome (Thomas 1974). It may be that these diverticulae have simply been recognised more frequently when patients have been examined myelographically in the supine position.

Matthews described the necropsy findings in one patient in which it was shown that these diverticulae extended backwards and encroached extensively on the laminae and spinous processes of a vertebra and eroded the entire posterior surface of the spinal canal in the lumbo-sacral region. The role of these diverticulae in the pathogenesis of the cauda equina syndrome remains unclear.

Several mechanisms have been postulated by which the lumbo-sacral nerve roots may be damaged in patients with ankylosing spondylitis (Thomas 1974). It should be noted that an increased incidence of multiple sclerosis has been recognised in patients with ankylosing spondylitis (Hassan 1976). Moreover interference with the blood supply may be a late consequence of spinal irradiation previously used for the treatment of painful ankylosing spondylitis.

Zeman and Samorajski however confirmed that delayed post-radiation myelopathy would occur between one year and invariably five years of irradiation (Zeman 1970). The cauda equina syndrome however developed seventeen to forty years after irradiation, so irradiation appears unlikely to be the cause of the cauda equina syndrome in patients with ankylosing spondylitis.

Weinstein incorrectly stated that spinal stenosis had not been previously described in ankylosing spondylitis patients (Weinstein 1982). He did however suggest that the narrowing of the spinal canal might result from the inflammatory and proliferative processes involved in ankylosing spondylitis. He emphasised the value of CT scanning of the spine in patients with ankylosing spondylitis in whom spinal stenosis may be difficult to recognise.

SPINAL STENOSIS IN ACHONDROPLASIA

The characteristically exaggerate lumbar lordosis and tilting of the sacrum were described by Breus and Kolisko in 1900 (Breus 1900). Donath and Vogl described the spinal abnormalities of achondroplasia in more detail, noting the decrease in the height of the vertebral bodies and shortness of the pedicles (Donath 1925). They stated that the short pedicles resulted from a premature synostosis of the centres of ossification of the body with those of the lamina. They also described the gibbus or dorso-lumbar kyphosis which may develop in later life.

Spillane in 1952 described three patients with achondroplasia who developed neurological complications (Spillane 1952). None of these patients had been involved in tumbling or acrobatics. He noted that the posterior surfaces of the vertebral bodies of the lumbar vertebra were concave, and the intervertebral disc spaces were unusually wide. The patients he described had weakness and numbness of the legs, and difficulty with micturition in two cases due to stenosis of the lumbar spine which responded to laminectomy, and in one case due to subluxation of the axis on the third cervical vertebra.

Spillane also referred to the possibility of compression of the brain stem in patients with associated hydrocephalus, the presence of upper cervical cord compression through cervical spine anomalies, and the possibility of deformities of the base of the skull such as platybasia and narrowing of the foramen magnum causing compression at that level also.

Nelson in 1972 described spinal stenosis as the most serious complication of achondroplasia (Nelson 1972). It occurs infrequently however since there are an estimated eight hundred and fifty to one thousand five hundred individuals affected by achondroplasia in the United Kingdom, but only thirty cases of spinal stenosis had been reported by 1972.

The prevalence of achondroplasia is between seventeen and twenty-nine per million of the population. One in two of the children born to an achondroplastic parent will be affected, since it is inherited as an autosomal dominant. There is however a high mutation rate, so that in fact the majority of affected persons are born to normal parents, with no previous family history. Although the aetiology is unknown, raised paternal age has been shown to be a significant factor.

The primary defect is failure of growth in the proliferative zone of

the growth plate. This results in an initially small cartilaginous anlage and subsequently short thick long bone. A vertebra is preformed in cartilage and ossifies from three primary centres, one of the body and one for each half of the posterior arch (Fig. 5:1). Impaired longitudinal growth at the latter centres causes a shortening of the pedicles and a reduction of the inter-pedicular distance.

At birth the achondroplastic spine has the normal 'C' curve of the flexed embryo. As the child begins to sit up, the secondary curve in the cervical region develops. The large size of the head together with the general hypotonia results in a postural kyphosis, which appears at the lower thoracic or upper lumbar region. This is usually temporary, and in most patients disappears once walking occurs. However in some patients this kyphosis persists, and may progress to become a structural abnormality with wedging of the apical vertebrae. Morch in 1941 in a review of eighty-one achondroplastic patients reported a persistence of this kyphosis into adulthood in one-third of the series (Morch 1941) (Fig. 18:3).

With the attainment of the upright posture the lumbar lordosis develops. This is excessively developed in the achondroplastic and increases as adulthood is reached. Within months of birth there is a progressive excavation of the posterior surface of the vertebral body, resulting in the classical scalloping seen in the adult. It is possible that this progressive excavation of the posterior surface of the vertebral body is brought about by pressure created by the normal spinal contents in the presence of short pedicles. This represents the only way the spinal canal can be enlarged (Fig. 18:4).

Nelson described a number of features which contributed to the development of spinal stenosis in achondroplastics. In addition to the short pedicles and reduced inter-pedicular distance, one should always bear in mind the small foramen magnum, and proximally displaced atlas or axis. The structural kyphosis most common at the thoraco-lumbar region, or a prolapsed intervertebral disc or hypertrophic osteo-arthritis of the posterior joints or an increased lumbar lordosis may all contribute to compression of the cord and cauda equina. The symptoms rarely present before the age of fifteen since this is the age when a significant kyphosis develops. More commonly symptoms appear towards the end of the third and fourth decades. Nelson reviewed seventy-one patients in whom thirty-three had spinal complications (forty-six per cent). He divided them into three groups according to age, that is under fifteen, from aged fifteen to twenty-nine, and over aged thirty.

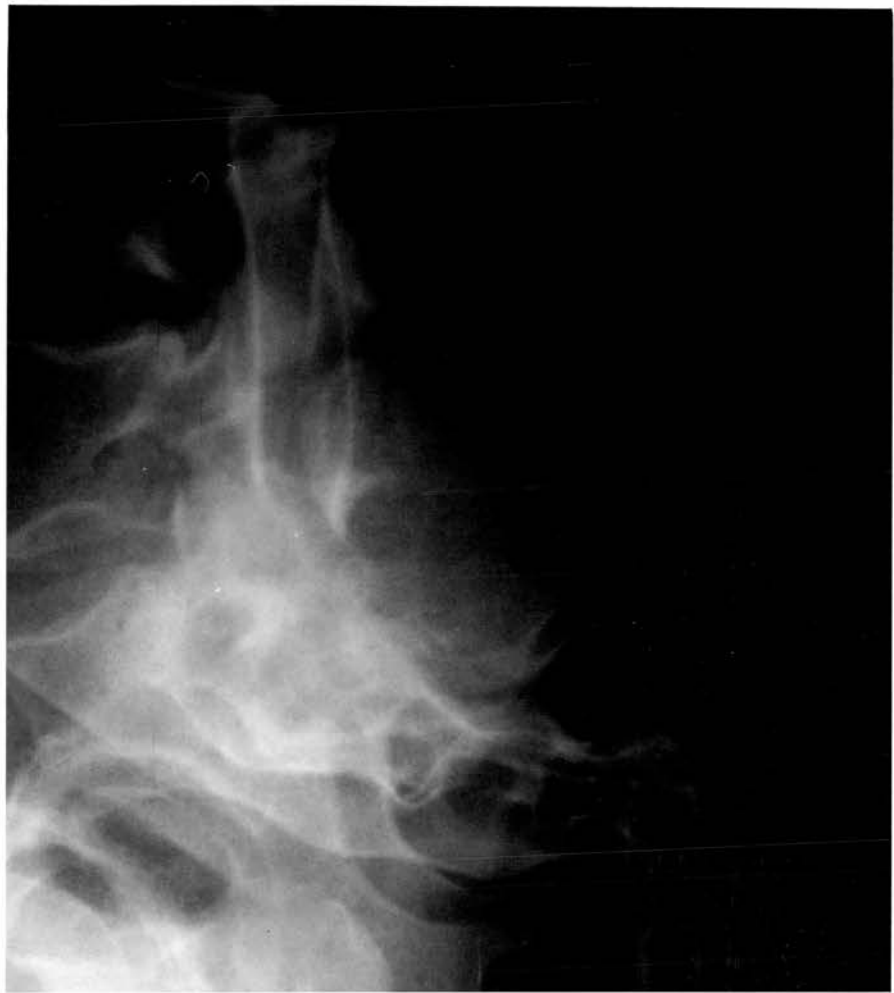


Figure 18:3. The horizontal sacrum of an achondroplastic patient. Despite the extreme lumbo-sacral lordosis, spinal stenosis may occur at any of the sites shown in Figure 18:4 in addition to the cervical spine.



Figure 18:4. The myelograms of three different patients each with achondroplasia, to show the different levels affected by spinal stenosis. Stenosis may occur at the thoracolumbar gibbus, or the mid-lumbar lordosis, or the lumbosacral hyperlordosis. Spinal stenosis is best managed initially with bed rest and traction followed by mobilisation in a spinal support. Although the initial results of extensive spinal decompression are rewarding the symptoms tend to recur some years later.

Nelson described four clinical syndromes in achondroplasia:

1. Single and multiple disc lesions
2. Generalised spinal stenosis often beginning in the lumbar region
3. Severe thoraco-lumbar kyphosis with spinal block
4. Foramen magnum insufficiency resulting in quadriparesis.

He then went on to make three recommendations:

- a) A progressive kyphosis in a child requires urgent splintage. If the kyphosis continues to progress, then fusion is required.
- b) The significance of early symptoms and signs of spinal stenosis must be stressed and early decompression performed as results are very disappointing once extensive neurological damage has occurred.
- c) Finally, careful pre-operative assessment of the whole spinal canal is necessary.

Ruth Wynne-Davies reviewed a series of forty-eight patients with achondroplasia and twenty-four with hypochondroplasia, looking amongst other things for the presence of spinal stenosis (Wynne-Davies 1981). She found the antero-posterior radiographs of the lumbar spine may frequently show the characteristic reduction of distance between the pedicles from the first to the fifth vertebra, but this was by no means found in every patient. Measuring the inter-pedicular distance from L1 to L4, she found that in sixty-nine per cent of achondroplastic patients the inter-pedicular distance became narrower from L1 to L4 whereas in forty-one per cent of normal individuals, the distance actually widened. However achondroplastics, hypochondroplastics and normal individuals may all have equidistance measurements between the pedicles of these vertebrae. Measurements at the fifth lumbar vertebra were found to be difficult and inaccurate.

Twenty-seven patients with achondroplasia and twelve patients with hypochondroplasia were studied for the features of spinal stenosis. They were aged between ten and thirty-four (mean twenty years), the symptoms were graded as mild (occasional pain or paraesthesia), moderate (persistent pain, paraesthesia or weakness), or severe (paralysis). Only three achondroplastic patients (eleven per cent) were free of symptoms, nine (thirty-three per cent) had mild symptoms and twelve (forty-four per cent) had moderate symptoms, and three aged ten, ten and thirteen had severe symptoms (eleven per cent). One of these three developed paralysis of the lower limbs between the ages of ten and eleven, and after investigation for spinal stenosis recovered spontaneously with rest. The second patient

developed severe backache between the ages of ten and eleven with persistent paraesthesia and weakness of the right leg. The back and leg pain occurred after walking only ten yards, and was relieved by rest. She had no treatment at this stage, but at the age of eighteen and again at nineteen a decompression was carried out. This was not successful, and at the age of twenty-four she is confined to a wheelchair. The third patient developed severe symptoms of spinal stenosis between the ages of thirteen and fourteen years. Decompression was successful and at sixteen he remains free of symptoms (Fig. 18:5).

In patients with hypochondroplasia eight out of eleven were free from symptoms. The more helpful warning sign of potential neurological complication however was a narrowed lumbar canal together with a persistent thoraco-lumbar kyphosis. In the presence of a persistent lumbar kyphosis complications are more likely if the inter-pedicular narrowing is severe, perhaps with an L1 and L4 ratio of 1.3 or more. It seems to be unusual for either kyphosis or narrowing by itself to lead to neurological complications.

SPINAL STENOSIS IN DIASTROPHIC DWARFISM

Diastrophic dwarfism is an autosomal recessive hereditary disorder producing abnormalities in bone, cartilage, connective tissue and muscle tissue. Walker noted that this deformity had the potential for causing spinal cord compression (Walker 1972), and shortly afterwards Kash reported an infant who had an insidious myelopathy which progressed over one and a half years to quadriplegia, a neurogenic bladder, and respiratory failure when the child was forty-one months old (Kash 1974). Post mortem examination revealed a kyphosis from the mid-lumbar to the sixth cervical vertebra with narrowing of the spinal canal and cord compression.

There is agreement that the lumbar pedicles are shortened in diastrophic dwarfism as they are in achondroplasia, although in the former this is probably limited to the lower lumbar levels (Bethem 1980). There is probably considerable variation in the inter-pedicular distance between different diastrophic dwarfs, and between different vertebra in the same individual (Fig. 18:6). This would account for continued disagreement in the literature. One of the largest series reported is by Walker of fifty-one patients in whom he found inter-pedicular distance tended to narrow caudally, or remain constant, or increase slightly, as one moves caudally (Walker 1972).



Figure 18:5. The lateral radiograph of the cervical spine of an achondroplastic female with spinal stenosis. She complained of weakness in the legs and unsteadiness on walking. A careful history revealed she had brachalgia and careful physical examination revealed evidence of an upper motor neurone lesion. Myelography revealed stenosis of the cervical , and not the lumbar, spine.



Figure 18: 6. Antero-posterior radiograph of the lumbo-sacral spine of a seventeen year old boy (M.S.) with diastrophic dwarfism. Note the widened inter-pedicular distance and spina bifida occulta.



Figure 18:7. Lateral radiograph of the lumbo-sacral region of the seventeen year old boy (M.S.) with diastrophic dwarfism. Note the horizontal sacrum with 90° hyperlordosis. There is however a spacious spinal canal both antero-posteriorly and transversely (Fig. 18:6), so spinal stenosis was not present.



Figure 18: 8. Antero-posterior radiograph of the hips and pelvis of a seventeen year old patient (M.S.) with diastrophic dwarfism, to demonstrate the horizontal sacrum associated with extreme hyperlordosis (Fig. 18:7). Pelvic and hip dysplasia are also well demonstrated.

The diastrophic dwarf shows exaggerated lumbar lordosis in childhood in fifty per cent of individuals (Fig. 18:7). This may be related to the hip flexion contractures as reported by Bailey (Fig. 18:8), and indeed these patients improve with Soutter procedures to the hips (Bailey 1973). In a reported series of nine patients with diastrophic dwarfism, Bethem found no evidence of a diminished inter-pedicular distance in the lower lumbar levels in three patients, whilst narrowing between the pedicles of the fourth and fifth lumbar vertebrae was definitely present in six patients, in some to a rather significant degree (Bethem 1980). However in none of these patients with narrowing did any symptoms suggestive of spinal stenosis develop.

None of the individuals with diastrophic dwarfism seen at the Nuffield Orthopaedic Centre developed evidence of spinal stenosis (Fig. 18:6 and 18:7).

SPINAL STENOSIS IN PAGET'S DISEASE

It is estimated that one in eleven thousand patients admitted to hospital has Paget's disease. Wyllie in 1923 first described the complications of Paget's disease of the spine (Wyllie 1923). Hartman reviewed two hundred and fifty patients with Paget's disease. Thirty-eight of these had Paget's disease of the vertebra (Hartman 1966). Ten of the thirty-eight had symptoms and signs of compression either of the spinal cord or the nerve roots, and five of these underwent laminectomy.

Jaffe estimated that malignant degeneration would eventually occur in two or three per cent of known cases of osteitis deformans. One case of osteogenic sarcoma complicating osteitis deformans of the spine was found in the English literature (Finneson 1958) (Fig. 11:9).

Men are more frequently affected by Paget's disease, with a sex ratio of about 11:1 (Teng 1951). Schmorl, in a series of ten thousand autopsies, noted Paget's disease in three per cent of patients more than forty years of age (Schmorl 1932). When the spine is involved, the commonest site is the thoracic spine. Cervical vertebrae are rarely involved. Neurological changes are less commonly associated with lumbar involvement, since there is more space in the neural canal at the level of the lumbar spine (Hartman 1966). One patient out of the ten with neurological compression described by Hartman had circumferential compression of the cauda equina by involved bone.

Cord and cauda equina compression are often preceded by a long period of non-specific symptoms, with minor neurological dysfunction. In patients with Paget's disease suspected of having lumbar canal stenosis, the diagnosis can be made by computerised tomography and in many patients the symptoms reversed by the use of calcitonin (Weisz 1983).

A vascular mechanism or "steal syndrome" has been postulated as an additional pathogenic factor in the production of neurological symptoms. This is thought to take effect through the diversion of blood into hyperaemic areas of Pagetic bone, thereby producing relative anaemic ischaemia of adjacent neural tissues. Although no anatomical proof has been found of this theory, it has been accepted as part of a combined pathogenesis, namely mechanical impingement and vascular dysfunction.

Calcitonin treatment can produce a partial or total recovery of paraparesis or paraplegia in Paget's disease. The number of such cases has increased in the last few years with initiation of treatment in the early phase, and prevention of a severe myelopathic syndrome. The symptoms of low back pain and leg pain which are usually bilateral are not necessarily affected by variations in posture unlike other forms of spinal stenosis.

ENDEMIC FLUOROSIS AS A CAUSE OF SPINAL STENOSIS

Skeletal fluorosis develops if the daily intake of fluoride exceeds 20 mg. (Hodge 1960). Crippling osteo-sclerosis usually appears some twenty years after the ingestion of the fluoride. Twenty-eight industrial occupations have been reported as at risk (Allcroft 1959), and tea reportedly contains from 56 ppm. to 399 ppm. of fluoride (Cholak 1960).

The first reported case of endemic fluorosis in Britain was in 1966 by Webb-Peploe (Webb-Peploe 1966). This was a fifty-seven year old carpenter who fell from a ladder eight years prior to admission and developed numbness and paralysis of both legs lasting for half an hour. Radiographs showed marked sclerosis of the pelvis and vertebral bodies, thought to be Paget's disease. However prominent bony spurs were noted at the sites of tendon insertions with marked vertebral lipping. A laminectomy was performed with good effect. The operative findings were that although the bone looked normal it was certainly thick and very hard. The lamina measured up to 2 cm. in thickness.

The radiographic features have been described by Roholm in 1937 .

(Roholm 1937). These are to quote:

"the affection is a system disease for it attacks all bones, though it has a predilection for certain places. The pathological process may be characterised as a diffuse osteo-sclerosis in which the pathological formation of bone starts both in the periosteum and in endosteum. Compacta densifies and thickens; the spongiosa trabeculae thicken and fuse together. The medullary cavity decreases in diameter. There is considerable new formation of bone from periosteum and ligaments that do not calcify or only in advanced age, undergo a considerable degree of calcification. All signs of bone destruction are absent from the picture."

The condition affects largely the pelvis, spine, ribs and lower limbs. The intervertebral ligament calcifies producing a "poker spine" in severe cases. "Rose thorn" multiple exostoses may give the appearance of hoar frost (Webb-Peploe 1966). Bones subject to the greatest stress are most affected, probably due to their greater calcium turnover.

SPINAL STENOSIS CAUSED BY A HARRINGTON HOOK

In 1983 Bowen reported the case of a twenty-two year old woman with an unspecified congenital myopathy who developed spinal stenosis eleven years after a T4 to L5 spinal fusion. This was associated with the slow progressive development of a lumbo-sacral lordosis, which had resulted in the Harrington hook at L5 tilting into the spinal canal (Bowen 1983). The tip of the hook had eroded the dura, and subsequently pressed on the nerve roots. Removal of the hook and fusion on the L5-S1 level relieved the symptoms. Clearly the fusion should have extended to the sacrum in the first instance.

POST-TRAUMATIC SPINAL STENOSIS

Post-traumatic spinal stenosis of the lumbar spine is characterised by the delayed onset of neural compression some time after the initial trauma. There is usually a significant asymptomatic interval between trauma and the onset of symptoms. The incidence of post-traumatic spinal stenosis is extremely low when looked at in the perspective of all injuries to the lumbar spine.

The initial trauma is usually a fracture or fracture dislocation of the lumbar spine, and the degree of narrowing caused directly by this should not be marked, although in one case reported by Inamochi it was (Inamochi 1981). The interval between trauma and the onset of neural

compression ranges from two to thirty years. Late reactive changes in facet joints and discs caused by trauma can also be responsible for subsequent spinal stenosis.

Hasue reported a patient who suffered a hyperextension injury to the lumbar spine and subsequently developed spinal stenosis. In many instances it is clearly difficult to link the traumatic episode directly with the development of spinal stenosis, particularly after an interval of up to thirty years, and even in the patient reported by Hasua, he noted that "degenerative spondylolisthesis of the fourth lumbar vertebra may have played a role in the narrowing of the spinal canal" (Hasue 1980). Trauma has however long been linked with the development of facet joint and disc degeneration. Traumatic spondylolisthesis may itself compromise the cauda equina or the fractured pars may heal with callus formation resulting in narrowing of the canal.

On the other hand, narrowing of the spinal canal prior to trauma may significantly influence the outcome. Firooznia reported three patients who became paraplegic after minor trauma to the spine without suffering a spinal fracture or dislocation (Firooznia 1985). Radiological investigation revealed marked stenosis of the spinal canal due to developmental stenosis with superimposed degenerative changes in two patients, and calcification of the posterior longitudinal ligament of the spine in one. Two patients recovered almost completely with conservative measures

The spinal cord may be able to tolerate slowly increasing mechanical pressure for many years as in slowly developing spinal arthrosis, or calcification of the posterior longitudinal ligaments. In these patients, the spinal cord conforms to the shape of the spinal canal, filling most of the available space without causing any neurological compression. In these circumstances, any additional pressure from swelling and oedema due to a minor trauma may tip the balance and result in major compression of the spinal cord or cauda equina to produce a significant neurological deficit.

OSTEO-ARTHRITIS OF THE HIPS

The frequency of osteo-arthritis of the hips in patients with marked spinal stenosis is thirty-three per cent (Surin 1982). This greatly exceeds the incidence of 0.15% of osteo-arthritis of the hip in the general population of the same age (Danielson 1964). This high incidence of concomitant osteo-arthritis of the hip and degenerative lumbar spinal

stenosis is relevant since patients undergoing total hip replacement may have unrecognised spinal stenosis. If such patients who have fixed flexion contractures of the hip joints are fully relaxed during an anaesthetic and placed in the supine position, the lumbar spine may be subjected to an exaggerated lordosis which may cause further damage to the cauda equina. Such patients are therefore at risk of developing paraplegia following routine total hip replacement.

In the Nuffield Orthopaedic Centre series of patients, fifteen per cent of those managed conservatively were noted to have osteo-arthritis of the hip, and ten per cent of those managed surgically had osteo-arthritis of the hip. This is not as high as the figure reported by Surin (Surin 1982), but is clearly above the incidence in the general population. This is the concept of Kellgren and Moore that these patients may belong to a group with a generalised polyarticular form of arthritis (Kellgren 1952).

C H A P T E R 19

CONSERVATIVE MANAGEMENT OF SPINAL STENOSIS

INTRODUCTION

A review of the literature on the management of spinal stenosis reveals numerous reports of the techniques and results of surgical decompression, but very little on the efficacy of conservative management. The reasons for this are three-fold:

1. The definitive diagnosis of spinal stenosis is made by radiculography and computerised tomography, and confirmed at surgical decompression, when the characteristic features of a tight spinal canal are visualised (Chapter 20). The patient who responds to conservative treatment requires neither radiculography nor computerised tomography, and therefore no matter how convincing the clinical presentation and physical findings many authors would consider that the definitive diagnosis of spinal stenosis had not been established.
2. Some patients who are investigated by radiculography and computerised tomography may then be managed conservatively for a variety of reasons. These patients would then be excluded from the surgical group, rather than included in a conservative group. The patient may have had previous back surgery, or the degree of functional overlay may dissuade the surgeon from operative management. When after careful consideration the decision is taken not to operate, or there is evidence of improvement, the patient is often discharged from follow-up and told to report back if any new problems occur. This group of patients is therefore not reviewed, and consequently not reported in scientific journals.
3. The prevalence of spinal stenosis in the community is unknown. Many elderly people do not seek medical advice if they have only minimal discomfort in the legs with exercise, or on extension of the spine. It is only when this discomfort interferes with everyday life that the medical practitioner is consulted. Some degree of spinal stenosis is probably very common, and it may be significant that many elderly people find it impossible to lie prone with any degree of comfort. We do not know how many patients overcome minor degrees of spinal stenosis through small modifications in their everyday lifestyle.

In this section of the thesis I report on the conservative management of one hundred and forty-nine patients who presented at the Nuffield

Orthopaedic Centre with the clinical features of spinal stenosis. In a series of two hundred and twenty-one patients with spinal stenosis, one hundred and forty-nine (sixty-seven per cent) were managed conservatively, and seventy-two (thirty-three per cent) treated by surgical decompression. In this report on the conservative management of patients with spinal stenosis, I hope that I have to a small extent corrected the imbalance in the reporting of patients with spinal stenosis treated conservatively, compared with those managed surgically. Clearly the more severe the disability, the more likely the patient is to be treated surgically, but nonetheless the inclusion of the conservative group is important to present the complete spectrum of the condition.

This chapter will therefore consider methods of conservative management of spinal stenosis and their effectiveness, and will describe also the medical treatment of spinal stenosis secondary to Paget's disease of bone.

METHODS OF CONSERVATIVE MANAGEMENT OF SPINAL STENOSIS

Many patients have symptoms of spinal stenosis which are not severe enough to warrant surgery, at least not until they had had an adequate trial of non-operative methods (Ailsby 1971). These patients may improve sufficiently with conservative treatment that surgery can be postponed indefinitely. Methods of conservative therapy include:

1. Training in the routine care of the low back. This includes instruction in lifting, posture and weight loss.
2. Isometric abdominal and back strengthening exercises (Williams 1965). Isometric exercises have been shown to raise the intradiscal pressure less than conventional isotonic exercises (Nachemson 1970).
3. An elastic back support or corset.
4. Epidural injection of a local anaesthetic agent combined with corticosteroids.
5. Non-steroidal anti-inflammatory drugs.
6. Immobilisation of the lumbar spine in a plaster jacket, with obliteration of the lumbar lordosis. Breig showed that when the lumbar spine moved from flexion to extension, the spinal canal shortened by an average of 2.2 cm. and the contained nerve tissues also shortened and became broader (Breig 1960 b). The ligamentum flavum became slack, and the cross-sectional area of it increased.

The intervertebral foramina narrowed, and there was a slight posterior protrusion of the discs at all levels.

In a group of twenty-nine patients with spinal stenosis secondary to degenerative spondylolisthesis, Fitzgerald reported that twenty-seven out of the twenty-nine were treated satisfactorily using a lumbo-sacral corset (Fitzgerald 1976). The authors noted the striking regularity with which these patients returned over the years for new corsets. In this group of patients with degenerative spondylolisthesis, patients with leg pain but without objective signs of nerve root compression responded well to conservative treatment, whereas those with leg pain with signs of nerve root compression were treated conservatively but without success. Electrophysiological testing of nerve root function was not performed in this study, but the presence or absence of neurological abnormalities in the lower limbs was used as a measure of severity of stenosis. Clearly the majority of patients with mild stenotic symptoms improved with conservative treatment, whereas the majority of patients with severe spinal stenosis did not and required surgical decompression.

In a series of two hundred and forty-nine patients with root canal stenosis reported by Porter, the majority received no active treatment since it was considered that there was no evidence any particular method of non-operative treatment affected the natural history (Porter 1984). Epidural injections in particular appeared to be of little value, since the injected material was unlikely to come into contact with a nerve root within a stenotic root canal. Only a small proportion of patients with chronic nerve root canal stenosis will require surgical decompression.

METHODS USED IN THE CONSERVATIVE MANAGEMENT OF SPINAL STENOSIS AT THE NUFFIELD ORTHOPAEDIC CENTRE, AND THE RESULTS OBTAINED WITH EACH METHOD

A. INDICATIONS FOR CONSERVATIVE TREATMENT

It is highly probable that many elderly patients do not seek medical advice when only minimal symptoms of spinal stenosis are present. For these individuals, minor modifications of their lifestyle may make the symptoms tolerable, or the natural history of the condition may result in a spontaneous remission. The spontaneous remission rate of mild spinal stenosis remains unknown and is likely to continue so because of the age group of the patients, and the absence of inexpensive, non-invasive diagnostic methods.

Patients suitable for conservative therapy may be unfit medically for surgery. They generally have few or no objective findings particularly on neurological examination and are able to continue with their employment or retirement activities. If pain and disability become so severe that the patient's employment or independence are threatened, or if a consistent objective neurological deficit develops particularly if it is progressive, or if the cauda equina syndrome develops then the patient will enter the surgically treated category.

B. PATIENTS AND METHODS

One hundred and forty-nine patients with symptoms of spinal stenosis were managed conservatively. Eight-six of these were male and sixty-three female. In thirty-two per cent of the males and twenty-six per cent of the females the diagnosis was confirmed by myelography, but in the remainder the diagnosis was reached purely on clinical grounds and by exclusion. However the degree of certainty with which one can reach a diagnosis on clinical grounds is high when following the principles described in Chapter 10. This is verified to some extent by the fact that none of the myelograms performed were normal, and all showed evidence of stenosis.

The average age of the males treated conservatively was sixty-three and of the females sixty. This is slightly older than the surgical group (fifty-six and fifty-four respectively) and may represent a bias on these ages from an elderly unfit population. A higher proportion of the conservative groups were in occupations which involved heavy lifting (thirty-six per cent of females and thirty-one per cent of males, compared with twenty-four and sixteen per cent in the surgical group). Compatible with this, forty-three per cent of the males described a lifting injury as the precipitating factor, whilst twenty per cent of the females in the conservative group were obese and another twenty per cent had had previous spinal surgery.

There was no difference between the medical and surgical groups when considering impulse pain, and a higher proportion of females in the conservatively treated group (twenty-four per cent) suffered night pains. Postural claudication was seven times less frequent in the conservative group, and the claudication distance was often further (up to two miles). There was, however, no significant difference between the conservative and surgical groups when considering the time taken before claudication pain was relieved, the frequency of low back pain, the duration of symptoms,

or the interval between the onset of low back pain and the onset of neurogenic claudication. For full details of these findings please refer to Chapter 10.

The following methods were employed in the conservative management of patients with spinal stenosis:

- (i) Bed rest with or without traction for two weeks
- (ii) Spinal corset for three months
- (iii) Plaster jacket for six weeks
- (iv) Non-steroidal anti-inflammatory drugs for three months
- (v) Epidural injection
- (vi) Physiotherapy - principally local heat and isometric back strengthening exercises
- (vii) Others, including weight loss, swimming, transcutaneous nerve stimulation, and a Yates drop foot appliance.

Patients sometimes admitted to visiting an osteopath or chiropractor and receiving treatment by manipulation or acupuncture at the same time as one of the above treatment methods. This clearly excluded that patient from the treatment group.

The above methods were employed exclusively in some patients, and because these patients either responded or were unfit for surgery, this group became the conservatively treated group. Other patients however received a period of conservative therapy before entering the surgical group, either because they failed to respond, or deteriorated neurologically during conservative treatment. This group constituted the surgical group, and most patients in the surgical group did, in fact, receive one or more forms of conservative therapy prior to surgery.

(i) Bed Rest for Two Weeks With or Without Traction

Forty-five patients in the entire series of two hundred and twenty-one (twenty per cent) were treated with a two week period in a hospital bed. The selection of traction was purely random and appeared to make no difference to the results. Patients confined to bed rest at home were not included, since one could not be certain they had received strict bed rest. This included meals in bed and the use of bed pain and bottle. The results of such treatment are shown in Table 19:1.

TREATMENT: BED REST: 2 weeks (N=45)				
		IMPROVEMENT	NO CHANGE	DETERIORATION
MEDICAL	Male (N=18)	75%	25%	0%
	Female (N= 8)	14%	14%	14%
SURGICAL	Male (N=12)	56%	33%	11%
	Female (N= 7)	60%	20%	20%

Table 19:1. The proportion of patients who either improved, noted no change or deteriorated following a two week period of enforced bed rest in hospital, expressed as a percentage of each sex / management group.

The patient was assessed at the beginning and at the end of the two week period of treatment and their response based principally on their claudication distance and pain severity. It should be noted that twenty per cent of females in the surgical group deteriorated during this two week period, but also that although a large number of patients did improve (fifty-six per cent to seventy-five per cent) this improvement was not sustained in the majority of patients once normal activities were resumed. Although fifty-six per cent of males and sixty per cent of females in the surgical group improved temporarily, they all ultimately required surgical decompression.

(ii) Spinal Corset ("Spencer" Corset)

One hundred and eleven of the two hundred and twenty-one patients (fifty per cent) were treated with a spinal corset for three months and then reassessed as above. The corset was found to be the most effective form of conservative therapy in both conservative and surgical groups (Table 19:2).

TREATMENT: CORSET: 3 months (N=111)				
		IMPROVEMENT	NO CHANGE	DETERIORATION
MEDICAL	Male (N=47)	78%	19%	3%
	Female (N=37)	67%	28%	5%
SURGICAL	Male (N=13)	46%	38%	16%
	Female (N=14)	54%	38%	8%

Table 19:2. The response of one hundred and eleven patients with spinal stenosis to a corset worn for three months, expressed as a percentage of patient in each sex/treatment group.

All patients were instructed to use the corset throughout the day, and some with severe back pain or leg pain especially at night found relief from wearing the corset in bed also. A greater proportion of patients in the conservative group (seventy-eight per cent of males and sixty-seven per cent of females) improved after three months compared with the surgical group (forty- six per cent and fifty-four per cent respectively). Often patients found such relief of symptoms from a corset that they continued with its use even after three months treatment. This was not encouraged because of the corset's effect on reducing spinal muscle power and tone. Very few patients deteriorated whilst wearing a corset.

(iii) Plaster Spinal Jacket

Thirty-seven patients out of the total of two hundred and twenty-one (seventeen per cent) were managed with a plaster spinal jacket. Despite newer lightweight materials available on the market, plaster of Paris was considered to provide the best fit to the patient through being more mouldable. The jacket was applied with the patient standing with the pelvis tilted forwards to obliterate the lumbar lordosis. It was moulded closely to the anterior superior iliac spines and the sacrum and from this foundation was built up to the nipple line and below the arms. It was not removed for six weeks and the patient reported on the symptoms at the end of this period. The results are shown in Table 19:3.

TREATMENT: PLASTER SPINAL JACKET: 6 weeks (N=37)					
			IMPROVEMENT	NO CHANGE	DETERIORATION
MEDICAL	Male (N=11)		64%	18%	18%
	Female (N= 6)		66%	17%	17%
SURGICAL	Male (N=11)		57%	14%	29%
	Female (N= 9)		44%	33%	23%

Table 19:3. The response of patients in each sex/management group to a period of six weeks in a plaster spinal jacket, expressed as a percentage of those treated in each group.

Only a small total number of patients were treated in a plaster spinal jacket, since for an elderly patient, particularly if living alone, this represents a considerable imposition on their mobility and independence. Also

biomechanical studies suggest that it is not possible to control spinal movement, particularly at the lumbo-sacral joint, unless one hip joint is also included in the jacket. This clearly is totally impracticable for most elderly patients.

The results illustrated in Table 19:3 indicate that a high proportion of patients deteriorate during the six weeks in a plaster jacket; that is, they have more leg pain and can walk a shorter distance before claudicating. This may be connected with the weight of the jacket and increased energy requirements of those carrying a plaster spinal jacket. However roughly one-half (surgical group) to two-thirds (conservative group) of patients claimed some improvement at the end of the six week period.

(iv) Non-steroidal Anti-inflammatory Medication

One of the many non-steroidal anti-inflammatory drugs such as "Brufen" or "Feldene" or "Naprosyn" or "Lederfen" was prescribed for a period of three months. The choice of drug was determined by patient tolerance, and patients with a history of gastric ulcer or skin reactions were not selected for this trial. Despite the widespread use of non-steroidal anti-inflammatories for low back pain, only forty-two patients were included since they received medication only and no other form of treatment. As many patients noticed no change as a result of this medication as noticed some improvement, and very few patients deteriorated (Table 19:4).

TREATMENT: N.S.A.I.D.: 3 months (N=42)				
		IMPROVEMENT	NO CHANGE	DETERIORATION
MEDICAL	Male (N=13)	50%	50%	0%
	Female (N=15)	43%	43%	14%
SURGICAL	Male (N= 8)	25%	75%	0%
	Female (N= 6)	60%	30%	0%

Table 19:4. The response of patients in each sex/management group to a period of three months on non-steroidal anti-inflammatory medication, expressed as a percentage of the total in each group receiving this treatment.

Only a small number of patients in the surgical group were treated using exclusively non-steroidal anti-inflammatory medication, since most of

these patients' symptoms were considered sufficiently severe to justify alternative treatment methods. This indicates that the patients in this treatment group were not entirely randomly selected.

(v) Epidural Injection

An epidural injection of Lignocaine and hydrocortisone was used in the management of forty-eight of the two hundred and twenty-one patients (twenty-two per cent) with spinal stenosis. In theory the hydrocortisone should reduce the degree of nerve root irritability by stabilising basement membranes and lysosomal membranes in and around the nerve root and by counteracting the immunological response to degenerate nucleus pulposus. In practice, however, only fifty per cent of patients in the conservative group noted any improvement and fifty per cent noted no change. In the female surgical group as many patients reported deterioration as reported improvement or no change (Table 19:5).

TREATMENT: EPIDURAL INJECTION: (N=48)					
			IMPROVEMENT	NO CHANGE	DETERIORATION
MEDICAL	Male (N= 9)		50%	50%	0%
	Female (N= 9)		50%	50%	0%
SURGICAL	Male (N=21)		33%	50%	17%
	Female (N= 9)		33%	33%	33%

Table 19:5. The response of patients in each sex/management group to an epidural injection, expressed as a percentage of the total in each group receiving this treatment.

Considerably more males in the surgical group received an epidural injection than any other group, yet both surgical groups reported minimal improvement (thirty-three per cent) with deterioration in a significant proportion of patients (seventeen per cent of males and thirty-three per cent of females).

The small number of patients who improved following an epidural injection is probably because in patients with spinal stenosis the injection is physically unable to reach the site of the compressed nerve root for lack of space around the nerve. Patients in the surgical group in fact deteriorated following an epidural. This may be because the mechanical effect of injecting a certain volume of fluid into an already compromised

spinal canal must be to produce further venous stagnation or anaemic hypoxia of the nerve roots only to augment the symptoms. On the whole epidural injections in spinal stenosis were found to be unreliable and unpredictable, and could make the condition worse.

(vi) Physiotherapy

Patients in this group were treated for a period of six weeks with heat, ultrasound, infra-red, and gentle isometric exercises to improve abdominal and paraspinal musculature. Maitland's manipulation and transcutaneous nerve stimulation was not included. Forty-eight of the two hundred and twenty-one patients were treated for a six week period exclusively by physiotherapy (twenty-two per cent). Clearly for an elderly person living alone, the exclusive attention of a young dynamic physiotherapist may be extremely beneficial psychologically. At the end of six weeks, the claudication distance and pain severity were recorded (Table 19:6).

TREATMENT: PHYSIOTHERAPY: 6 weeks (N=48)					
			IMPROVEMENT	NO CHANGE	DETERIORATION
MEDICAL	Male (N=15)		71%	29%	0%
	Female (N=17)		62%	25%	13%
SURGICAL	Male (N=11)		50%	25%	25%
	Female (N= 5)		40%	20%	20%

Table 19:6. The response of forty-eight patients to a six week period of physiotherapy, expressed as a percentage of the total in each sex/management group.

A smaller proportion of patients in the surgical group responded to physiotherapy (fifty per cent of males and forty per cent of females) than in the conservative group. Between one-fifth (females) and one-quarter (males) of patients in the surgical group in fact deteriorated during the six week period of physiotherapy, possibly indicating how sensitive some patients with spinal stenosis are to exercise. The response of the conservative group of patients was, however, more favourable (Table 19:6).

(vii) Other Methods of Conservative Management

The numbers of patients treated by other means was too small and the duration of treatment too variable to permit any conclusions to be drawn. It is a strong clinical impression, based on this series however, that in obese patients dietary loss of weight is frequently associated with improvement in symptoms. Some patients find swimming beneficial, although this is only a small group. The transcutaneous nerve stimulator provided considerable relief of very localised pain for a small group of patients.

The use of a Yates splint drop foot appliance was indicated in a number of patients. Although this may improve the gait considerably and be well accepted by the patient it cannot be expected to improve the claudication distance or reduce the severity of leg pain.

The observation that total hip joint replacement results indirectly in improvement of back pain was not confirmed in this series. The number of patients with spinal stenosis who underwent total hip replacement prior to spinal decompression was, however, too small to permit any firm conclusions.

THE MEDICAL TREATMENT OF SPINAL STENOSIS IN PATIENTS WITH PAGET'S DISEASE OF THE VERTEBRA

Dysfunction of the spinal cord or cauda equina secondary to Paget's disease of the vertebra is usually attributed to bony compression and is fortunately rare, although more than one hundred cases have been described since the first report by Wyllie in 1923 (Wyllie 1923). The treatment until recently was surgical decompression of the spinal cord or cauda equina (Klenerman 1966). The availability of several new drugs over the past fifteen years however (Russell 1979), raises the possibility that relief of neurological symptoms and signs might be achieved by medical treatment alone, and subsequent relapse avoided by their use. These drugs include calcitonins, the diphosphonates and mithramycin and are effective in reducing both the pain and the biochemical indices of disease activity.

Douglas reported in 1981 the medical treatment of eight patients with paraparesis associated with Paget's disease of the vertebra (Douglas 1981). Treatment for three to eighty-seven months with calcitonin or with diphosphonates produced marked clinical improvement in seven of these patients. The eight patients were aged from thirty to seventy-five years

and were treated in Sheffield since 1970. Their response to salmon calcitonin (Calsynar), to porcine calcitonin (Calcitare), to ethane 1-hydroxyl-1, diphosphonate (disodium etidronate, EHDP, Didronel), and to dichloromethylene diphosphonate (Cl_2MDP) was reported.

From this series and a review of nineteen additional case reports it was concluded that a favourable clinical response was seen in about ninety per cent of patients, and that this response may occur very rapidly. Results were better or as good as those obtained by surgical decompression. Several of the patients included in the study were referred with recurrence of neurological signs after surgical treatment and clearly had severe disease. These neurological improvements were unlikely to be due to the natural history of the disorder, since spontaneous recovery from cord compression due to Paget's disease has not been reported, and probably does not occur. (Fig. 19:1).

It was postulated that paraparesis in some cases might be due to diversion of the blood supply from the spinal cord to the highly vascular Pagetic bone giving rise to a vascular "steal" phenomenon. Douglas suggested that medical treatment should be used more widely to avoid or delay the need for operation and reduce the risk of recurrence. It was pointed out however that these patients required life-long follow-up because of the possibility of relapse and further treatment being required.

In 1983 George Weisz reported the successful reversal of symptoms of spinal canal stenosis in association with Paget's disease using high dosage calcitonin (Weisz 1983). The diagnosis of stenosis was made using computerised tomography in the three patients reported. In addition to loss of leg pain, the treated patients also had loss of tenderness of the spine at the involved bony levels, increased spinal mobility and a reversal of the biochemical indices such as serum alkaline phosphatase activity and 5HP urinary excretion. The dosage used was 160 units intramuscularly for the first two months, followed by half that dosage in the following months.

The report by Weisz is of interest in that bony canal stenosis was demonstrated by computerised tomography and indentation of the dural sac visualised by myelography, yet the syndrome of spinal stenosis was successfully halted and reversed by medical treatment.

Three types of drugs are therefore available for the management of Paget's disease of the spine associated with neurological complications:

1. Calcitonin. This became available in the early 1970's. Although it



Figure 19:1.

Paget's disease of the vertebra may result in symptoms of spinal stenosis from a "vascular steal" phenomenon. This is often amenable to medical treatment using calcitonin. This lateral radiograph of the thoraco-lumbar spine, however, illustrates a complication of Paget's disease which is not so readily treated: that of osteogenic sarcoma.

it is very effective in some patients, its long-term use may result in the development of resistance to the drug. Sometimes this is due to antibody formation, but in other patients in whom resistance develops, no significant antibody titre can be detected.

2. Mithramycin. This is an antibiotic with cytotoxic activity. Its potential toxicity in producing thrombocytopenia and impairment of renal and hepatic function have discouraged its widespread use.
3. The diphosphonates. These are a group of compounds which inhibit the growth and dissolution of hydroxapatite crystals in vitro, and inhibit bone resorption in organ culture and in vivo. They have been used for several years in the treatment of Paget's disease, but when given in high doses (20 mg. per kg. per day), can induce a mineralisation defect (Smith 1973). These adverse effects are not seen with lower doses (5 mg. per kg. per day), but these are less effective in suppressing pain and reducing the biochemical indices of disease activity.

The results of medical treatment of spinal stenosis due to Paget's disease must be looked at in the perspective of surgical results. The largest such series was reported by Sadar, Walton and Gosman in 1972 (Sadar 1972). They collected ninety patients, sixty-four of whom were explored surgically. Improvement occurred in fifty-five of these patients (eighty-five per cent), but this was only slight in four patients, and three were found to have sarcomatous change. Two patients were unchanged and one was made worse by surgical exploration. There were seven operative deaths (eleven per cent), and six patients underwent repeated laminectomies.

Douglas reported a favourable clinical response in about ninety per cent of a smaller series of twenty-seven patients, and this together with the work of Weisz would confirm the importance of medical management in patients with spinal stenosis due to Paget's disease of the vertebral column.

CALCITONIN IN THE TREATMENT OF NEUROGENIC CLAUDICATION

It is of great interest that Porter has successfully treated patients with lateral recess stenosis using Calcitonin (Porter 1986). It is known that calcitonin reduces vascularity of bone and that deafness from Paget's disease due to neurological compression of the eighth cranial nerve

responds to calcitonin. It seems most likely in the early stages of lateral canal stenosis nerve root ischaemia occurs, and since the nerve root shares a finite blood supply with its surrounding bone, then an explanation exists in the "vascular steal" phenomenon for Porter's observations.

Forty-one patients with neurogenic claudication were treated by Porter using calcitonin. Eleven patients noted improvement in walking distance; five of these had degenerative spondylolisthesis (Porter 1983). Fifty-eight per cent of those patients with bilateral and equal leg pain distal to the upper calves who could walk less than one mile, whose pain was relieved by rest, and who had a positive myelogram and no more than one "inappropriate sign", responded to calcitonin therapy (nineteen patients). This suggests that it is possible by careful selection to identify a group of patients suitable for calcitonin therapy.

C H A P T E R 20

THE SURGICAL MANAGEMENT OF SPINAL STENOSIS

INTRODUCTION

The surgical treatment of spinal stenosis does not lend itself to study by means of double-blind controlled clinical trials. Recommendations for treatment in the literature and textbooks are based upon the experience, sometimes over a life-time, of an author or group of authors with a specific interest in spinal stenosis. The early series reported consisted of small numbers of patients followed up for only short periods of time (Teng 1963). An increased awareness of and interest in spinal stenosis has to some extent relieved this problem such that a major series from a spinal centre usually in the United States of America would now consist of around fifty patients treated surgically (Rosomoff 1981).

Exploratory operations of the spine to establish the diagnosis of spinal stenosis are now no longer required. The advent of water-soluble contrast radiculography and computerised tomography enables surgical decompression to be a carefully planned operation and not a "look and see" adventure. The extent of nerve root compression visualised radiographically can be correlated with the clinical features and the appropriate, exact, and precise operation performed for each individual patient. Despite improved imaging techniques however, the decision to operate remains still a clinical one, and the results of surgery still are assessed on clinical grounds. These tend to be largely subjective, such as the relief of leg pain following surgery, or the patient's return to work. Objective criteria for pre- and post-operative assessment such as electrophysiological testing or the return of an ankle reflex, are in fact useful monitors of the success of decompression. The absence of such objective neurological improvement following surgery however may not necessarily indicate the inadequacy of surgical decompression, as much as the state of the nerve root itself which may have undergone such extensive intra-neural fibrosis that recovery is not possible even following appropriate and extensive decompression.

PROBLEMS ENCOUNTERED IN ASSESSING THE RESULTS OF SURGERY

1. It is not possible to compare the results of surgical treatment with the results of conservative treatment for a number of reasons. It has already been stated (Chapter 19) that patients with only

minimal functional impairment from spinal stenosis tend to be treated conservatively. This group would include many ageing patients whose activity level is already declining through cardio-vascular or respiratory failure, or associated degenerative change in the hip or knee joints or because of an altered life-style following retirement. Patients who are otherwise fit and well may require surgery when their functional incapacity is due solely to spinal stenosis. Normally it is the more severely affected patients who are treated by surgical decompression.

2. Spontaneous remission of symptoms may occur with time even in some patients who are severely affected (Yates 1981). Two patients in the series reported by Blau and Logue were not operated upon (Blau 1978). One of these patients showed deterioration whilst the other showed slight improvement with time. A seventy-two year old book-maker was reported with increasing bilateral leg pain and numbness at a walking distance of four hundred yards. Electro-myography showed bilateral L5-S1 denervation affecting also the paraspinal muscles. Tomography confirmed spinal stenosis, but surgery was declined. By the following year his walking distance had increased spontaneously to one mile (Yates 1981).
3. Methods of assessing patients objectively before and after treatment are inadequate (*vide supra*). In practice the clinician tends to rely on the patient's own reports of improvement or deterioration in claudication distance, and in the severity of pain in the leg with exercise. Leg pain may not necessarily be caused by nerve root or cauda equina compression or claudication, and may in fact be referred from the facet joints or ligamentous structures of the spine with exercise or be of vascular origin even in the presence of peripheral pulses, or be caused by joint disease or metabolic disease of bone.
4. The patient's age and expectation of life and the pressure to return to work may all influence the choice of treatment and the outcome. Wiltse observed that once the patient had severe symptoms from spinal stenosis, he did not get well with time as does the younger patient with a herniated disc (Wiltse 1976). Wiltse considered that surgery was the only solution for these people. The clinical results as judged by relief of pain in the elderly are better than in the thirty to fifty year age group. This may be because these people



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varying degrees of thickening of the ligamentum flavum and inter-spinous ligaments. He pointed out that this is not readily appreciated unless the canal diameter is evaluated with the patient's body in neutral extension rather than in the flexed position. Brodsky paid particular attention to resection of a portion of the base of one or more spinous process and the intervening projecting ligamentous tissue, rather than doing a complete central laminectomy which he reserved for the more severe grades of spinal stenosis.

Verbiest noted in three patients all with "pure absolute stenosis" that the dural sac was narrow, and remained narrow even after surgical decompression (Verbiest 1975). The neurosurgical literature emphasises the importance of enlarging the dural sac and either leaving it open, or closing it by means of a fascial graft. It is reported that even in the presence of adhesive arachnoiditis, opening the dura may relieve symptoms (Epstein 1978). Getty described one important reason for failure of surgical decompression as "inadequate decompression" (Getty 1980). He unfortunately did not define this, but stated that re-operation in this group seemed worthwhile. These results were reported in a rather empirical fashion with seventeen patients out of thirty-one decompressed classified as "good" although a total of twenty-six patients (eighty-four per cent) were satisfied. This was with a mean follow up of 3.5 years with a range from one to ten years. Despite the fact that the majority of patients were satisfied with the results of surgery, most were unable to continue their hobbies such as walking or gardening.

8. The levels included in surgical decompression may significantly influence the result. Verbiest identified areas of "relative stenosis" where actual compression did not exist at that time but where it could be anticipated as developing in later years, and hence he extended what he called a "preventative decompression" to include these areas. Of the thirty-one patients reported by Getty, twenty in the degenerative group were decompressed at the L4-5 level, in addition two were decompressed at L2-3, fourteen at L3-4, and twelve at L5-S1. In the mixed group of degenerative and developmental stenosis the L4-5 level and the L3-4 levels were decompressed in all eight patients, and L5-S1 in four patients. In the idiopathic group, decompression extended from L3 to L5 in two patients, and from L2 to L5 in one patient. Clearly the cause of

spinal stenosis influences the extent of nerve compression and therefore the extent of decompression required. Failure to appreciate the developmental component of spinal stenosis could result in an inadequate decompression.

INDICATIONS FOR SPINAL DECOMPRESSION

The indications for surgery in spinal stenosis vary from centre to centre (Verbiest 1975). More than fifty per cent of patients are greatly improved by conservative treatment. The presence of muscle weakness in the foot is not necessarily a strict indication for early surgery (Hakelius 1972; Weber 1975). Severe pain or bladder paralysis constitute the strictest indications. A study of fifty-nine orthopaedic surgeons in Britain revealed that they operated on fewer than ten per cent of cases referred to them with disc problems, whilst the neurosurgeons operated on more than fifty per cent (Glover 1971). Although no comparable report exists of patients with spinal stenosis, it would not be surprising to find the same ratio existed in this area also.

Indications for surgical treatment of spinal stenosis are as follows:

1. Intolerable claudication pain in daily living activities while on proper supportive treatment.
2. Presence of significant progressive muscle weakness. The shorter the time interval between the onset of motor weakness and treatment, the better the chance of recovery of motor function post-operatively.
3. Spincter dysfunctions. When sphincter dysfunction becomes evident, operative treatment is urgently indicated.

SHOULD SPINAL FUSION BE COMBINED WITH DECOMPRESSION?

The principle objective of surgical decompression is to relieve all pressure from bone, ligament, joint or disc structures on vulnerable nervous tissue contained within the spinal canal, the lateral recesses and the nerve root canals. Decompression of the central part of the spinal canal and the lateral recess is usually accomplished without jeopardising the integrity of the facet joints. To fully decompress the nerve root as it travels laterally past the facet joint, removal of the entire facet joint may be required or the articular facet may fracture during decompression.

The prime objective of surgery is clearly to achieve adequate nerve

decompression without jeopardising the stability of the spine. Bio-mechanical studies sectioning various anatomical structures in sequence have demonstrated not surprisingly that the more structures that are sectioned or removed, the less intrinsic stability the spine retains (Nagel 1981). In most patients it is possible to achieve a satisfactory compromise by combining decompression including the nerve root canals without jeopardising stability. In a small proportion of patients however, the facet joints are sacrificed and the question then arises: "should the spinal segment be fused?"

Instability is not a black and white phenomenon. It is a spectrum dependent upon the integrity of the remainder of the spine, the age of the spine in particular the disc, and the level of activity and stress to which the spinal segment is subjected by the individual concerned.

It has long been assumed that destruction of the facet joint in the course of a full laminectomy would produce instability of the spinal column. In 1970 Roaf stated that:

"bone should be removed well laterally, but it is inadvisable to destroy the joint between the inferior and superior articular processes".

If the facet joint was resected he recommended spinal fusion as do many other (Roaf 1970). Other authors report that the preservation of the zygapophyseal joint is not necessary in the adult patient (Shenkin 1976). Gill and White and others have found that removal of the posterior element in patients with spondylolisthesis does not increase the vertebral displacement (Gill 1965). Indeed there are many reports that spondylolisthesis (with spondylolysis) does not increase after the age of twenty years (Laurent 1961; Wiltse 1962). In degenerative spondylolisthesis however it has been reported that the risk of progression of the spondylolisthesis is approximately sixty-six per cent following decompression if the intervertebral disc is removed at the time of decompression (White 1977).

The debate therefore continues but it should also be stated that "instability" is not easy to define, and that excessive movement at an intervertebral segment may itself be the cause of further nerve root irritation and possibly inflammation, with the development of arachnoiditis, and further radiculitis. It would seem reasonable therefore to fuse those patients in whom exaggerated intervertebral movement can be demonstrated at operation following decompression (Fig. 20:1-20:3).

When fusion is required it should be performed at the time of the initial decompression procedure. Clearly there are absolute and relative



Figure 20:1. Lateral radiograph of the lumbar spine of a forty-nine year old doctor's receptionist with spinal stenosis at the L4-5 level treated surgically by wide decompression and inter-transverse fusion. The arrow indicates the L3-4 level where there is no evidence of instability or spondylolisthesis (see Figure 20:2 and 20:3).

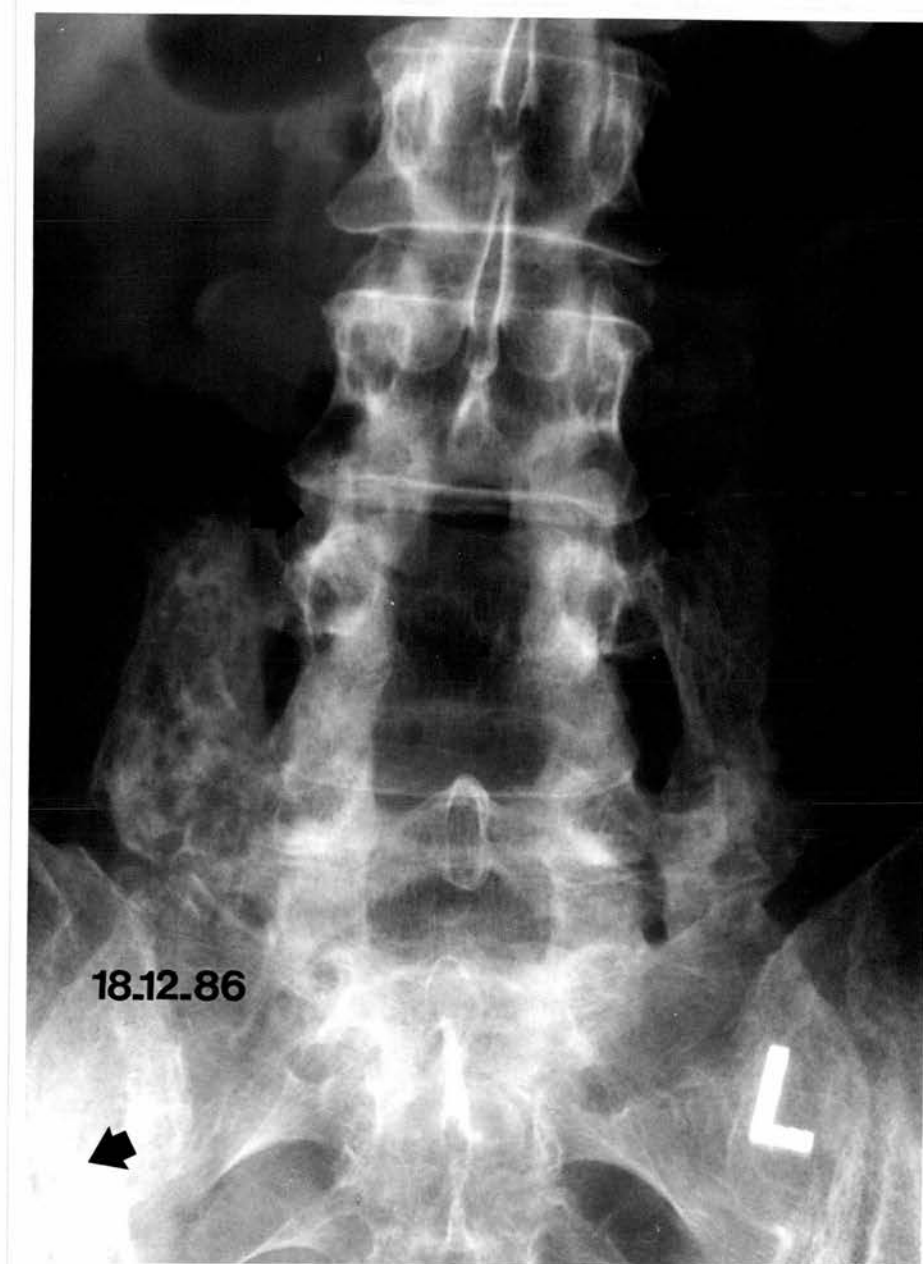


Figure 20:2.

A.P. radiograph of the lumbo-sacral spine of the doctor's receptionist (J.M.) four years following decompression and fusion. The patient has pain at the site of donation of the graft (arrowed) where the sacro-iliac joint was perforated, and at the L3-4 level above the fusion (arrowed).



Figure 20:3. The lateral radiograph of the lumbar spine of the doctor's receptionist (J.M.) now aged fifty-three with painful degenerative spondylolisthesis at the L3-4 level immediately above the fusion (arrowed) with evidence of early spinal stenosis arising from this level. This is one of the disadvantages of combining fusion with decompression.

indications for fusion in this group of patients. When the indications are relative and the surgeon adopts an expectant policy, planning to fuse in one year's time if the symptoms do not abate, the final result is most unlikely to be as satisfactory as an initial decompression and fusion procedure. This may be the result of excessive intervertebral movement following wide decompression causing further damage to nerve roots.

A conservative approach to treatment with traction and bed rest is rarely successful in patients with symptomatic lumbar stenosis (Critchley 1982). Furthermore if the spine is maintained in extension by a lumbar support or hyperextended when lax under anaesthesia, there is a risk of further damage to the cauda equina. Many patients have waited five or more years between the onset of symptoms and surgery; others have been made worse by ill-considered myelography or limited mid-line laminectomies. Nowadays the preferred operative procedure is a partial under-cutting facetectomy with decompression of the nerve root canal by removal of hypertrophied bony foramina, ligamentum flavum, and sequestered disc material. The success rate of operative treatment can be maintained as high as eighty-five per cent by such means even in the presence of adhesive arachnoiditis (Critchley 1982).

THE PATIENT'S POSITION ON THE OPERATING TABLE

When surgical treatment has been recommended after careful discussion with the patient and relatives, and after confirming the patient's general fitness for surgery, it is vitally important that the patient is correctly positioned on the operating table. Correct positioning facilitates the meticulous surgical technique required in decompression of spinal stenosis. Incorrect positioning makes surgery difficult and dangerous and possibly life-threatening (Fig. 20: 4-20:6).

The two major problems encountered by the surgeon in spinal decompression are (a) inadequate exposure and (b) failure to control bleeding.

(a) Exposure

Any position which decreases the lumbar lordosis facilitates the surgeon's entry via the posterior elements into the bony spinal canal to expose its contents and gain access to the intervertebral disc. It has already been stated that allowing the patient's spine to fall under the influence of gravity or during movement whilst the patient is

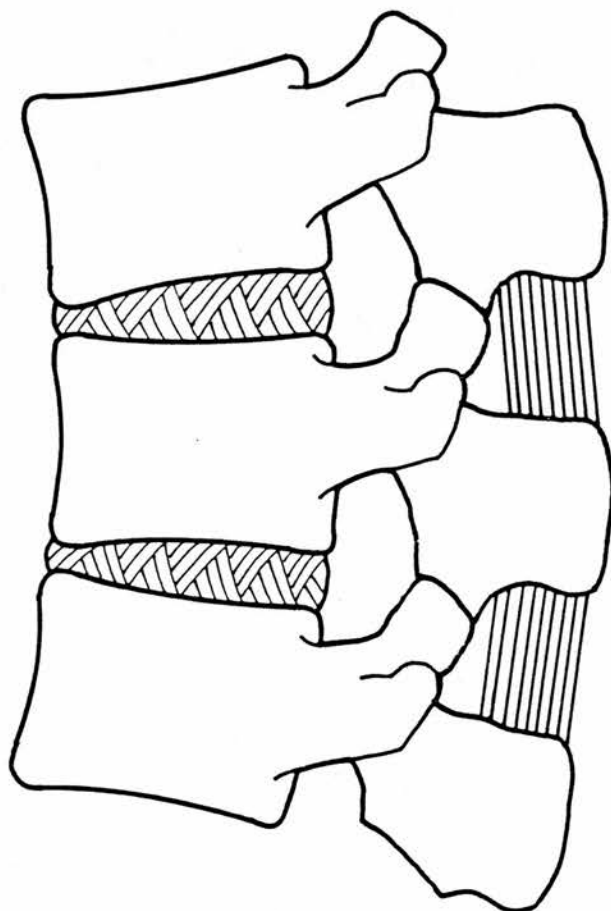


Figure 20:4. The surgical approach to the canal of the spine devoid of degenerative change is made easier by flexion of the spine which opens the interlaminar space.

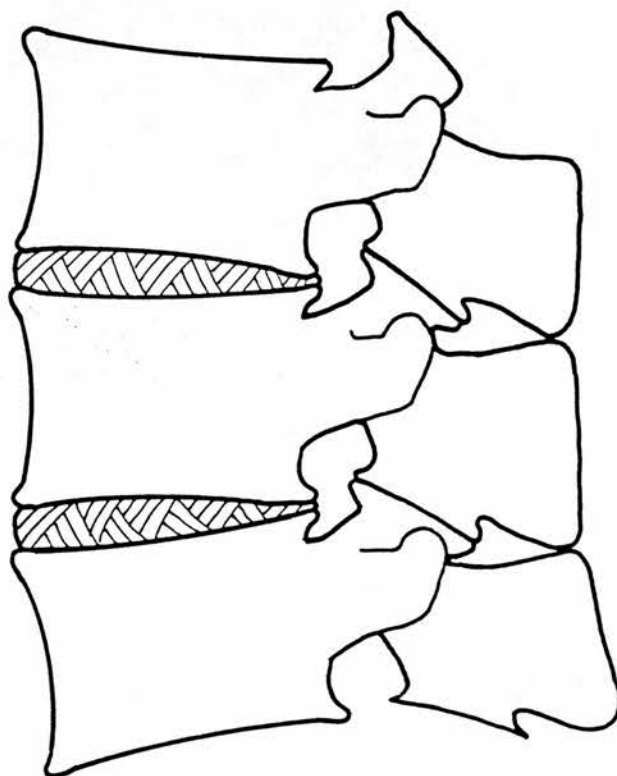


Figure 20:5. The surgical approach to the canal of the degenerate spine is restricted since the spine may not flex and the interlaminar space is non-existent with shingling of the laminae.

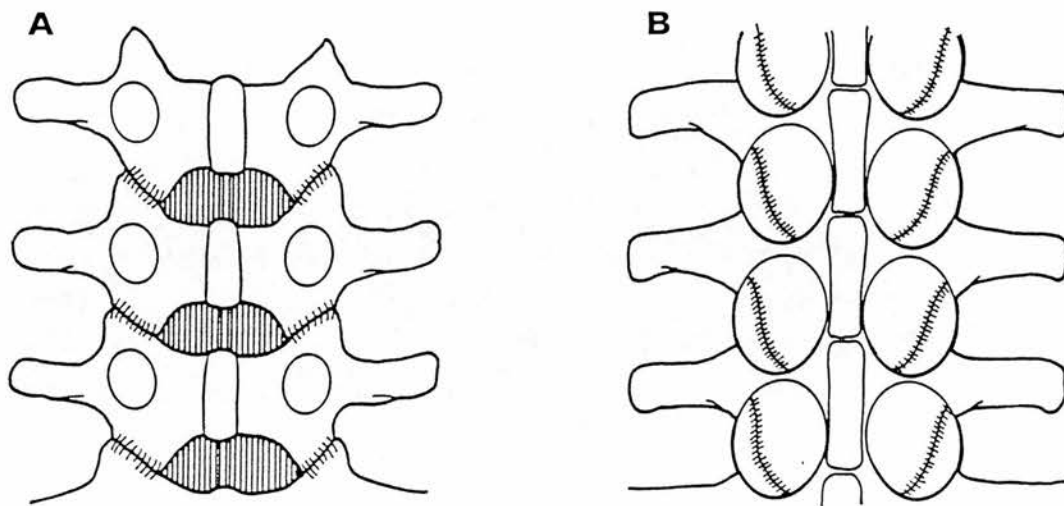


Figure 20:6. Figure A illustrates a normal spine in flexion prior to fenestration and discectomy, whilst Figure B represents the typical appearance of a spine prior to decompression for severe degenerative change. The following features should be noted:

1. It is not possible to flex the spine to open up the interlaminar spaces because of generalised stiffness
2. The spinous process tips are in contact ("kissing spines" seen on radiographs) with false joint formation
3. It is difficult to strip the muscle attachments because the tip of the Cobb travelling down the side of the spinous process enters the recess between lamina and facet joint instead of stripping laterally across the lamina
4. The laminae are not visualised initially because of pronounced facet joint hypertrophy
5. The facet joints encroach towards the midline
6. Once the lamina have been exposed, **it is difficult to enter** the spinal canal because of "shingling" or overlapping of the inferior lamina by the lower edge of the lamina above
7. Between lamina and facet joint, and between the facet joints lies extra-spinal fat which is often indistinguishable from intra-spinal or epidural fat and may suggest to the surgeon that he has already entered the spinal canal. It is essential to define the bony landmarks of lamina and facet joints to avoid possible confusion.

anaesthetised into an acutely extended position may cause further and sometimes severe damage to the cauda equina in patients with spinal stenosis. For these two reasons the lumbar spine should be maintained in some degree of flexion throughout positioning and during surgery.

(b) The Control of Bleeding

Bleeding from the vertebral venous plexus and decorticated bone presents a serious obstacle to the surgeon as landmarks are obscured, operating time prolonged, and vital structures may be endangered. It is unlikely that the degree of blood loss would pose a life-threatening situation, but excessive bleeding is certainly time consuming, and therefore prolongs the operation. Of more significance is that the surgeon may compromise the extent of his proposed surgical decompression, because of uncontrolled bleeding.

In 1940, Oscar Batson demonstrated the free communication via the valveless system between the veins throughout the vertebral canal, and those of the chest, abdomen and pelvis via the intercostal and lumbar and other connecting veins (Batson 1940). The use of adequate theatre lighting supplemented when necessary by a surgeon's headlight, bipolar coagulation, and magnifying loupes, ensure that the epidural venous plexus can be adequately identified and protected during surgery, and that if bleeding should occur its source can be traced and the bleeding arrested promptly.

The positioning of the patient on the operating table has been criticised in certain reports where injuries have occurred to vital structures which lie in close proximity to the vertebral column during back surgery. The intra-abdominal viscera, aorta, or iliac arteries and inferior vena cava and iliac veins may be pushed against the posterior abdominal wall within reach of the surgeon's instrument if the abdominal cavity is compressed.

Other problems may develop related to poor positioning of the patient on the table.

1. Arterial hypotension may develop as a result of reduced venous return, which itself is caused by pressure on the abdomen during surgery. Such arterial hypotension may fail to respond to treatment, and result in the development of cardiac dysrhythmias, myocardial ischaemia and cardiac arrest and possible cerebral damage and even fatality.
2. Arterial and venous obstruction in the lower extremities or venous

stasis in the lower extremities pre-disposing to thrombo-phlebitis and deep vein thrombosis.

3. Traction injuries to individual nerve roots.
4. Lower leg compartment syndromes.
5. Acute myoglobulinuria with lower nephron syndrome.

In an attempt to determine the most advantageous position for surgery, the inferior vena caval pressure was measured in ten subjects who were otherwise normal, but undergoing fenestration and discectomy or surgery for lumbo-sacral instability. The venous pressure was recorded in the following positions:

- (a) Prone with bolsters
- (b) On a Wilson frame
- (c) Lateral decubitus
- (d) Georgia prone (kneeling)
- (e) Knee-elbow position
- (f) Canadian frame described by Hastings (Hastings 1969).

The average values and range of inferior vena caval pressures in centimetres of water recorded in the prone position with bolsters was 15.9, with Wilson's frame 10.1, lateral decubitus 11.1, Georgia prone 20.7, and the knee-elbow position 9.4.

The Hastings frame was found to be superior with regard to exposure afforded the surgeon, blood loss and ease of ventilation. Since acute flexion of the hips and knees was avoided, neurovascular complications including thrombo-phlebitis were not encountered.

It is therefore essential that the patient is correctly positioned, and this remains the personal responsibility of the surgeon to ensure a satisfactory outcome for both the patient and the surgeon from the operation.

SURGICAL TECHNIQUES OF SPINAL DECOMPRESSION

With the loss of space around the cauda equina or nerve root, there is a decline in the fat content and presence of loose connective tissue. Adhesions may develop between the ligamentum flavum and dura and with further compression axonal conduction and irritability is slowly altered, principally because of changes in the axoplasmic transport both proximo-distal and disto-proximal (Mayfield 1973).

Surgical treatment can alleviate compression on the neural structures

but does not alter the underlying arthropathy of the posterior facet joints or the abnormal biomechanics or biochemistry, and does not reverse changes such as intra-neural fibrosis and nerve root damage. On the other hand a patient with a complete myelographic block and severe backache can experience a substantial although not complete lessening of the pain with surgical decompression.

Elderly people should not be denied operation because of their age. Relief of pain in this group of patients has been reported to be better than that obtained in patients who are thirty to fifty years old with the general diagnosis of spinal stenosis (Wiltse 1979).

It is essential that the proper equipment is available. This consists of a headlight for illumination, bipolar coagulation, coated instruments, and loop magnification when indicated. Through the application of meticulous carefully planned surgery the results should range from seventy per cent resolution of symptoms (Wilson 1971) to eighty per cent good and excellent clinical results (Ray 1982), even in patients where pain has been long-standing. The surgical technique does not vary between congenital, developmental and degenerative stenosis. Patients with congenital stenosis come to surgery earlier however, around the age of twenty to fifty, whereas patients with degenerative stenosis present much later. Perhaps the most significant factor in determining satisfactory operative results is the surgeon's ability to follow the anatomical road map of the stenotic lumbar canal provided by the CT scan and myelogram. With knowledge of the nature and severity of various compressive elements at every level, the appropriate surgical approach and technique may be selected in order to provide adequate space for nerve roots.

LEVELS OF DECOMPRESSION

It is important to decompress enough levels to reach an area where the dura is pulsating freely (Kirkaldy-Willis 1974; Nelson 1973). Wiltse stated that it was necessary to "decompress as much as necessary, and if in doubt decompress more" (Wiltse 1976). Rosomoff reported fifty patients who underwent one hundred and ten neural arch resections (Rosomoff 1981). Only ten patients had single arch removals, twenty-three were double, fifteen triple, one had four level decompression, and one patient had five level decompression. Degenerative stenosis only occasionally extends above the L3 level. Rosomoff reported that the

the better results were achieved in those patients who had multi-level surgery, suggesting again the principle that all disease segments must be corrected if return to function without pain is to be attained.

Verbiest recommended the removal of any compressive agent in an area of "relative stenosis", that is above or below an area of absolute nerve compression. He reported in 1977 that:

"to abstain from an extensive decompression may result as we have learned from personal experience, in a recurrence of symptoms of stenosis in later years due to the formation of a scar or osteophyte" (Verbiest 1977).

He did point out on the other hand that extensive decompression involves a risk of so-called "iatrogenic stenosis" by scar tissue formation bridging the laminectomy defects. There is therefore a narrow dividing line between a decompression of inadequate length and an excessively long decompression.

The levels most frequently decompressed in the seventy-two patients treated surgically at the Nuffield Orthopaedic Centre were the lumbar fourth and fifth (Table 20:1). This is consistent with other published series and is an indication that the spinal canal is most narrow in the lumbar region at the fourth lumbar level, and that degeneration is maximal at the lumbar four/five and lumbar five/sacral one levels. Three levels were decompressed in twenty-four per cent of males and fourteen per cent of females, and only one level decompressed in thirty-two per cent of males and twenty-one per cent of females.

LUMBAR LAMINA REMOVED	MALE (N=47)	FEMALE (N=25)
2/3	5	0
2/3/4	2	0
3/4	5	7
3/4/5	22	14
4	16	7
4/5	34	57
5	16	14

Table 20:1. The level of spinal decompression required in the seventy-two patients with spinal stenosis treated surgically at the Nuffield Orthopaedic Centre, expressed as a percentage of the male and female groups.

The extent of decompression should be decided pre-operatively on the results of myelography and CT scanning, since during surgery, with the lumbar spine well flexed, the bony and ligamentous spinal canal may appear deceptively capacious. This is of considerable assistance to the surgeon in facilitating decompression but when stenosis is postural or relative (Verbiest 1977) can be misleading. The extent of surgical decompression required should be determined pre-operatively. To confirm that one's pre-operative planning has been accurate, however, a soft 2 mm. catheter should pass easily proximal and distal to the decompression, and along the nerve root canals. A probe or Watson-Cheyne dissector may be used but cautiously for this purpose.

SPINAL DECOMPRESSION IN DEVELOPMENTAL SPINAL STENOSIS

Adequate decompression should involve thorough decompression of neural contents in all three dimensions - sagittal, coronal, and vertical length of the spine.

For a Type 1 concentric stenosis, resection of both superior and inferior articular processes in addition to total removal of laminae bilaterally, will provide adequate room for neural elements. Rarely, trimming of the pedicle is required to provide further room in cases of severely contracted types of stenosis (Lee 1978).

In Type 2 stenosis (sagittal flattening) total removal of laminae will give ample space for the neural elements. The entrances of the nerve root foramina may be widened when necessary without disrupting the apophyseal joints.

In Type 3 stenosis (abnormal articular process), total removal of the lamina and resection of both inferior and superior articular process on the involved side should provide adequate decompression.

Total removal of the laminae and articular processes, as in Type 1, should be the procedure for those who have bilateral pathological involvement. To obtain adequate decompression of the lateral recess of the spinal canal and foramina, one is frequently forced to remove the entire inferior articular process and almost the entire superior articular process. The superior articular process cannot be exposed well without resecting the entire inferior articular process because of an abnormal arrangement of the apophyseal joint and because of the abnormal size and shape of the superior articular process. The most common error in decompressive surgery is inadequate decompression of the lateral recess under the superior articular process.

Spinal fusion should be performed in young patients who have had total resection of the posterior bony elements of the vertebrae, and in particular bilateral total facetectomy. As with other nerve entrapment syndromes, the longer the duration of the disease and the more severe the pre-operative symptoms, the worse the post-operative results. It is of interest to observe at operation a permanent hour-glass deformity of the dura which fails to expand after thorough decompression of the bony spinal canal.

Severe and prolonged compression of a nerve may produce permanent damage to the nerve to the degree of axonotmesis. Those patients with persistent hour-glass deformity of the dura may have such permanent damage to nerve roots (cauda equina) that post-operative recovery may be significantly delayed or may not take place at all. Surgery should be encouraged in patients with milder deformities whose symptoms are steadily and slowly worsening despite conservative therapy.

The goals of operative treatment should not be set too high. Complete relief of pain and complete recovery of function is unlikely even after adequate decompressive surgical procedure. Instead, reduction of pain to the level of tolerance of activities of daily living, and more importantly, prevention of further deterioration of function should be the goal. Post-operatively, most of the patients are not able to return to work that requires lifting, walking long distances, standing, sitting for a long time, or travelling in a car for long distances.

Ten per cent of males in the Nuffield series and five per cent of females were considered to have developmental stenosis (Table 20:2).

	MALE (N=47)	FEMALE (N=25)
Developmental	10	5
Degenerative: Central	15	5
Central & Lateral	18	15
Lateral	8	10
Degenerative and Disc	23	15
Spondylolisthetic	8	40
Post-laminectomy	18	10

Table 20:2. Classification of the surgically treated patients as a percentage of males and females.

The borderline between developmental and degenerative, and between developmental and degenerative and disc was not always clear. Patients with developmental stenosis tended to be younger and have very extensive narrowing of the entire lumbar spinal canal, with short and sometimes apparently non-existent pedicles on CT scanning (Fig. 13: 3) and with minimal degeneration or disc disease. The degree of degeneration or disc disease in these patients would be totally inadequate to explain the symptoms and signs of spinal stenosis in a spinal canal of normal dimensions.

In other patients in this group a congenital anomaly of the spine was evident such as a non-incarcerated hemi-vertebra posteriorly situated which intruded into the spinal canal. In the case illustrated (Fig. 20:7 and 20:8) symptoms of stenosis appeared in a twelve year old girl who developed claudication on running. Following anterior resection of the hemi-vertebra with fusion, the symptoms were relieved and the child resumed full physical activities.

The Herniated Disc in Developmental Stenosis

In young adults with developmental spinal stenosis, Paine and Haung reported that developmental narrowing was the sole cause of symptoms in only eight per cent of their patients (Paine 1972). Other factors, such as spondylosis and herniation of the nucleus pulposus influence the onset of symptoms. In the presence of a narrow lumbar vertebral canal, a very small disc protrusion can produce significant symptoms of compression. The surgical treatment of a young patient who presents with symptoms of nerve root compression due to disc herniation into a narrow canal has not been defined clearly. Some authors perform a two-level laminectomy (L4 and L5) in addition to a discectomy at the L4-5 level to allow sufficient room to avoid future nerve entrapment if subsequent degenerative change develops (Vaughan 1978). Others address surgically only the abnormalities identified on myelogram (Paine 1972).

Recurrence of pain in these patients will more than likely be due to another disc herniation or superimposed degenerative changes. Their pain-free interval therefore is unpredictable but may last for decades. The potential de-stabilising effect of multiple level laminectomies in a young patient may in itself accelerate the degenerative process and indeed shorten the symptom-free period (Kornberg 1984). There is no



Figure 20:7. The lateral radiograph of a twelve year old girl (D.W.) with severe pain and weakness in the legs on running. There is anterior body failure of segmentation of L1 and L3 with a non-incarcerated posteriorly placed fragment of the L2 vertebra complete with posterior elements. This is being extruded into the spinal canal with growth and is an example of congenital spinal stenosis, although the child was symptom-free until the age of eleven.



Figure 20:8. Lateral radiograph of the myelogram of D.W., a twelve year old schoolgirl with congenital spinal stenosis. This shows a virtually complete "block" at the upper margin of the L2 vertebral fragment with widening of the canal inferiorly. This was treated surgically by anterior spinal decompression and fusion using rib strut grafts. One year following surgery the schoolgirl had returned to normal, unrestricted activities.

evidence that patients have a shorter pain-free interval without prophylactic decompression. Indeed it is more likely that spinal canal decompression in a young adult with developmental stenosis whose symptoms are clearly secondary to a herniated disc may lead to premature degenerative change and mechanical low back pain through the potential de-stabilising effect of multiple level laminectomies.

SPINAL DECOMPRESSION IN DEGENERATIVE SPINAL STENOSIS

(i) Laminectomy

The original technique was described by Gill and associates (1955). Gill proposed laminectomy with removal of the entire bony arch including both inferior and adjacent superior articular processes at all levels of bony involvement.

Following Gill's description of neural arch resection, Verbiest also advocated complete removal of the facet joints to decompress the nerve roots (Verbiest 1977). He did not describe post-operative spondylolisthesis, but did state that unroofing of the intervertebral foramina at several levels could result in a considerable reduction in height of the lateral walls of the vertebral canal. He stated that if complete resection of the pedicles as well as the facet joints was included then the lateral walls of the spinal canal became practically non-existent and this carried a high risk of post-operative stenosis.

Wiltse stated that it may not be possible to decompress the nerve and still save the pars interarticularis, and that in these instances it is permissible to channel out along the nerve root performing a foraminotomy (Wiltse 1976). He stated that this completely de-stabilises the spine posteriorly and in these cases "one should not also perform discectomy, or there will be too much instability". He stated however that post-operative spondylolisthesis virtually never occurs in cases of degenerative stenosis where there is no degenerative spondylolisthesis pre-operatively.

Grabias discussed further the problem of facet joint removal, and stated that in general "the medial half of the facet must be removed, and not the entire facet" (Grabias 1980). He stated that if only one half of the facet and the pars interarticularis remain, then stability of the spine usually is assured. Also removal of the pars interarticularis on one side only does not jeopardise spinal stability. In cases when scarring

is present from previous surgery however Grabias considered that it was not possible to decompress the nerve and still save the pars inter-articularis, and an open channel can be created dorsal to the nerve. Rosomoff did describe post-operative spondylolisthesis in one patient, but he stated that subluxation was secondary to another traumatic event (Rosomoff 1981). This was treated conservatively, and fusion was not performed, and the symptoms remitted with no further slip.

The next question to consider is the correct choice of surgical instruments for decompression. Verbiest considered that in patients with "absolute stenosis" the absence of a reserve space in the mid-sagittal diameter, which may be as narrow as 4 mm., causes there to be considerable risk of neural damage during surgical decompression (Verbiest 1977). Some authors consider that thickening of the lamina is unusual (Jones 1968), but most would agree that the lamina is usually thickened and also sclerosed. The bony rongeurs may not bite well, and if the tip of the blade is introduced under the lamina, it may well cause nerve damage (Verbiest 1977) (Fig. 20:9). Verbiest therefore recommended the use of a chisel and mallet for the removal of the lamina, peeling off layers in a plane parallel to the dural theca. The last thin layer covering the dura he removed using fine-bladed forceps. Similarly overhanging portions of the articular facets or the lateral parts of the lamina producing narrow lateral recesses and gutters can be split off piecemeal using a chisel.

Where the inter-laminar space is obliterated by overlapping lamina, laminectomy commences at the next normal space. Wiltse stated that in degenerative stenosis, the spinous processes are removed along with the laminae out to 1 cm. medial to the facet joints (Wiltse 1976). He recommended where possible saving the facet joints, but it must be stated that quite often the facet joints are so hypertrophic that there is bony encroachment from the facet joints towards the midline, and the measurement of 1 cm. must be looked upon as arbitrary.

An important issue regarding surgical technique as well as outcome is raised by the question: "How wide is a wide laminectomy?" Although total facetectomy can be accomplished bilaterally in patients over fifty without the development of spinal instability, it is rarely necessary for adequate decompression. Satisfactory decompression can usually be obtained by under-cutting the facet and by total removal of the lateral attachments of the ligamentum flavum. However, on completion of the

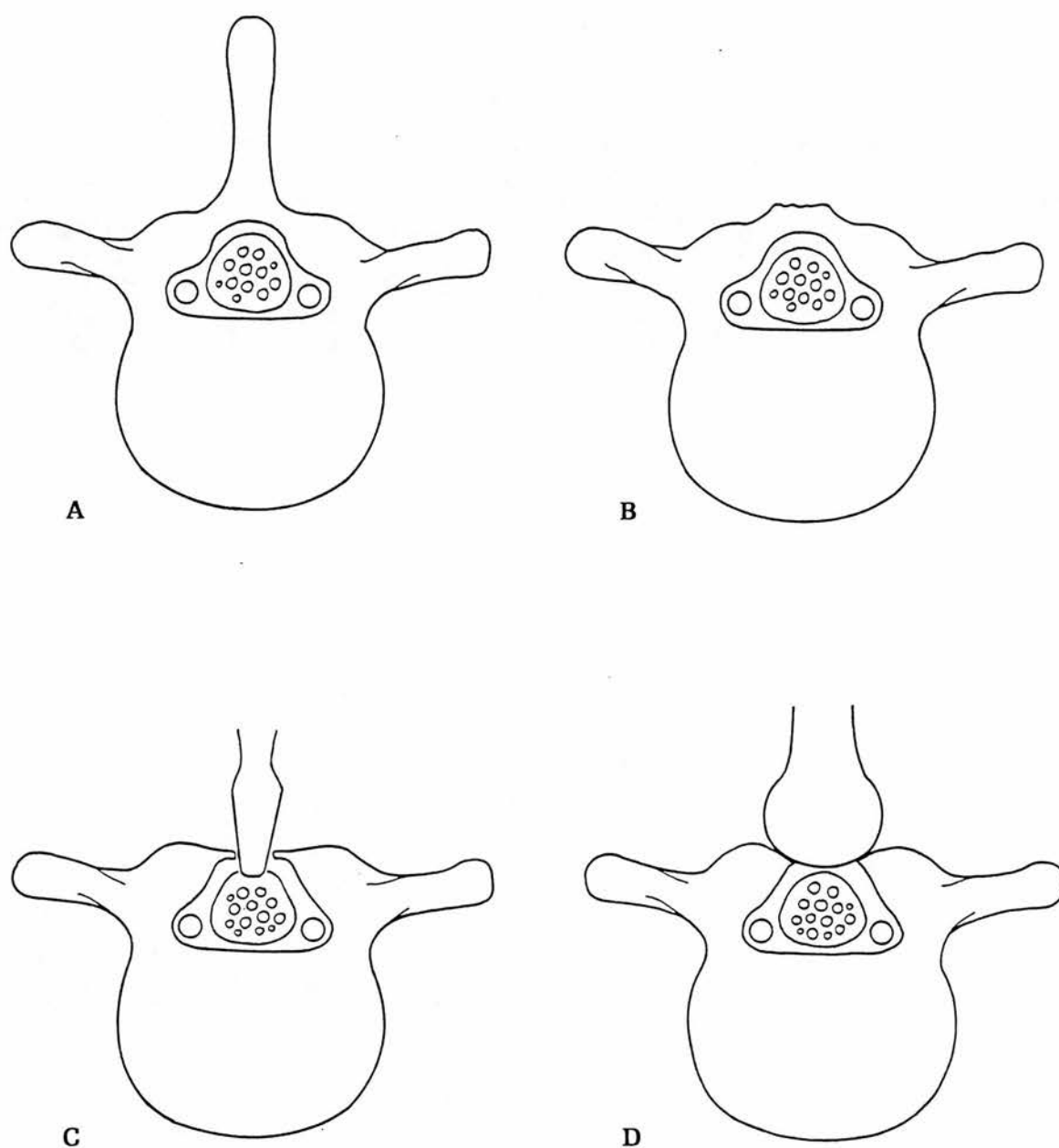


Figure 20:9. Diagrammatic cross-sections of the spine to illustrate one method of entering the spinal canal in stenosis. The canal must be entered carefully since the dura may lie immediately deep to the lamina. The spinous process is removed (B) and the canal entered using large bone nibblers (D). Small narrow bone nibblers may enter the canal inadvertently and tear the underlying dura (C).

decompression, it should be possible to easily palpate both the roof and floor of the nerve root foramen as well as the pedicle above and below with an angled dissector in order to be sure that the nerve root is fully decompressed. Palpation of the nerve root canal should be performed with great caution and should not be attempted until the nerve root has been well visualised within the lateral recess. Otherwise, blind instrumentation of the foramen may result in additional nerve root injury or profuse venous bleeding.

The high speed air drill initially with a cutting burr and later with a diamond burr can be an invaluable tool in facilitating atraumatic decompression of spinal stenosis (Weinstein P.R. 1983). Insertion of an interlaminar spreader may considerably improve exposure by enlarging the interlaminar space and separating the articular processes.

Although decompression for extensive lumbar stenosis is a lengthy and tedious operation the final stages of nerve root exposure and decompression are most delicate and require utmost attention and care. The operating microscope or magnification loupes with a headlight and intense illumination are of considerable assistance in this dissection facilitating decompression and haemostasis in the lateral recesses and nerve root foramina. Magnification is not generally useful during the initial midline decompression unless repair of a dural laceration is required.

The surgical technique for decompression of degenerative stenotics used by the author is illustrated in Figures 20:10-20:16.

(ii) Removal of the Ligamentum Flavum

The surgical anatomy of the ligamentum flavum is illustrated in Figures 20:17 & 18. For a more detailed consideration of the anatomy of this ligament please refer to Chapter 5.

Some authors report that the ligamentum flavum is thickened and many confirm that in some patients it is the principle compressive agent (Jones 1968). Despite this a technique was described by Bowen in 1978 in which he made use of the lateral extensions of the ligamentum flavum, carefully preserving them during a laminectomy (Bowen 1978). He then replaced the lateral extensions of the ligamentum flavum between the bleeding bone exposed by removal of the medial one-third of the inferior articular process using a small osteotome and the adjacent nerve tissue. Free fat grafts from the subcutaneous tissues were placed over the

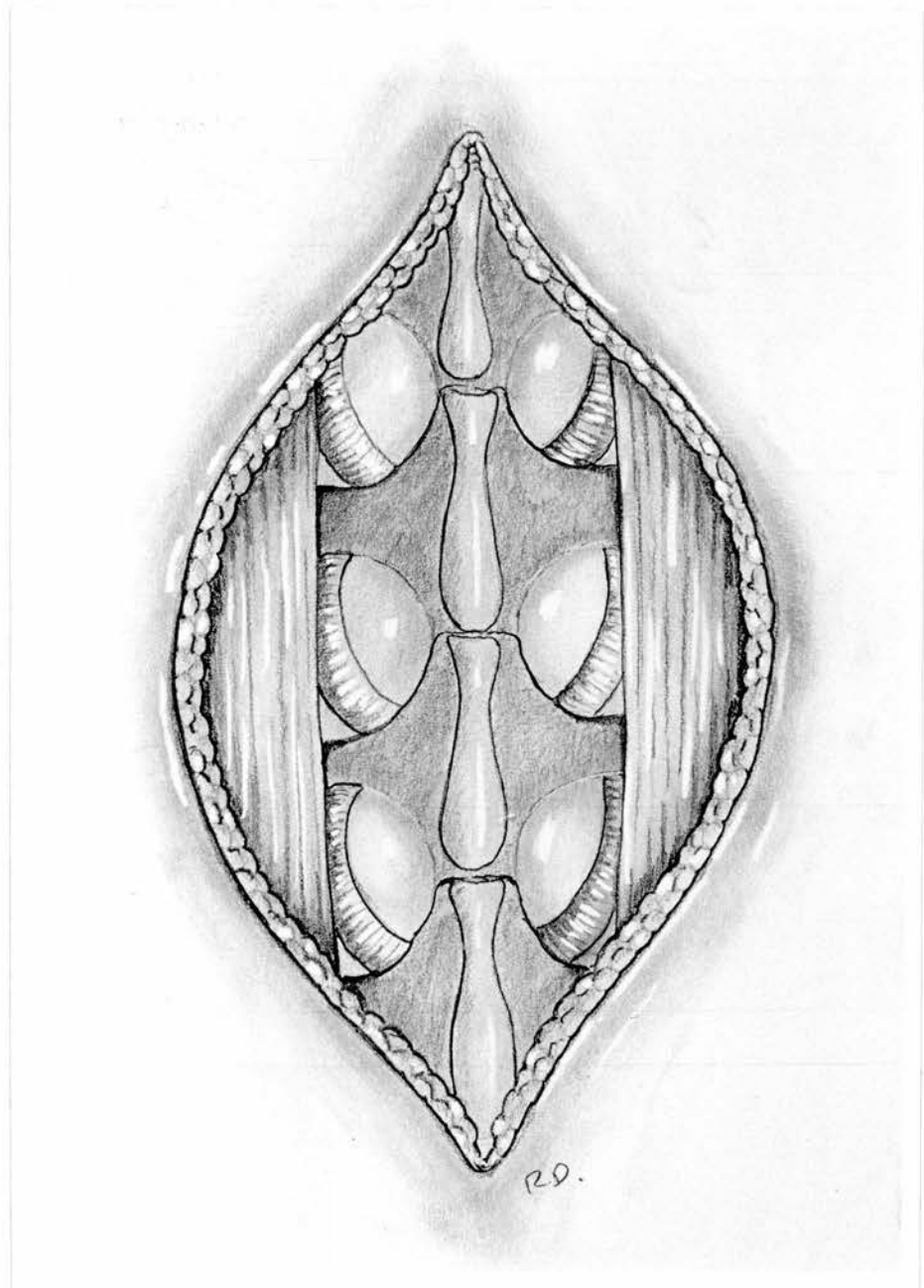


Figure 20:10. A midline longitudinal incision stripping the muscles from their bony and ligamentous insertions reveals "kissing spinous processes", enlarged facet joints, and often initially no discernable interlaminar space.

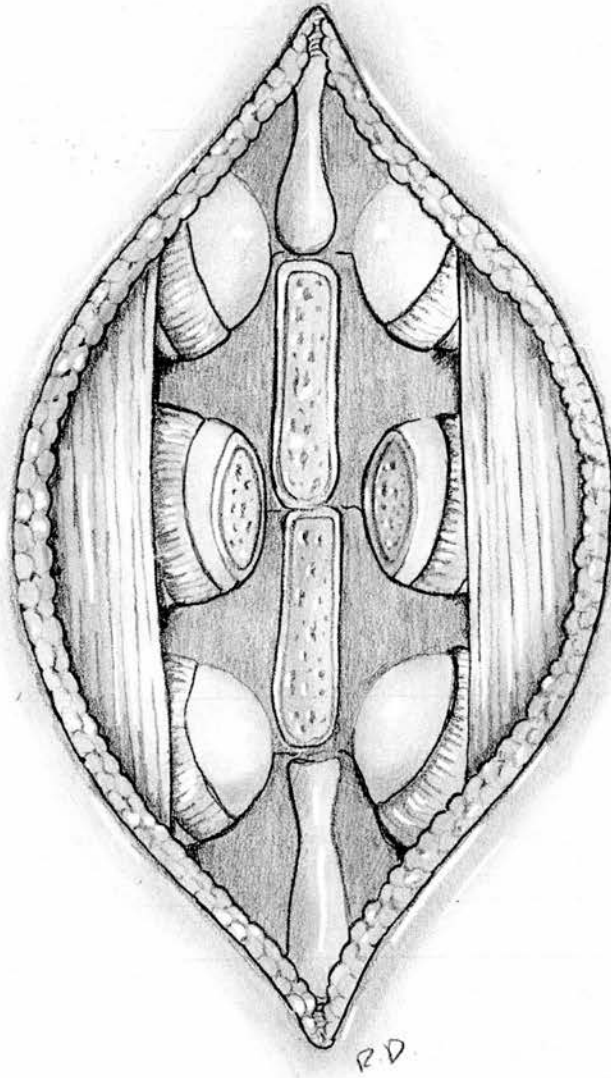


Figure 20:11. The spinous processes and medial aspects of the enlarged facet joints are removed using bone cutters and nibblers to reveal the interlaminar space.

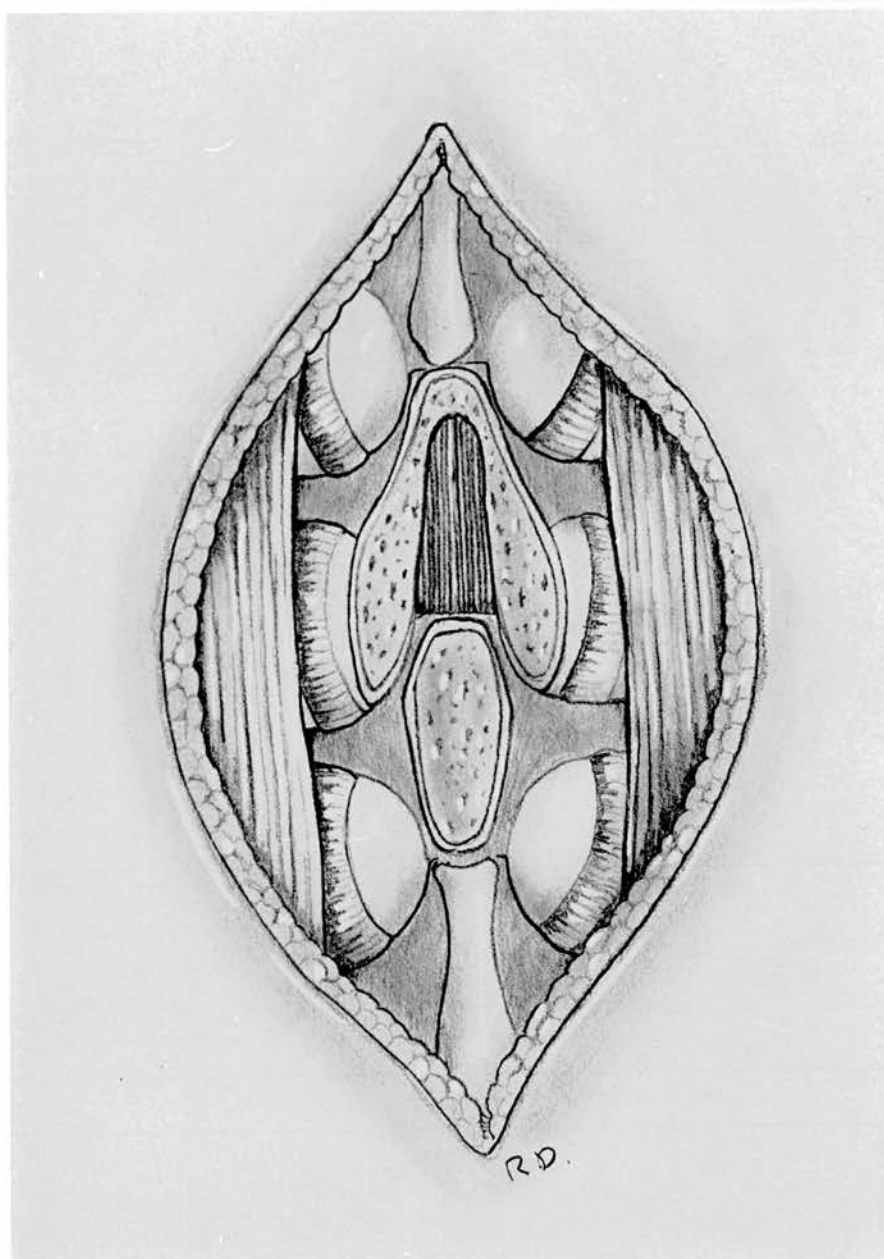


Figure 20:12. The lamina is removed centrally including the medial aspects of the inferior articular facets to expose the ligamentum flavum (see Figure 20:9).

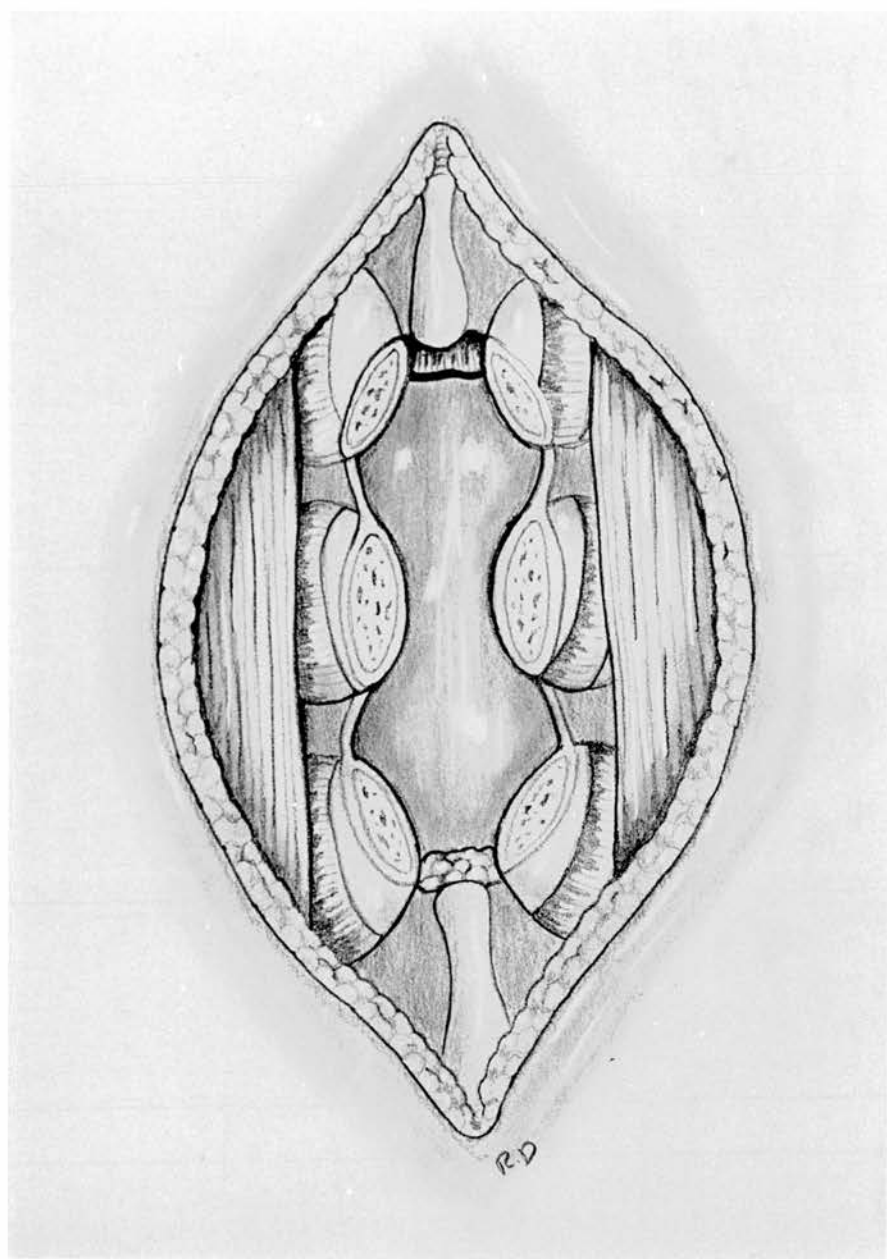


Figure 20:13. The ligamentum flavum is carefully incised taking care not to penetrate the dura which is often adherent to the ligamentum flavum. A blunt dissector is useful to separate the two structures prior to removal of the ligamentum flavum and the remains of the lamina proximally, distally and laterally as far as the pars interarticularis. This drawing illustrates the next ligamentum flavum proximally and the appearance of normal epidural fat caudally. There remains significant intrusion into the canal by enlarged facet joints in the central part of the decompression.

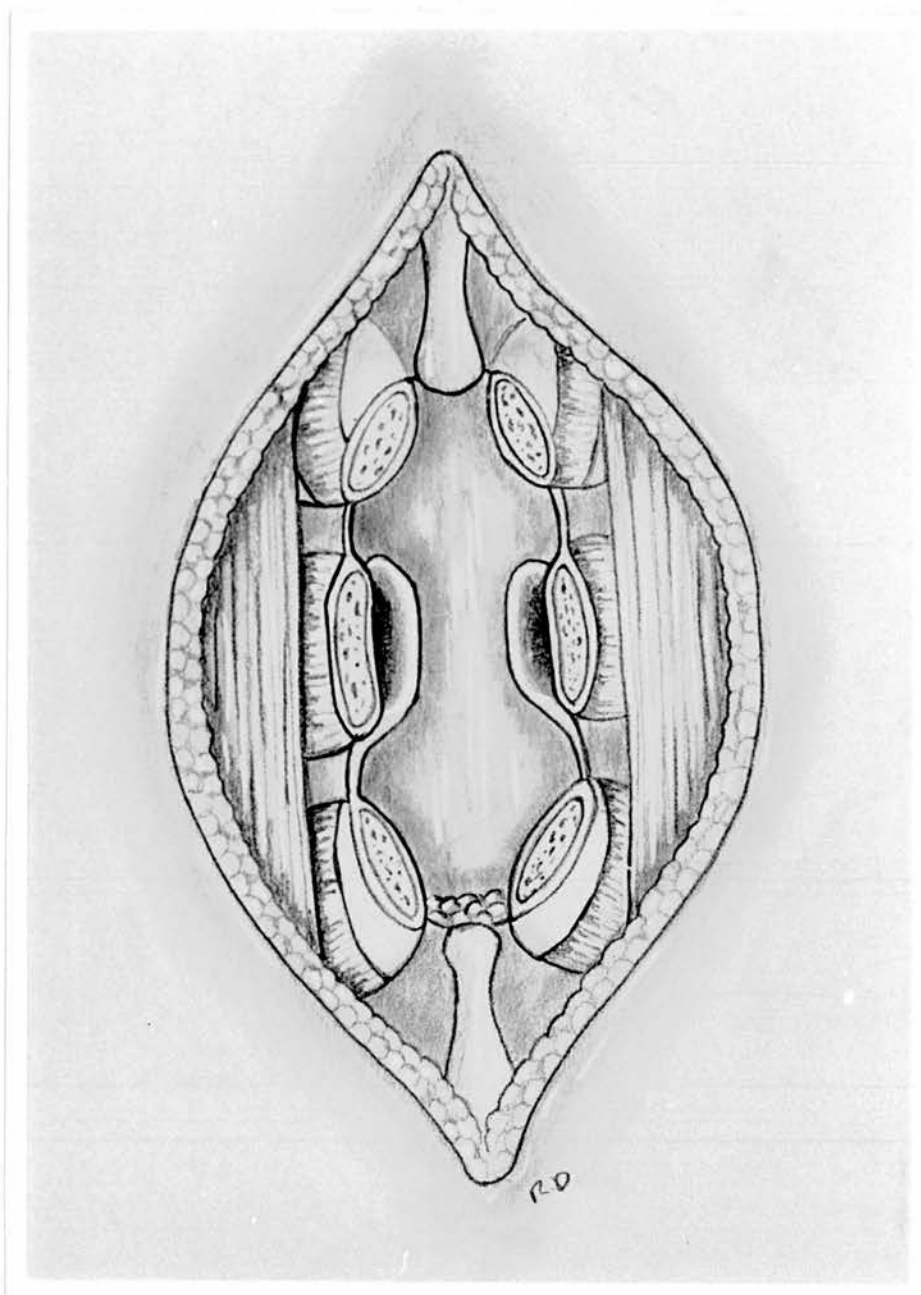


Figure 20:14. Using an osteotome as illustrated in Figure 20:19, the medial portion of the inferior articular facet is split off to reveal part of the superior articular facet beneath it. This superior facet continues to constrict the canal. The remaining ligamentum flavum rostrally has been removed.

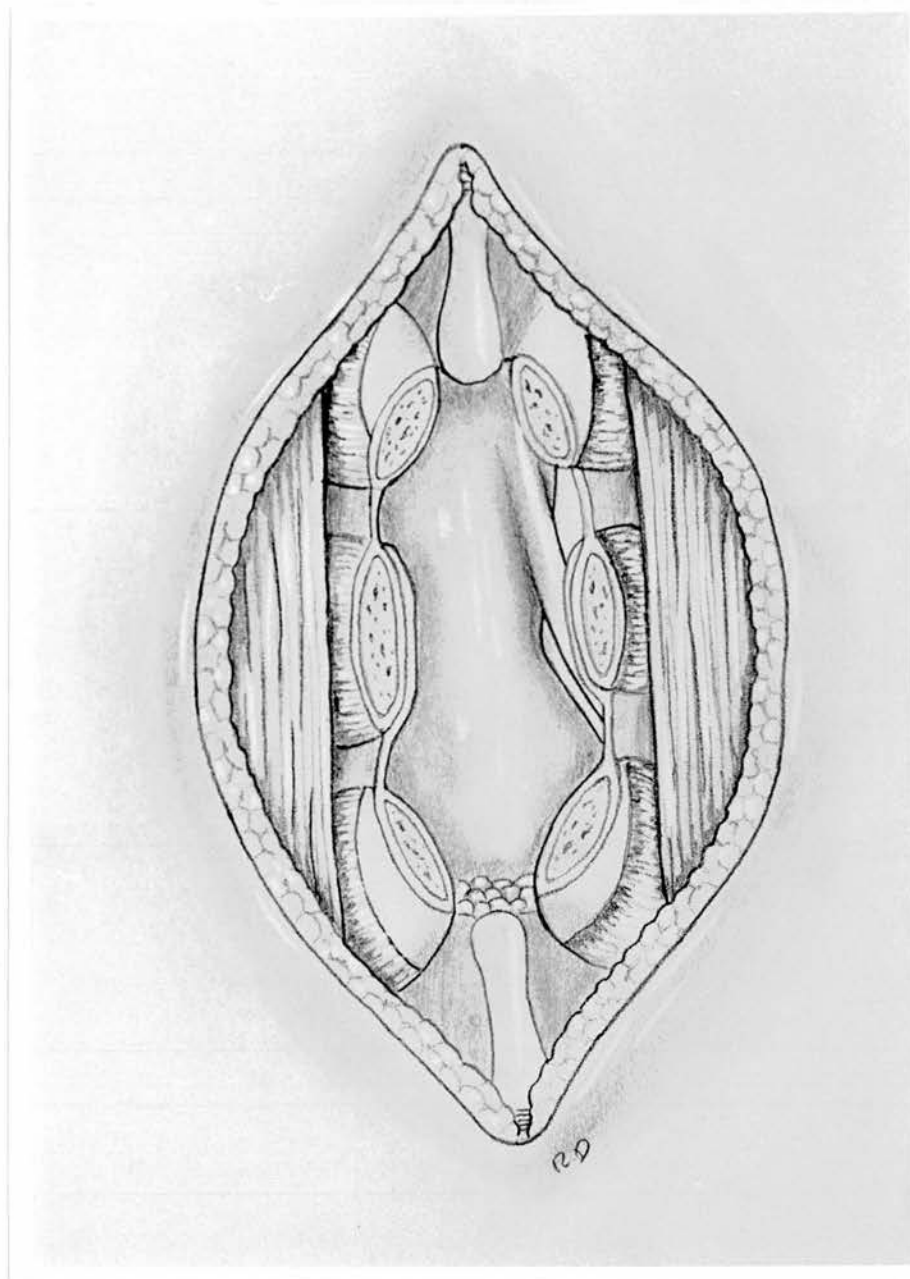


Figure 20:15. The medial portion of the superior articular facet has now been removed, not by using a Kerrison or Cloward punch which would damage the underlying nerve root, but by using a fine osteotome which passes part way through the facet and then twisted to break off a sliver of the joint whilst protecting the nerve root with a MacDonald dissector (see Figure 20:19). This shaving of the facet can be repeated or a larger portion of the facet can be removed en bloc. The fragment should be carefully teased by blunt dissection from its soft tissue attachments. Forceful pulling of the fragment may avulse the underlying nerve root. The dura has been retracted medially to reveal the underlying nerve root.

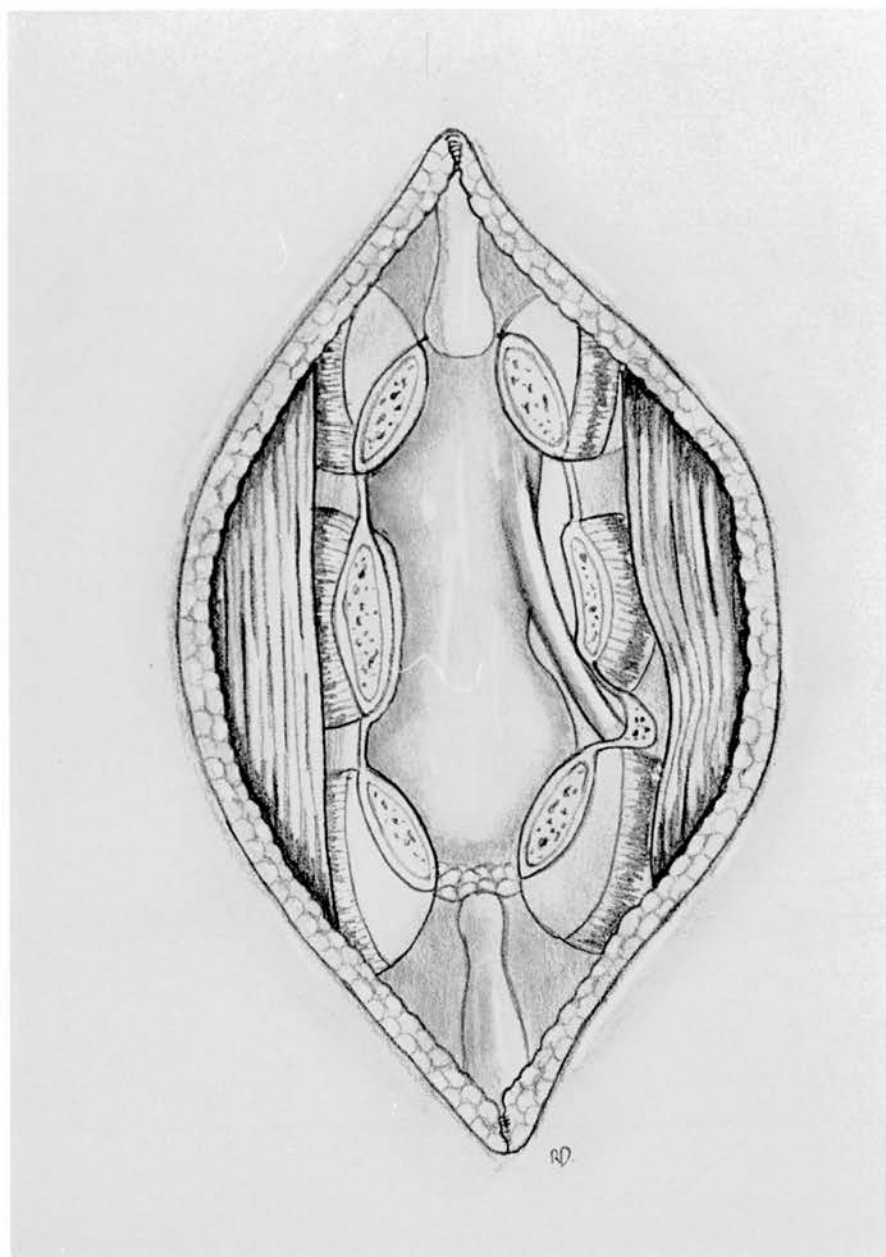


Figure 20:16. The dura has again been retracted medially to expose the nerve root. If, after lateral recess decompression by partial undercutting facetectomy, the nerve root is still gripped or constricted in the nerve root canal then a nerve root canal foramenotomy and decompression can be performed using rongeurs. A Cloward should not be inserted into the nerve root canal to avoid further nerve root contusion. The roof of the nerve root canal is seen to be free from bony constriction. The bone of the pars interarticularis at this point is extremely hard and strong. It is useful to palpate the width of the pars using a Watson-Cheyne dissector.

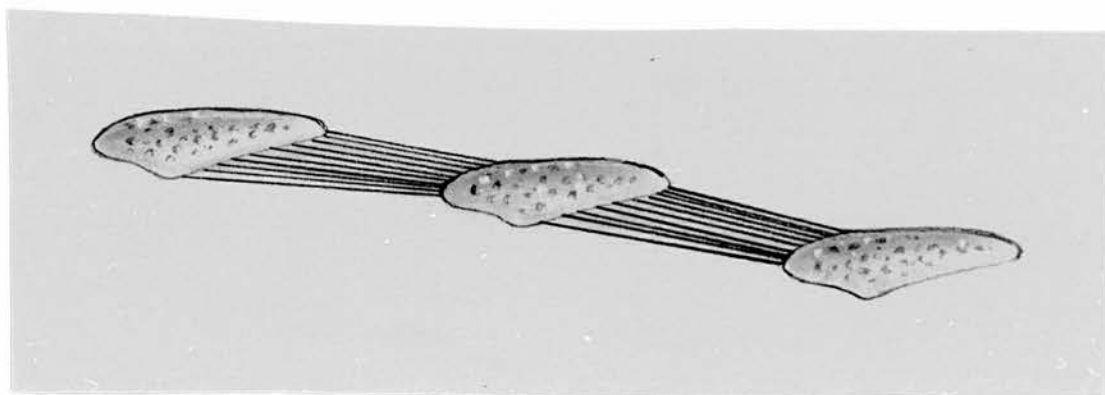


Figure 20:17. Longitudinal section of lamina and ligamentum flavum to illustrate extensive cephalic origin (left) of ligament from roughened deep surface of lamina and its insertion (right) caudally into the upper margin of the lamina below at a more superficial level.

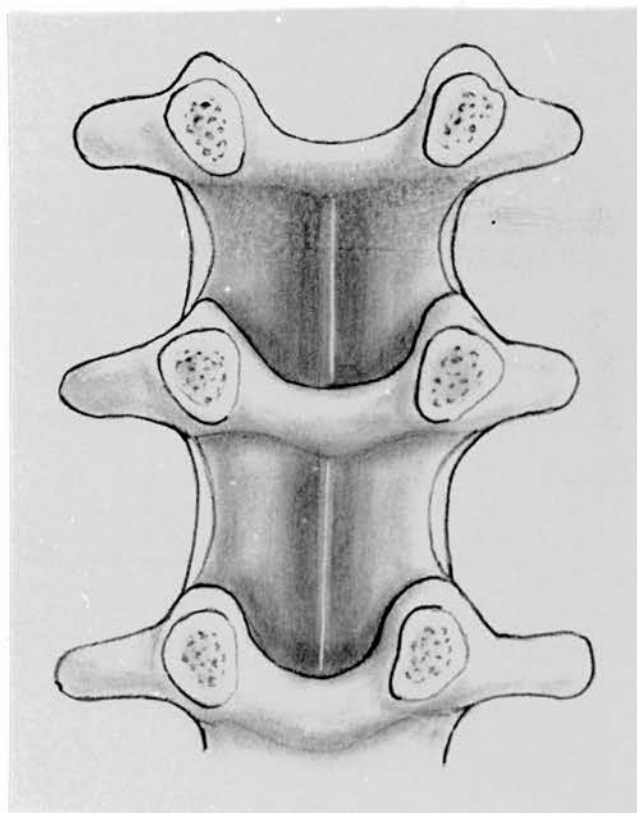


Figure 20:18. The ligamentum flavum and upper part of lamina viewed from inside the spinal canal after sectioning the pedicles. Note there are two ligamenta flava at each level separated in the midline by a little fatty areolar tissue and blending laterally with the capsule of the facet joints anteriorly.

posterior aspect of the dura to prevent adhesions between the ligamentum flavum and the dura, and the erector spinae muscles. There is some evidence however that remnants of ligamentum flavum can calcify with time and produce stenotic symptoms some years post-operatively (Brown 1938).

It must be recalled that the lateral extensions of the ligamentum flavum blend intimately with the anterior capsule of the facet joint. Thickening of the ligament at this site with facet joint subluxation (which is common in degenerative disease) may be the principle structure compressing the nerve root and so should be removed.

(iii) Lateral Recess and Nerve Root Decompression

The use of a rongeur or punch for decompression of a very narrow nerve root foramen carries a considerable risk of damage to the nerve root (Fig. 20:19). Verbiest again considered that unroofing with the use of a chisel is to be preferred (Verbiest 1977). It must be remembered that he considered removal of the facet joints important, and he described driving the chisel in a lateral direction causing it to separate each related articular process from its pars interarticularis. The inferior articular process was first removed with the bevelled surface of the chisel turned cephalad, and then the superior articular facet removed with the chisel turned caudad.

Wiltse considered that it was important to remove the osteoarthritic build-up on the vertebral body margins in front of the spinal nerve (Wiltse 1976). He used tiny osteotomes and chisels to remove these osteophytic ridges. More recently small punches have been made to punch in these ridges, thereby relieving anterior pressure on the nerve roots without causing excessive local bleeding from decorticated bone. The technique of lateral recess and nerve root canal decompression used by the author is illustrated in Figures 20:14 and 20:15.

(iv) The Importance of Preserving the Disc

The indiscriminate removal of disc material, which is valuable in preserving intervertebral height and therefore spinal canal volume, is not recommended. Rosomoff emphasised this point and the importance of enlarging the canal particularly laterally beneath the articular processes as the absolute necessity (Rosomoff 1981). Grabias stated that a

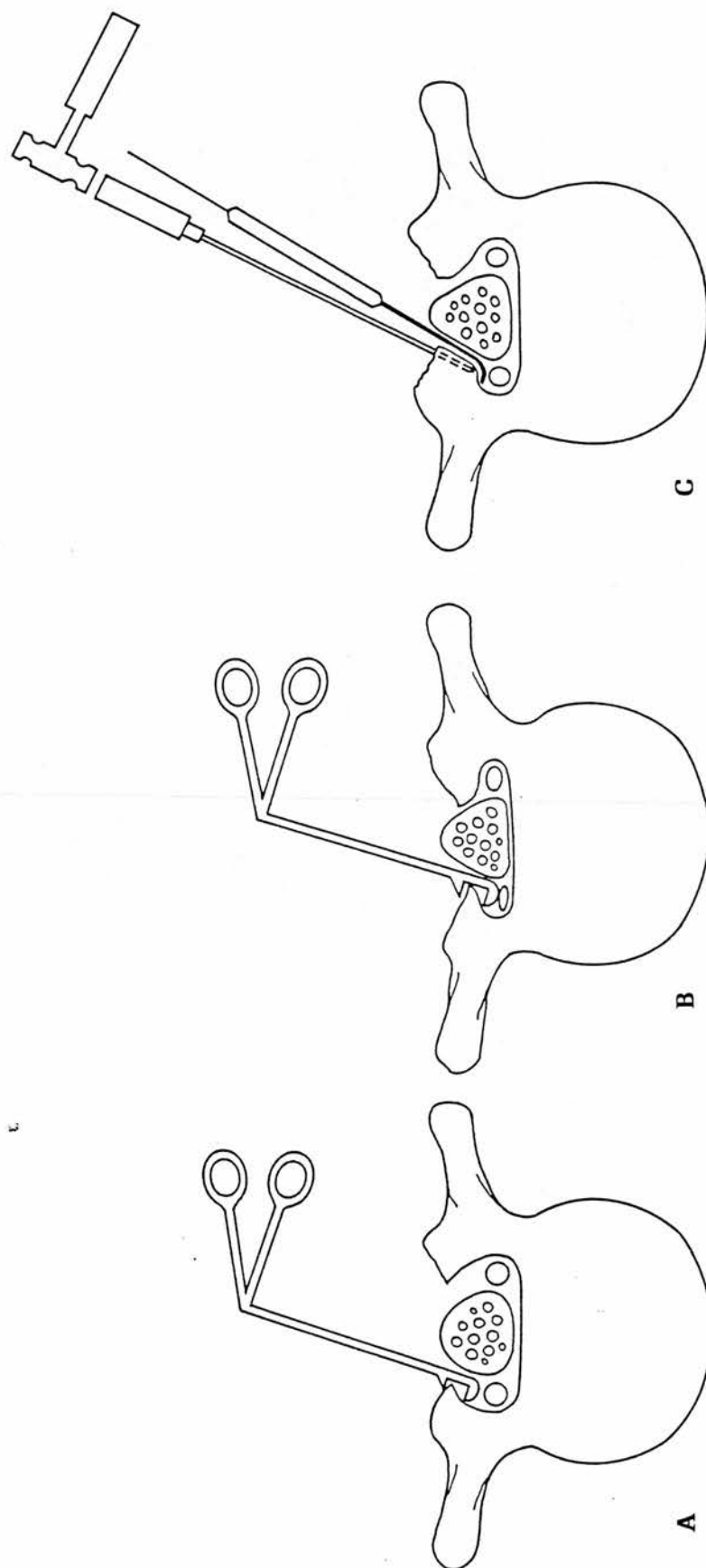


Figure 20:19. In the absence of lateral recess stenosis (A) rongeurs will effectively remove bone laterally without risk to the nerve root. When lateral recess stenosis is present however (B) rongeurs must be avoided since they will result in further damage to an already compressed nerve root. In these circumstances a fine osteotome must be used with a MacDonald retractor to protect the nerve root, splitting off slivers of bone until the recess is decompressed (C).

routine discectomy should not be performed on degenerative hard discs since removal of the annulus fibrosus and posterior ligament increases the potential for instability (Grabias 1980). Wiltse agreed that where the annulus is hard and fibrotic the space is better not entered, as this increases instability and does little good, but he did state that discectomies are done at levels where the annulus appears to be soft and bulging, and advocated the removal of osteo-arthritic ridges adjacent to the disc space with a portion of the annulus and the lower border of the pedicle (Wiltse 1976).

Wilson recommended discectomy "when indicated by myelography" (Wilson 1977), and other series report removal of disc material in twenty per cent of patients undergoing decompression (Wilson 1971). Verbiest stated that when a disc protrusion occurs in an area of absolute stenosis it should not be removed before the related neural arches have been resected. Unless it is clear from the myelogram and at surgery that bulging of the disc is a cause of continued nerve root compression or tension, it is probably best left intact to protect the spine from further painful collapsing down (reduction of disc height) with consequent stress on the facet joints and nerve root canal stenosis.

(v) Resection of the Pedicle

If after dorsal decompression the nerve root remains kinked by a hypertrophic pedicle then careful resection of the infero-medial part of the pedicle is performed. It is often the case that the nerve root remains tight as it exits below the pedicle after the dorsal bone and medial portion of the facet have been removed. The thickening of the pedicle or the descent of the pedicle with narrowing of the disc tethers the nerve root at this level. Removal of the medial and inferior portions of the pedicle is required if the nerve is to have freedom of excursion. Nerve protectors have been designed by Wiltse to protect the nerve when decompressing in front of it in the nerve root canals (Wiltse 1979). Ehni also found a ballpoint elevator helpful, and a Kistner probe dissector may be very helpful when exploring around the nerve roots, dura, and intervertebral foramina (Ehni 1977).

(vi) The Dura

On the whole the orthopaedic literature recommends not opening or

enlarging the dura by a graft or artificial membrane, even when the dura is thickened, fibrotic and non-pulsatile following bony decompression (Wiltse 1976). On the other hand the neuro-surgical literature recommends often the need to open the dura to sufficient length to decompress the cauda equina roots

"until there is adequate flow of cerebrospinal fluid and no hindrance to the intrathecal passage of a soft rubber catheter cranially and caudally" (Jones 1968).

The dura may either be patch-grafted or left unsutured. There is really no meeting point between these two opposite views expressed in the literature and no published controlled trial to verify either statement.

THE COMPLICATIONS OF NEURAL ARCH RESECTION

It has already been noted that one of the main reasons for a poor surgical result is the failure to appreciate the presence or extent of spinal stenosis during removal of a herniated disc. During spinal decompression it is possible to further damage a nerve root, to decompress insufficiently, or to decompress so generously that the risk of post-operative stenosis from scar formation is considerable. Other complications such as wound infection, cerebrospinal fluid leak, meningitis, haematoma, and damage to abdominal viscera need not be considered further. The complication of spinal instability and post-operative spondylolisthesis will be considered later in this chapter.

SURGICAL DECOMPRESSION OF LATERAL RECESS STENOSIS AND SUPERIOR FACET ENTRAPMENT

The presence of "shingling" of the lamina is strongly suggestive of lateral recess stenosis. Even when the patient is on the operating table in the extreme flexed or crouched position there is little or no space between the laminae. The horizontal infero-medial half of the superior facet covers the lateral recess, and the over-hanging portion has to be removed before the nerve root can be exposed and decompressed.

The term "occult spinal stenosis" has been used to describe this condition when myelography demonstrates a normal antero-posterior diameter to the spinal canal but there is lack of filling of the lateral recess (Choudhury 1977). This may be mistakenly interpreted as a disc prolapse, but simple excision of the nucleus pulposus will not alleviate the symptoms, and may in fact make the condition worse by causing

further loss of disc height and nerve root compression and possible kinking of the nerve root as it passes caudal to an enlarged pedicle.

Compression of the nerve root and failure to demonstrate filling of the nerve root dural sleeve on myelography is intermittent in the early stages of the superior facet syndrome. In flexion the superior facet moves in a caudal direction in relation to the nerve root above, allowing the dural sleeve to fill, but in extension of the lumbar spine the superior facet travels cranially relative to the nerve root and impinges upon it preventing the nerve root dural sleeve from filling. Many such patients have had previous fenestration and discectomy alone resulting in little relief of their symptoms.

In patients undergoing operation for the first time the use of a Cobb's elevator is sufficient to strip the muscle from the laminae and this is not destructive of the periosteum of the laminae or the capsule of the facet joints (Getty 1981). In patients who have had previous surgery an osteotome may be necessary to strip muscle and scar tissue from the laminae although a sharp Cobb's elevator may also suffice. The sacrum is identified in all cases and meticulous haemostasis must be maintained.

Removal of hypertrophic bone from around the nerve root in the lateral recess should not be performed using a Cloward or similar rongeur, since this involves the introduction of the distal blade into the lateral recess and may cause further damage to a nerve root which is already inflamed and particularly vulnerable to further injury (Fig. 20:19). A fine osteotome should be used to shave off slivers of bone. The osteotome should pass only part way through the roof of the lateral recess, and then the bone split by twisting the osteotome taking care to avoid pushing the bone into the spinal canal or passing the tip of the osteotome into the canal (Fig. 20:19).

Removal of this roof of the lateral recess allows the demonstration of an acutely injected irritated nerve root which confirms the nature and level of the pathology. The tissues around this may be normal or may show varying degrees of scarring with prominent new bone formation. The nerve root may be discoloured and tightly wedged laterally within the recess and firmly bound down by adhesions. These adhesions should be carefully released taking care not to damage the nerve root. It may then be retracted and at this point the nerve sheath may be seen to fill with cerebrospinal fluid and resume a normal appearance.

This filling has proved to be a good prognostic indicator (Epstein 1972). In eight patients reported by Epstein, lateral recess stenosis involved the L4-5 interspace, in five the S1 root was trapped beneath the facet of the sacrum, and in two patients both the L5 and the S1 roots were affected.

If patients who are suspected of having a prolapsed intervertebral disc and in the absence of CT verification, are explored and found to have no disc herniation, it is mandatory to explore the lateral recess and nerve root foramen. This may require a hemi-laminectomy and should include the removal of as much of the medial horizontally-orientated portion of the facet as is required to expose the nerve roots in the extreme lateral and foraminal recesses. Instability has not resulted from this procedure.

In patients with superior facet entrapment of the nerve root, movement of the facet joints is probably responsible for chronic root irritation and intermittent entrapment of the nerve. Prevention of the normal excursion of the nerve root in the lateral recess during such movement probably results in peri-neural fibrotic change with adhesions and reactive nerve swelling. As already noted, oedema of the nerve root is not removed by lymphatics, but is organised by fibrous tissue formation. It may be that the presence of peri-neural fibrotic change and adhesions indicates a degree of intra-neural fibrosis and permanent nerve root damage.

A fine Fraser or malleable uterine probe or 2 mm. soft rubber catheter can be used to check for adequate decompression of the intervertebral foramen, after decompressing the lateral recess.

After careful haemostasis using bipolar coagulation, the dural sac and nerve roots are overlaid with an isolated fat graft, and the wound closed in several layers to avoid the formation of a haematoma. Patients who report improvement or relief of leg pain on recovery from the general anaesthetic can be expected to do well.

Partial Under-cutting Facetectomy

Getty reported in 1981 a technique of partial under-cutting facetectomy with removal of ligamentum flavum and minimal but adequate bone to minimise post-operative low back pain (Getty 1981). This technique will be described in some detail.

The width of the pars interarticularis and especially its outer border is carefully defined, using a Watson-Cheyne dissector. A bony dimple that is situated medially on the pars interarticularis is located and removed (Fig. 20:20). This opens part of the roof of the root canal. The nerve root, which may now be visible, is identified and the direction of the root canal is defined by gentle probing. Every attempt is made to see the root, but this is not always possible at this stage because subluxation and overgrowth of the facets may have hidden it from view. The nerve root must also be identified at its origin from the dural sac and this may require the removal of more bone from the lamina of the vertebra above the fenestration (Fig. 20:21). The root canal is then decompressed using a fine osteotome which is advanced in an oblique direction, as indicated in Figure 20:20. The initial cut is made in the line of the nerve root. This is roughly parallel to the longitudinal axis of the spinal canal where the root passes under the facet joint before turning outwards below the pedicle. In this manner possible damage to the nerve root is minimised and if possible a MacDonald dissector is interposed between root and facet to provide additional safety. The osteotome is advanced with the percussion effect of rapid light blows in order to reduce further the risk of sudden uncontrolled advance. The use of a Kerrison's or Cloward rongeur or similar instrument in this narrow space will inevitably damage further the nerve root.

The initial osteotomy is obliquely through the inferior articular process of the upper vertebra at the level of decompression. When the articular surface of the superior articular process of the lower vertebra is reached, the osteotome is twisted to free the osteotomised fragment which is then eased out with a rongeur. At no stage in this operation should the fragments be forcibly pulled out or damage may be done to the underlying nerve.

The osteotome is now advanced through that part of the superior articular process of the lower vertebra which is causing compression and this bone is extracted in the same careful manner. The lateral attachments of the ligamentum flavum are removed with this portion of the bone, sharp dissection being used when necessary. It is important that the whole length of the facet joint complex in a cephalo-caudal direction is adequately decompressed. The removal of more bone from the lamina of the uppermost vertebra may be necessary to give access to

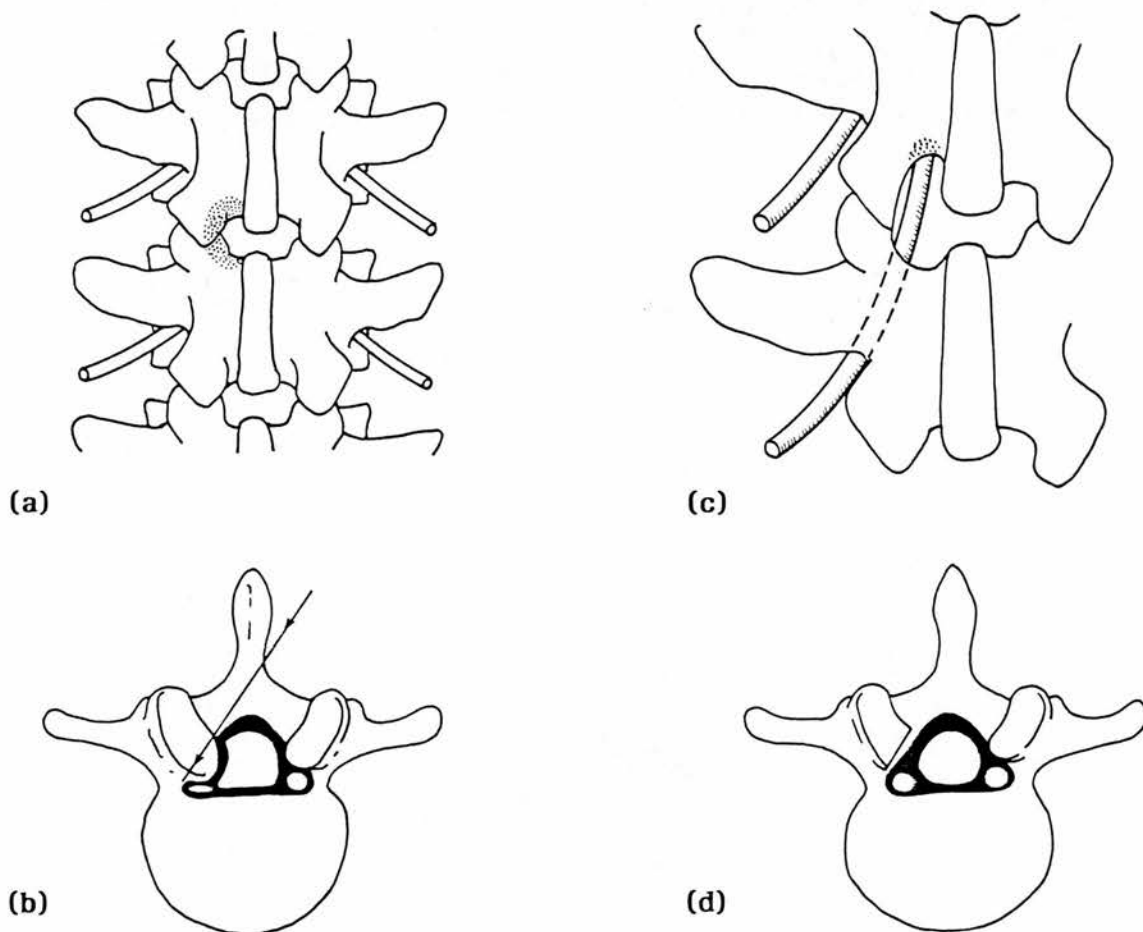


Figure 20:20. The partial undercutting facetectomy is performed by removal of the stippled area of bone (a), using an osteotome to resect the undersurface of the facet joint (b). This exposes the nerve root (c) and decompresses the lateral recess (d). In patients with widespread degenerative stenosis or developmental stenosis partial undercutting facetectomy by itself is inadequate.

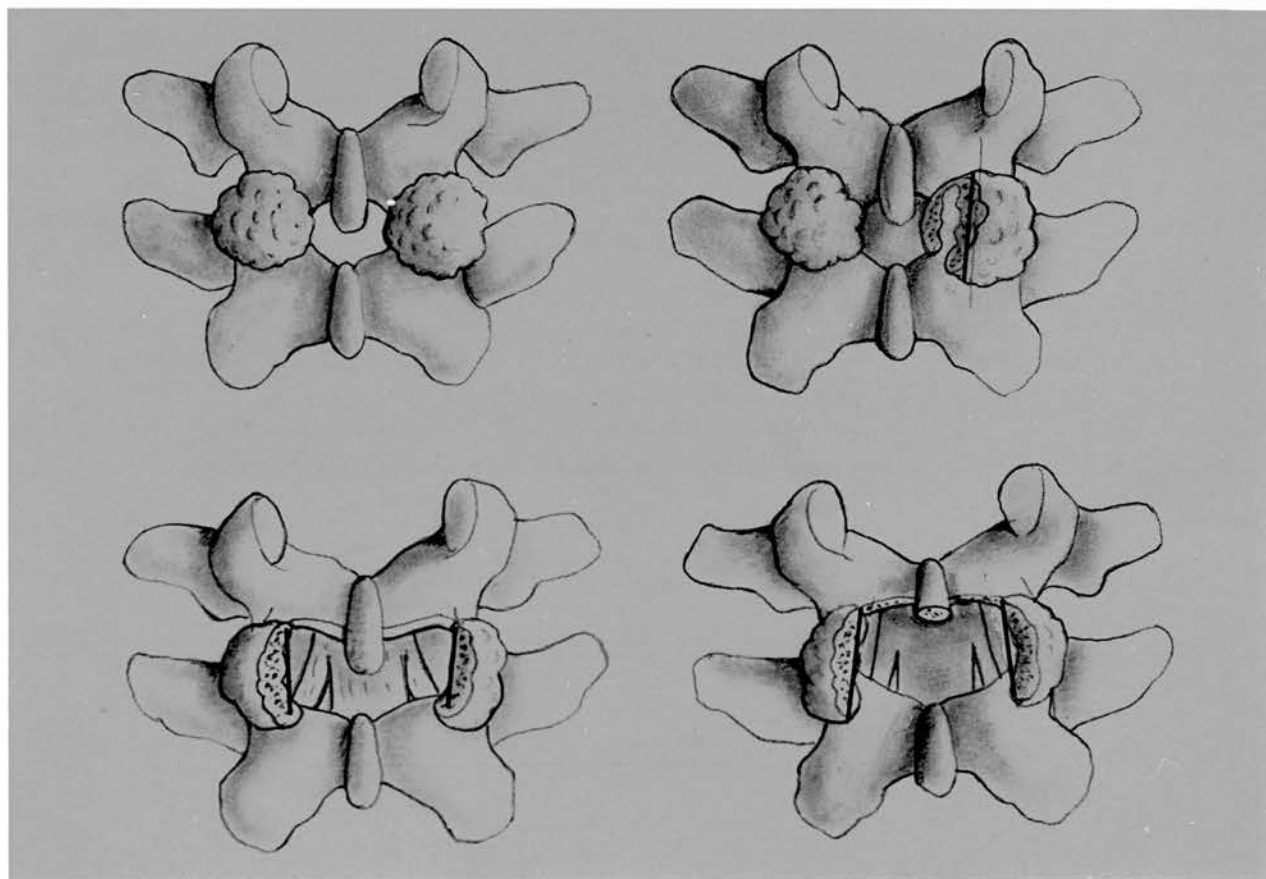


Figure 20:21. Drawings to illustrate the limited approach for lateral recess decompression by partial undercutting facetectomy. This approach is useful also for central stenosis which is clearly confined to the motion segment, but should be used only cautiously in the presence of developmental stenosis. The supraspinous ligament and more of the spinous process can be left in situ to provide additional stability for the spine.

the uppermost part of the facet joints. When hypertrophy and subluxation of the facets hide the nerve root osteotomy is performed in the same way (Fig. 20:22). Provided that the root is identified where it arises from the dural sac, and the described precautions are taken, the root will not be damaged. Getty stated that there had been no problems of nerve root damage using this technique.

At the end of the procedure the nerve root should pass freely through the root canal from its origin at the dural sac to its passage out through the intervertebral foramen. If it is seen to be kinked around the pedicle, it is necessary to remove a layer of bone from the pedicle using an osteotome.

There is often a small bulge due to an old degenerative disc lesion, though this may be represented only by a bony ridge. Getty does not usually operate on the disc unless partial facetectomy has failed to provide adequate decompression, but careful search and clearance will be required if a sequestered disc lesion is suspected.

After operation patients are nursed supine for six hours. Log-rolling movements and straight leg raising are started as soon as possible after this. The patients are allowed to stand and walk as soon as they have control of their spine, provided that their temperature is normal and their wound is satisfactory.

Various techniques of facetectomy have been described (Putti 1927; Briggs 1945; Schatzker 1968; Shenkin 1976; Bowen 1978). The difference between Getty's method and that of Bowen (Bowen 1978) is the removal of the ligamentum flavum in order to see the lateral recess clearly, and because it contributes to compression in the root canal. The technique is a partial facetectomy and preserves spinal stability. The pars interarticularis is preserved and no patients in Getty's series developed spondylolisthesis post-operatively.

Fifty-nine per cent of the patients achieved a good result but eighty-five per cent of patients were satisfied with the outcome of their treatment. The incidence of low back pain in the good group fell from eighty-nine per cent to thirty-three per cent, and was described as an ache by most patients.

The high success rate in patients who had previously undergone spinal operations is due to the fact that most of them had previously had a negative exploration of the spine and excision of a minimal bulge at the intervertebral disc. Hardly any of these patients had gained relief

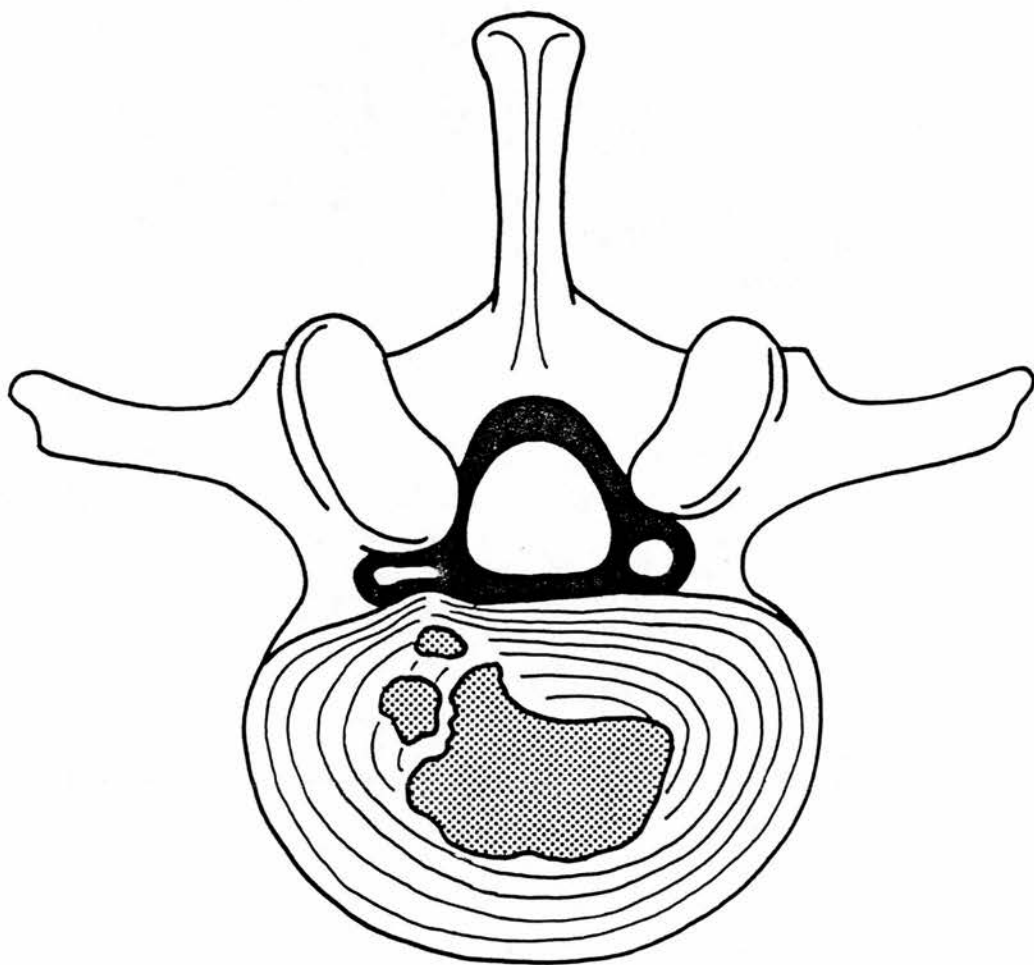


Figure 20:22. When disc prolapse is combined with a developmental anomaly of the facet joint or gross degenerative enlargement of the facet joint, it may not be possible to identify the nerve root and perform discectomy before partial undercutting facetectomy. The risk of surgical trauma to the ischaemic nerve root is diminished by performing a partial undercutting facetectomy prior to root mobilisation and discectomy.

of their leg pain after their original operation. The true cause of symptoms had not been appreciated so that re-operation was carried out in a previously unexplored area. Bony entrapment should always be suspected when a significant prolapse of the disc is not found and the root should be traced outwards along its canal.

SURGICAL DECOMPRESSION OF NERVE ROOT CANAL STENOSIS

Isolated disc resorption is not an unusual phenomenon in an otherwise normal lumbar spine even late in life. When neurological sequelae develop and the patient is treated by a standard laminectomy, then the results are often poor. By contrast, excellent results can be obtained by performing bilateral nerve root canal decompression combined with laminectomy and in rare instances where instability exists, performing a local spinal fusion (Crock 1976).

In patients with nerve root canal stenosis the intervertebral discs are usually degenerate, but are not protruding. The hypertrophic superior facet deformed by thickening of the joint capsule and spurs at the articular margin is the principle cause of nerve root foraminal compression. Secondary reactive scarring with evidence of acute and chronic inflammatory change is present usually around the nerve roots. At times complete facetectomy may be required unroofing the nerve root foramen by cutting a tract through the entire zygo-apophyseal joint. Instability due to facet joint removal alone is not observed in the elderly (Epstein 1973). The younger and more active the patient the more likely instability is to develop, and when removal of the facet joints is combined with discectomy, then post-surgical spondylolytic spondylolisthesis is more liable to occur (Fig. 20:23).

The critically limited reserve space for the nerve root within the nerve root canal makes it particularly vulnerable to compression by slight bulging of softened fibro-cartilage, a small osteophyte, or a fragment of extruded disc. The entrapped root may be overlooked if the recess is not carefully explored by a fine probe or soft rubber catheter. Decompression is not considered complete until the nerve root is unroofed as it passes over the annulus and margin of the vertebral body around the pedicle and through the proximal portion of the foramen (Fig. 20:24). The ligamentum flavum is excised along with all significant intrusions of disc material and osteophytes. In patients where a narrowed degenerate disc is bordered by hypertrophic osteophytic margins, it may be appropriate

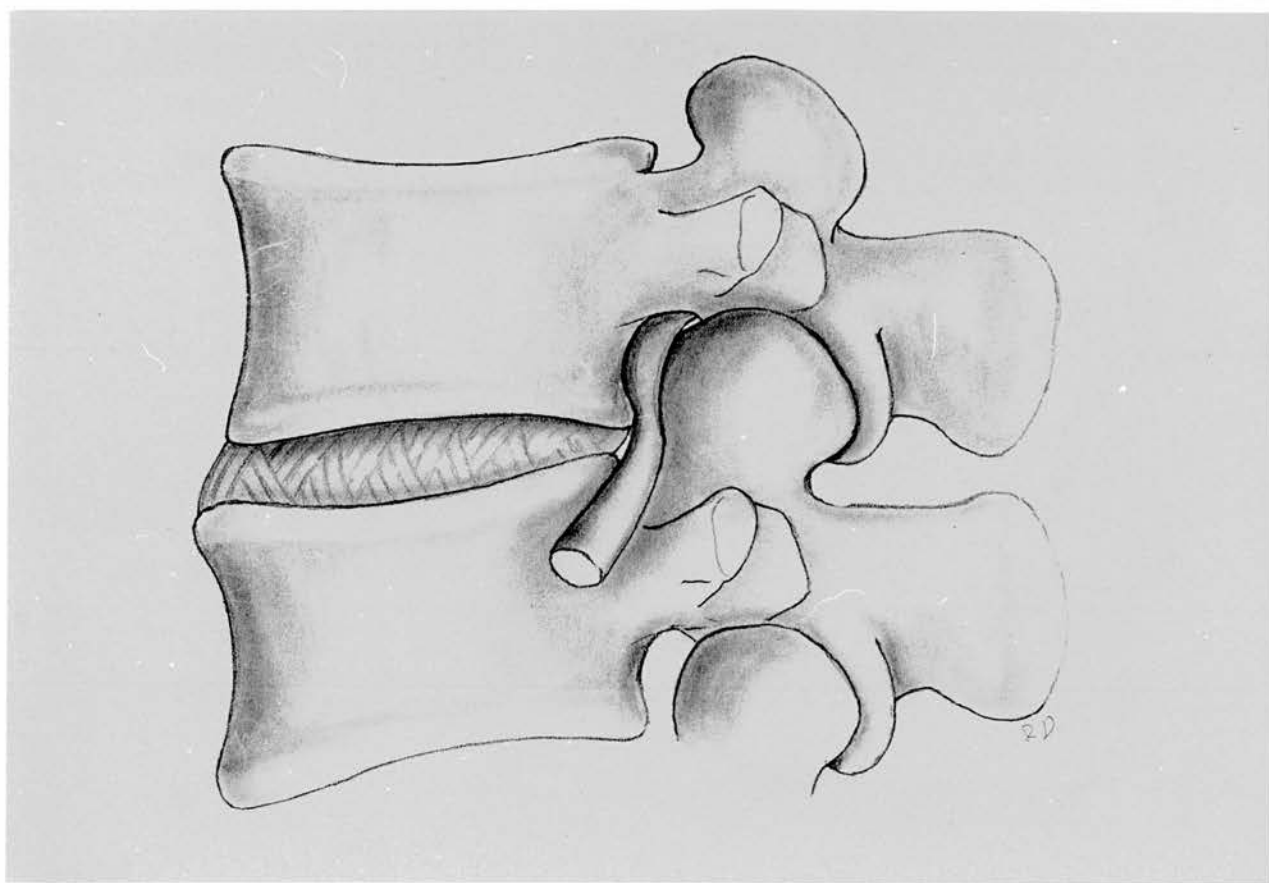


Figure 20:23. Nerve root canal stenosis is often the result of a number of factors. The enlarged superior articular facet, marginal osteophytes on the vertebral body, a bulging annulus fibrosus laterally, the descending pedicle and abnormal movements of the degenerate or congenitally abnormal (e.g. tropism) spine all can contribute to nerve root canal stenosis. The surgeon must decide which of these he is to address surgically by pre-operative investigation. The results of an extensive nerve root canal decompression are shown in Figure 20:24.

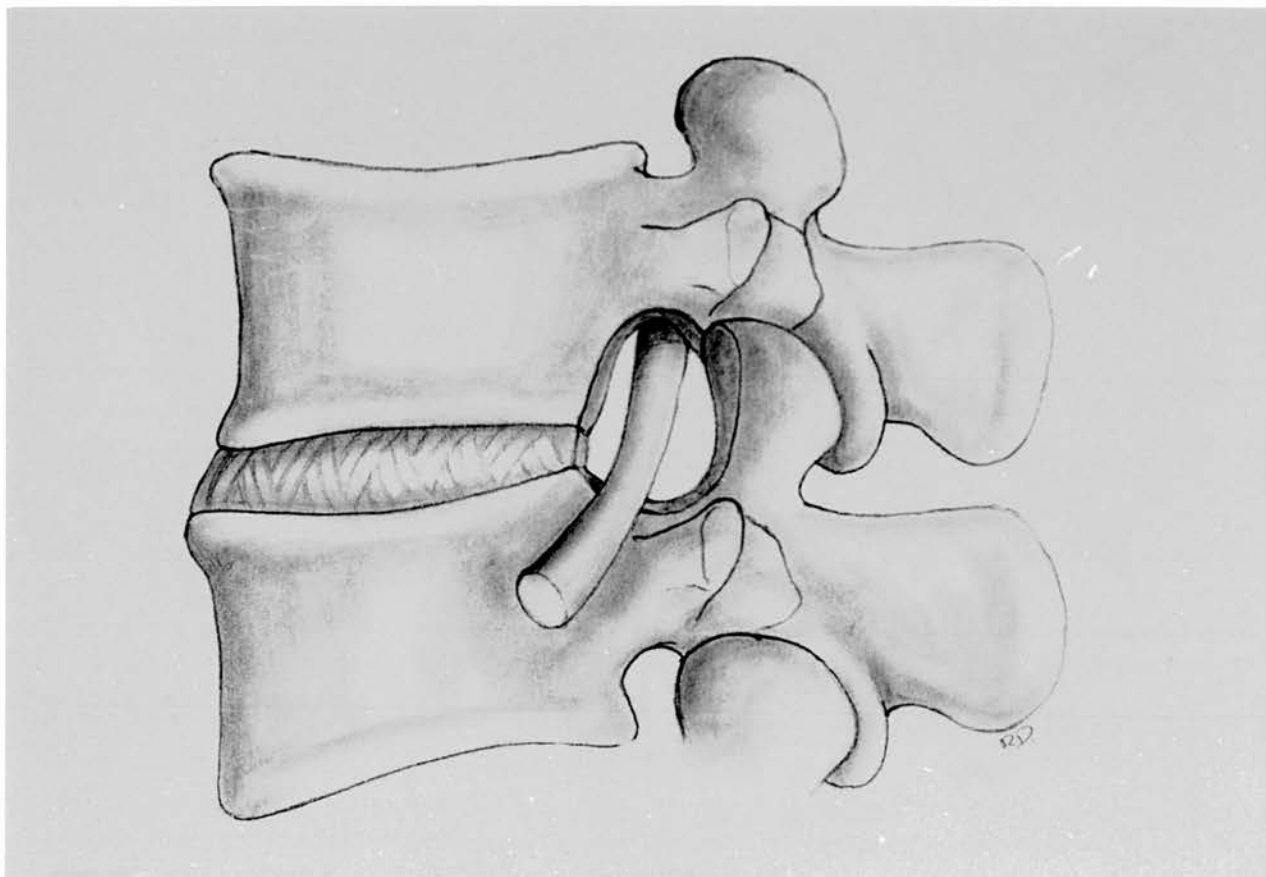


Figure 20:24. The nerve root canal following full decompression by partial facetectomy, partial resection of the pedicle and annulus fibrosus and body osteophytes. In practice, decompression is usually performed dorsal to the nerve root since interference with the disc may de-stabilise the spine and removal of body osteophytes encourage nerve root adhesions. It may however be possible to punch the osteophytes into the vertebral body and thereby reduce local bleeding and adhesion formation.

to punch these osteophytes back into the vertebral body, rather than remove them since this promotes less bleeding from raw bone surfaces, and less chance of traumatising the nerve whilst removing sharp spikes of bony spurs.

SPINAL DECOMPRESSION IN DEGENERATIVE SPONDYLOLISTHESIS

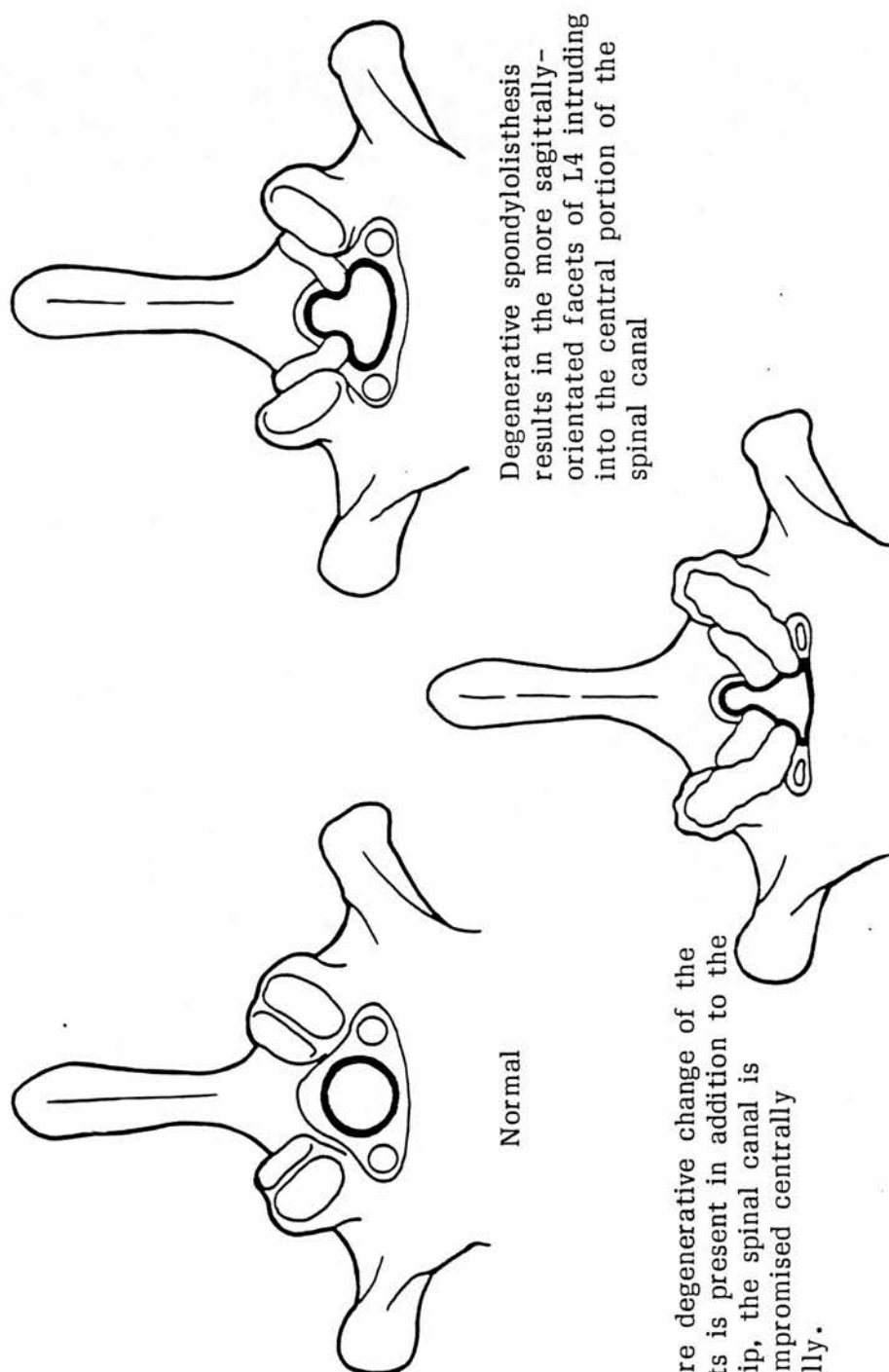
In degenerative spondylolisthesis the pars interarticularis is intact. Loss of disc height with age combined with degeneration in sagittally orientated facet joints and a partially sacralised or stabilised fifth lumbar vertebra pre-dispose to the development of this condition which is six times more common at the L4-5 level than at the L3-4 level (Wiltse 1976). It also occurs six times more commonly in women than in men.

The lumbo-sacral angle is often reduced. Sacralisation of L5 is four times more frequent in people with degenerative spondylolisthesis and it occurs more frequently in Negro females than in Caucasian females (Rosenberg 1976). It may occur at more than one level most usually at the L3-4 and L4-5 or the L4-5 and L5-S1 levels (Fitzgerald 1976). Eighty per cent of patients present with back pain alone which may be managed by a lumbo-sacral support or by surgical fusion, and in twenty per cent of patients leg pain predominates. (Fig. 20:25)

(i) Technique of Spinal Decompression

Rosenberg considered that nerve compression in degenerative spondylolisthesis occurred principally in the central part of the canal rather than the intervertebral foramina (Rosenberg 1976). Exposure at the level of the slip reveals two rugged domes of bone formed by the zygo-apophyseal joints. The articular processes at the level of the slip are markedly enlarged, and give the appearance of being closer to the midline than average. Part of this is due to the marked enlargement of the inferior articular process at L4. The L4 spinal nerve however is seldom involved. The exuberant part of both masses is removed so as to define the joint lines and expose the inter-laminar space.

The ligamentum flavum is excised and the medial third of each facet is either nibbled away or cut away using a small osteotome. Rosenberg advocated saving if possible the lateral half of the zygo-apophyseal joint at the level of the spondylolisthesis. This bilateral partial vertical facetectomy exposes and decompresses the entrapped nerve root, for



When severe degenerative change of the facet joints is present in addition to the forward slip, the spinal canal is further compromised centrally and laterally.

Figure 20:25. Diagrams to illustrate the effect of degenerative spondylolisthesis on the shape of the spinal canal. The upper view of the fifth lumbar vertebra is shown with the inferior articular facets of the fourth lumbar vertebra superimposed.

example the fifth lumbar root at the L4-5 level. The theca is compressed by the lower edge of the fourth neural arch, and by the two hypertrophic joints and the area of constriction is visualised as white and thickened and pulsation is absent distally. Removal of the lower half (Fitzgerald 1976) or the lower third (Wiltse 1976) of the lamina of L4 and the spinous process may be sufficient to allow the thecal sac to expand, but if in doubt the whole neural arch should be excised. Wiltse advocated the removal also of the proximal two-thirds of the lamina and spinous process below the slip to give sufficient decompression.

There is no doubt that if the articular process is inadvertently broken off on both sides further spondylolisthesis almost invariably occurs. If in addition the disc is entered at the level of the spondylolisthesis, and a generous portion of the posterior longitudinal ligament is divided, then the extent of further slip may be very severe. The disc therefore should be left intact.

Figures 20: 26-20:31 indicate the technique used by the author for decompression in patients with degenerative spondylolisthesis, prior to surgical fusion.

(ii) Spinal Fusion in Degenerative Spondylolisthesis

When both the nerve roots and the theca are free of compression and pulsation re-established, the primary objective of surgery has been achieved, and in the majority of patients no further surgery is necessary. Fitzgerald and Newman however recommended that in the younger and more active patients fusion may be indicated because the amount of slip may increase after the operation. In patients below the age of fifty-five and especially in the rare case of a patient below the age of fifty, Wiltse followed decompression with an inter-transverse fusion at the spondylolisthetic level. Cauchoix recommended a unilateral posterior fusion on the side opposite a unilateral arthrectomy to prevent further slip of the vertebra (Cauchoix 1976).

After bilateral arthrectomy a solid fusion is considerably more difficult to achieve because the area of fusion must be limited to the transverse processes, and because the nerve roots may be further compressed by new bone formed around the grafts (Cauchoix 1976). The incidence of successful fusion is no better than fifty per cent if only the transverse processes are left. If the lateral masses and facets have been preserved, then the incidence is higher (Wiltse 1976). Fitzgerald and Newman considered that occasionally there was sufficient facet bone

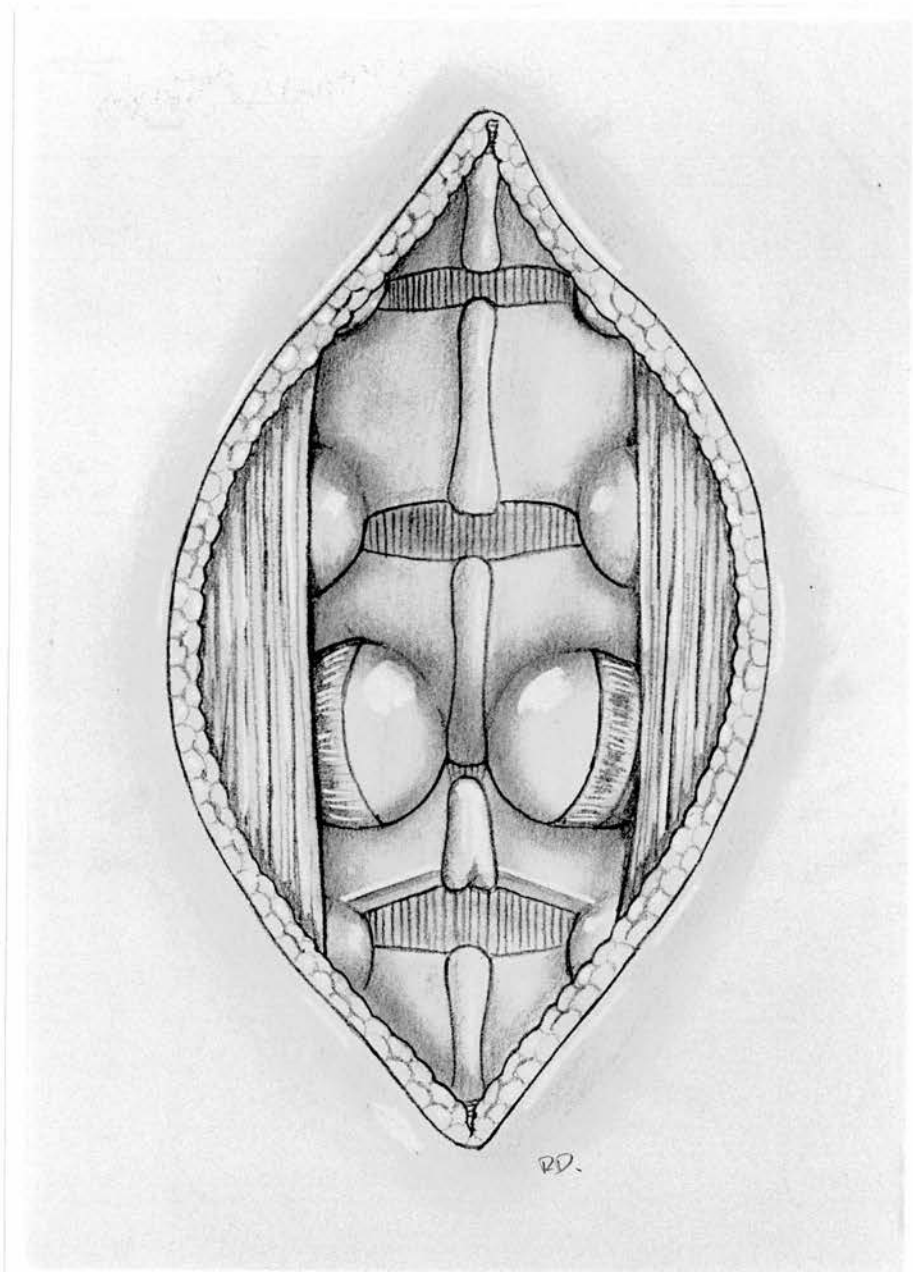


Figure 20:26. Enlargement of the facet joints and abnormal mobility is usually obvious at the level of degenerative spondylolisthesis. At surgery the "step" in the spinous processes often palpable pre-operatively can be confirmed.

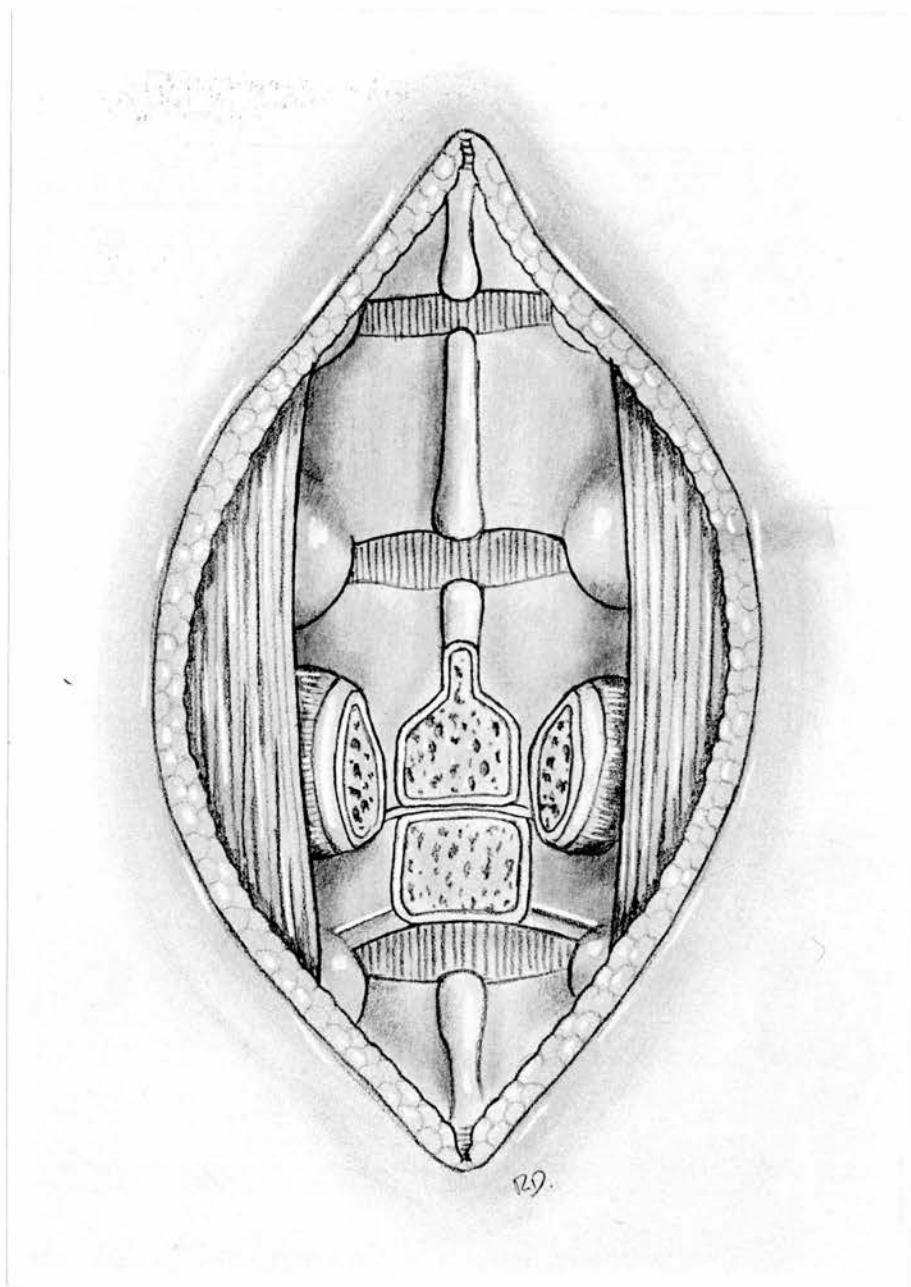


Figure 20:27. The entire spinous process of the lower level can be removed but only the caudal portion of the spinous process of the level above.

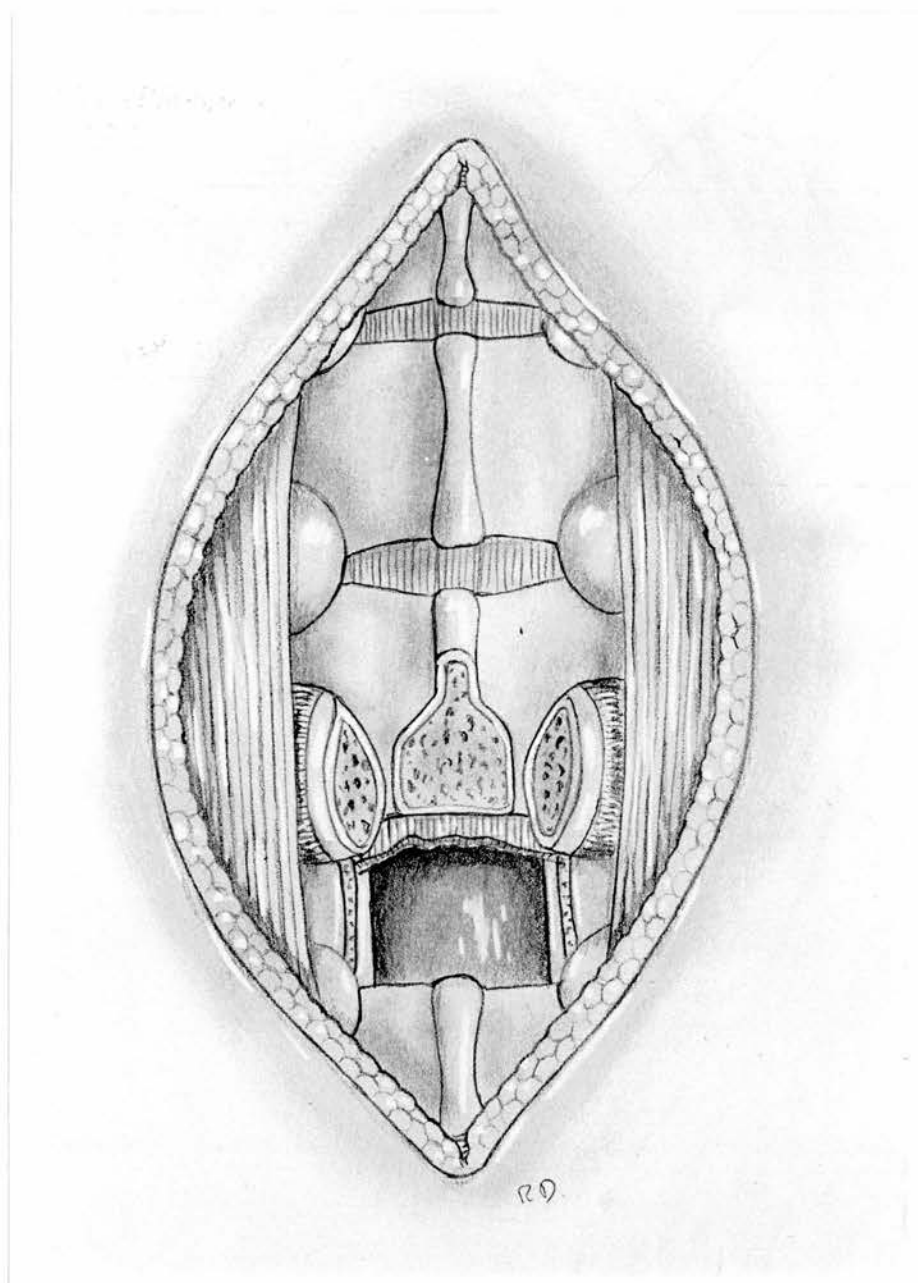


Figure 20:28. The spinal canal should be entered at its widest and not at its narrowest level. This is the level below the spondylolisthesis where there is least risk of inflicting damage on the cauda equina. The ligamentum flavum at the level of the spondylolisthesis is often adherent to the underlying dural sac.

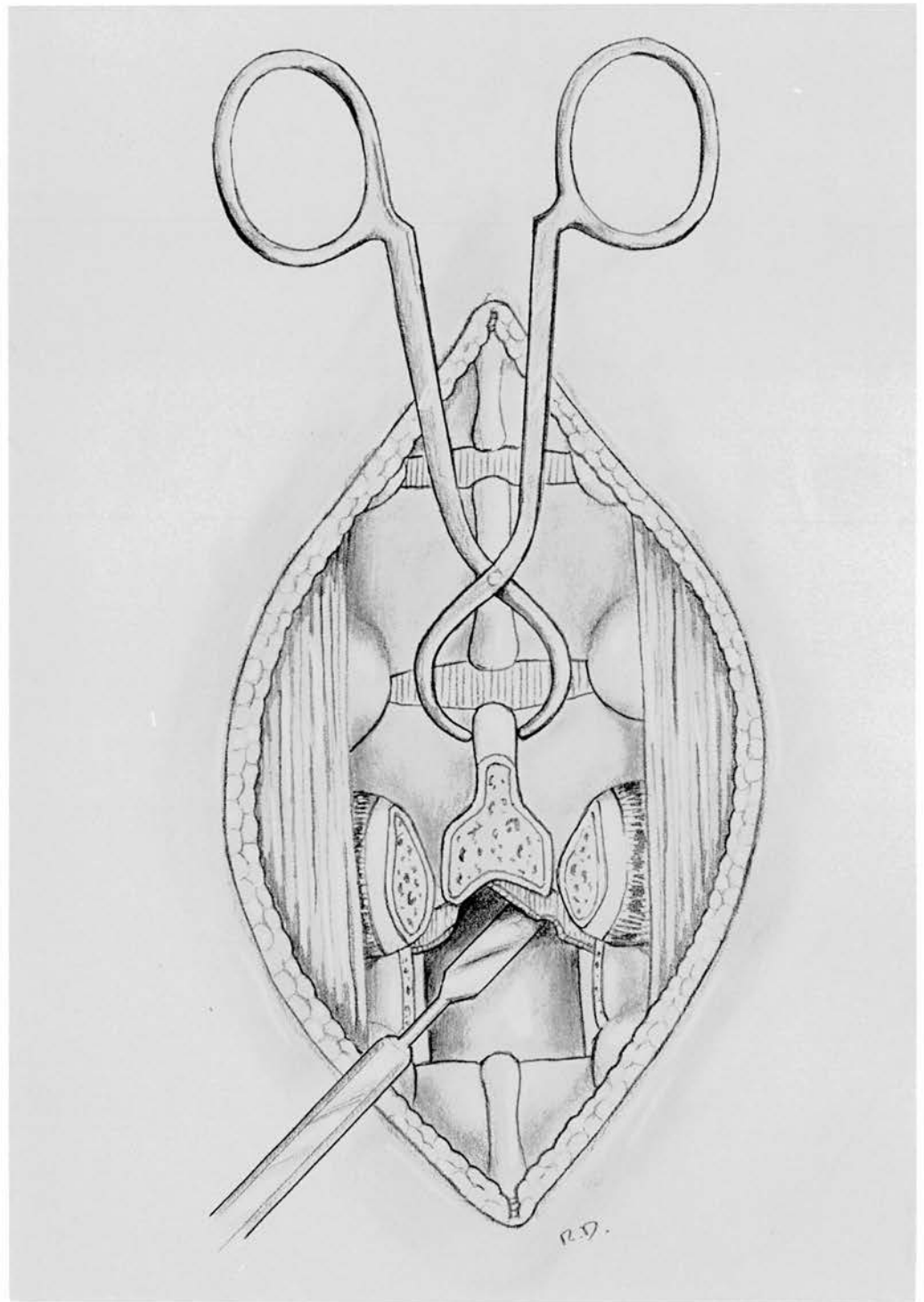


Figure 20:29. The narrowest part of the spinal canal is at the ligamentum flavum and the caudal border of the lamina above the slip. At this site the cauda equina is trapped between the caudal margin of lamina above and cephalad margin of vertebral body below. To facilitate safe decompression the lamina above should be elevated using a towel clip and a blunt MacDonaldis dissector used to separate ligament from dura prior to removal of ligamentum flavum.

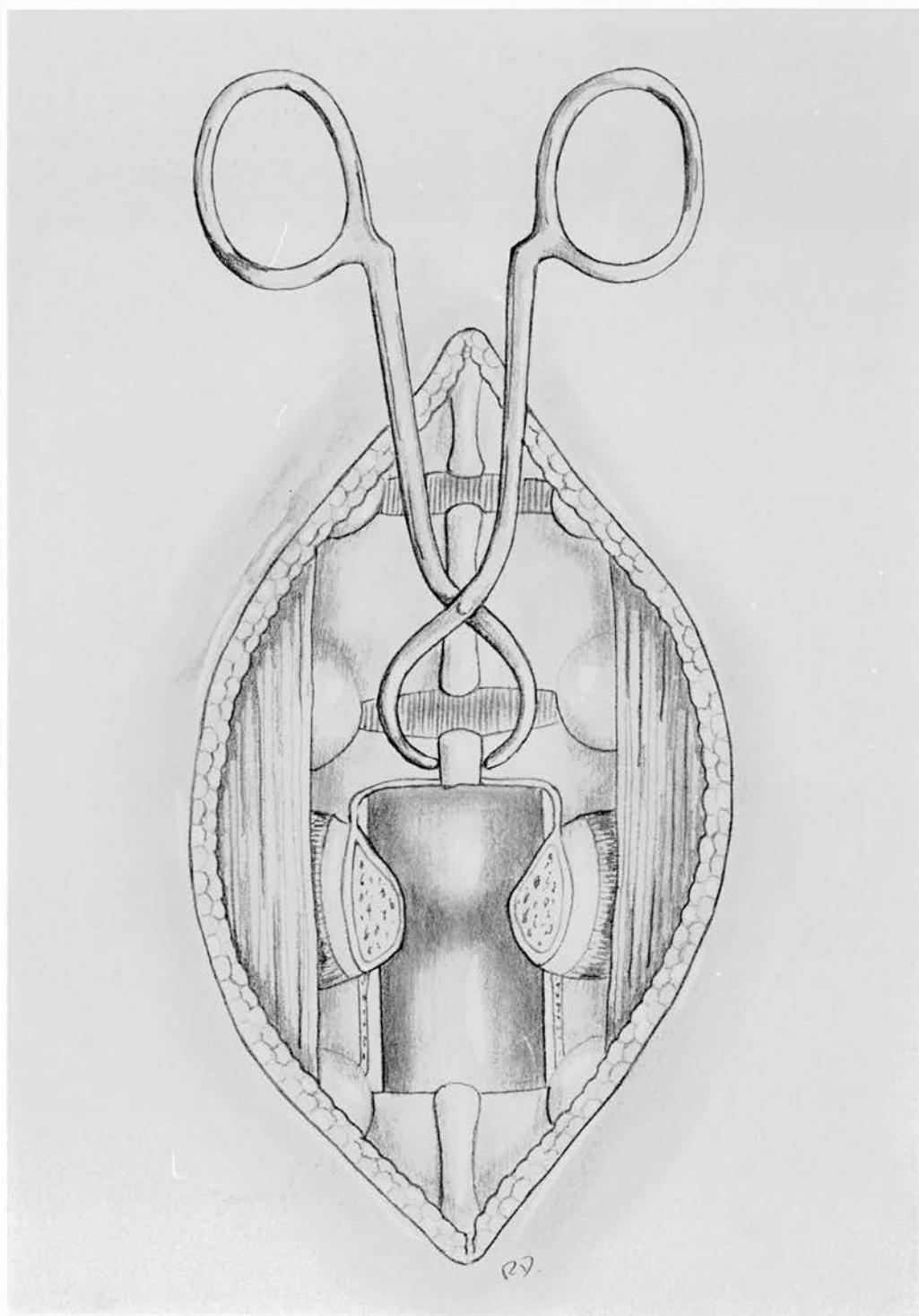


Figure 20:30. The inferior articular facets of the vertebra immediately above the spondylolisthesis are usually the cause of significant lateral recess and central stenosis at the level of the slip. By elevating the cephalad vertebra using a towel clip partial undercutting removal of these facets is greatly facilitated whilst protecting the nerve roots which lie anterior to them. To tap an osteotome into these facets without elevating them would result in direct blows by the deep surface of the facet on the underlying nerve roots because of the abnormal degree of mobility at this segment.

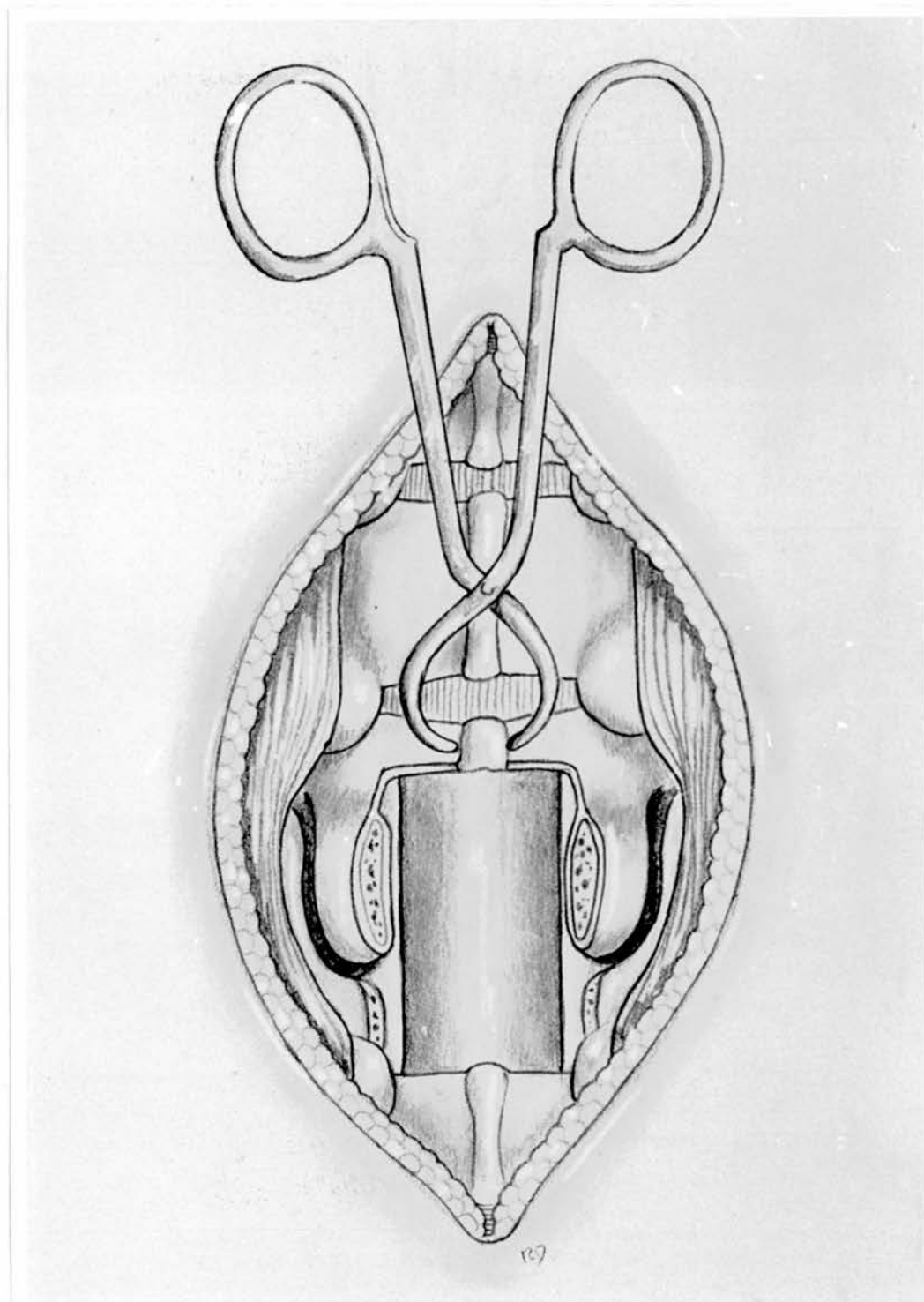


Figure 20:31. Following partial undercutting facetectomies the dural sac is no longer indented. The facet joints should be prepared for fusion by removal of any residual articular cartilage and careful decortication of the subchondral sclerotic bony plate. Care should be exercised to avoid splitting off the inferior articular facets.

remaining to permit fixation using long screws. Fusion of one segment of a spine which is affected by generalised degeneration may aggravate symptoms at a different level. On the other hand, adequate decompression alone may result in instability and further slip.

Honma noted following surgery in dogs that ligamentous hypertrophy and epidural scar formation was significantly increased after wide laminectomy when stability of the spinal column was disrupted by discectomy and anterior longitudinal ligament section (Honma 1980). Cauchoix reported three patients following decompression who underwent secondary spinal fusion because of an increasing slip. In two of these the secondary slip was reduced using Harrington instrumentation, and a one level fusion was done with good results in both patients. He stated that "spinal fusion is generally advisable" when spinal instability can be anticipated (Cauchoix 1976).

Figures 20:32-20:33 indicate the author's technique of inter-transverse lateral mass and intra-articular fusion following decompression of degenerate spondylolisthesis.

(iii) To Fuse or Not to Fuse Following Decompression

Feffer studied the effect of spinal fusion by comparing two groups of surgically treated patients with degenerative spondylolisthesis (Feffer 1985). Eight patients in whom decompression was accompanied by fusion had a more favourable outcome than eleven who were treated by decompression alone. Clearly the numbers were too small for statistical analysis, but this does represent the first serious attempt at a controlled trial.

The decision to fuse in any one operation is rarely a logical one, but usually based on the surgeon's recent experience and his interpretation of it. Young and active patients are often fused, as are patients who have been subjected to extensive decompression; how young, how active, and how wide the decompression may safely be are still valued judgements.

Also, does a fusion always prevent further post-operative slipping? There is little agreement and objective criteria are hard to come by. Certainly the amount of bone resected is important, and again the surgeon walks a knife edge between removing enough bone to decompress the neural elements yet preserving sufficient bone to avoid painful instability and further slipping. A radical facetectomy may result in only thirty-three

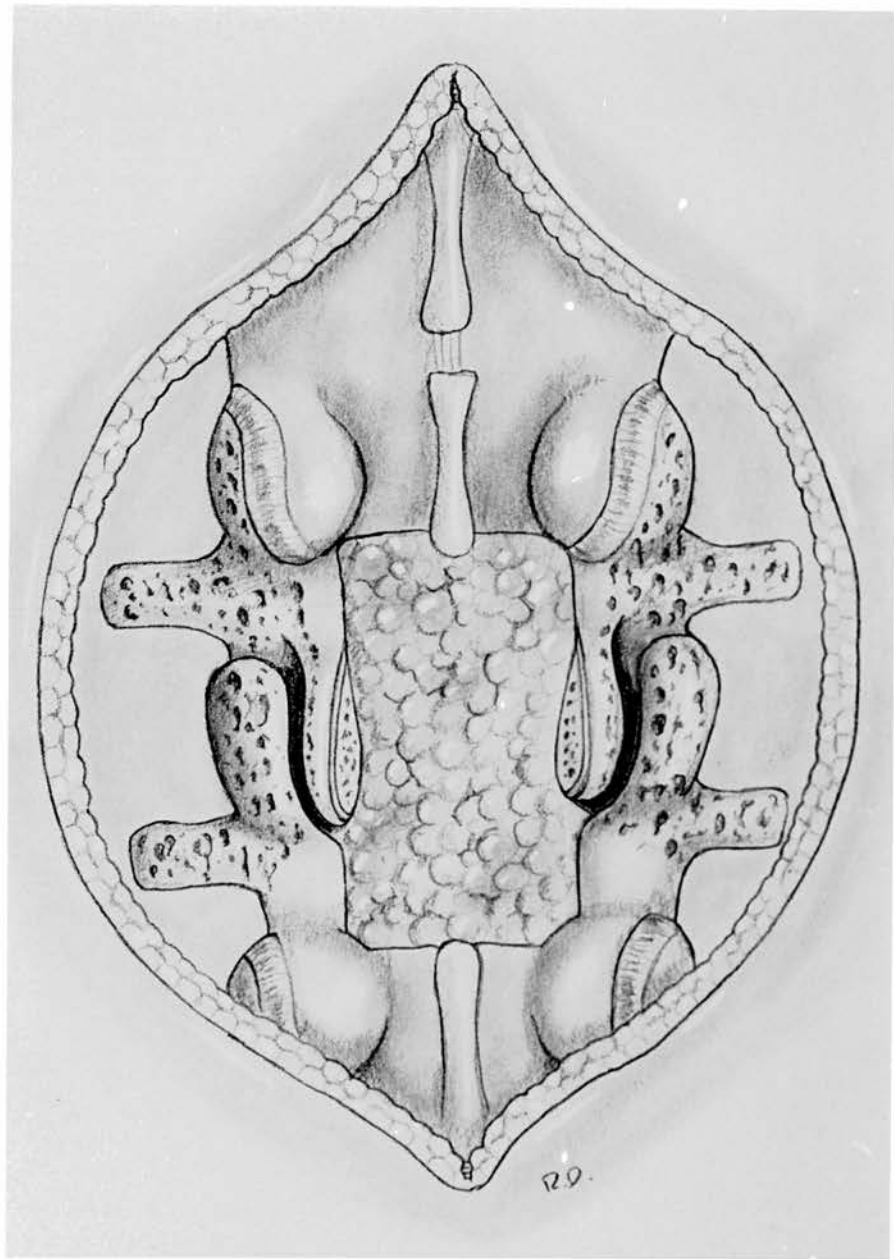


Figure 20:32. The adjacent pars interarticularis, transverse processes, and lateral surface only of the cephalad superior articular facet should be carefully and meticulously decorticated. Great care should be exercised to avoid damage to either the joints above or the joints below. The facet joints most easily damaged are the cephalad ones and this may result in premature degeneration and persistent pain following an otherwise satisfactory fusion. The transverse processes are often extremely fragile and easily fractured. The thin delicate membrane between the transverse processes should not be penetrated since the roots of the lumbo-sacral plexus lie on its anterior surface and bone from the graft may cause irritation of the roots at this site if the membrane is ruptured.

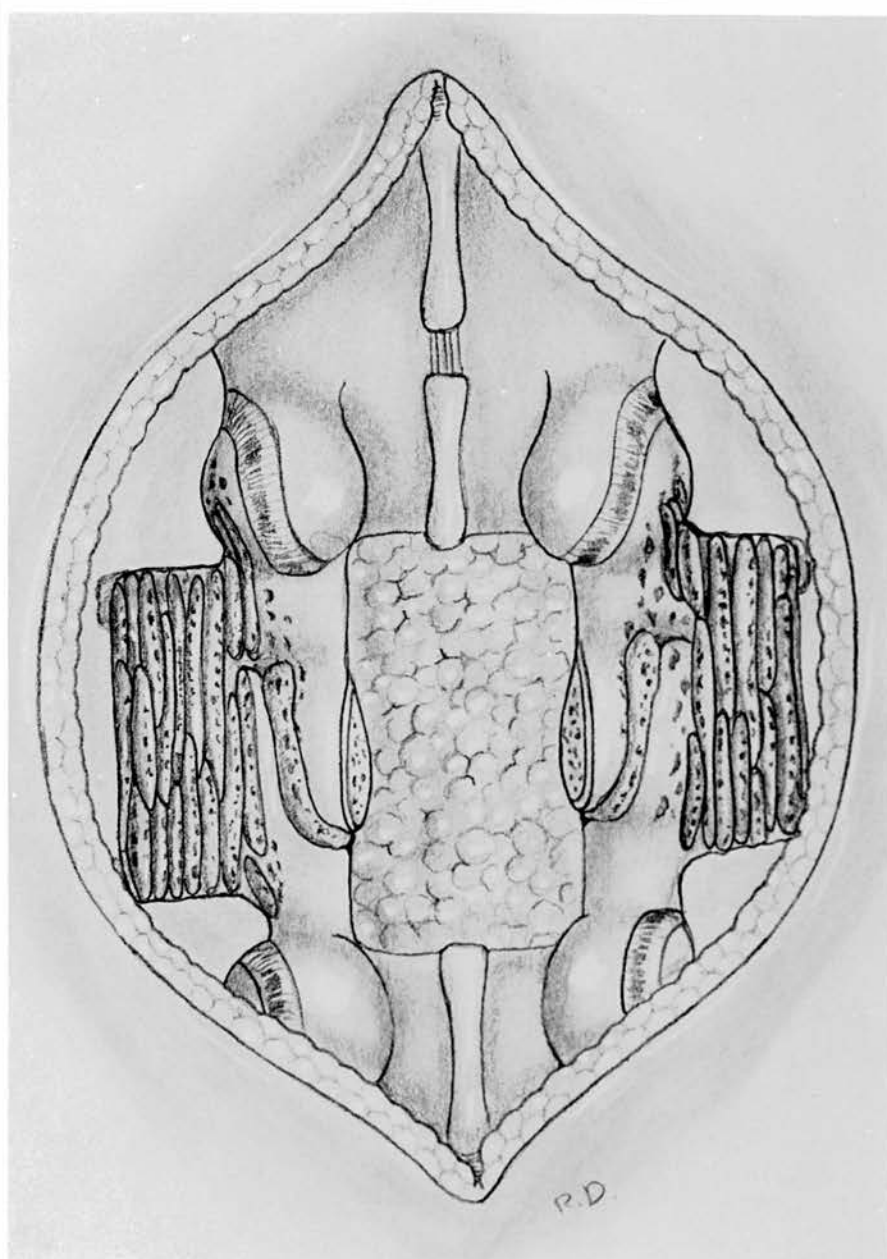


Figure 20:33. Cortico-cancellous strips of bone graft are then packed on to the decorticated area and wedged into the decorticated facet joints. This latter bone will be gripped tightly and compressed within the "joint" as the upper vertebra attempts to slide forwards again. The bone graft will however help to reduce partially the spondylolisthesis and help to stabilise this hyper-mobile segment. Great care must be exercised in not allowing graft to enter the spinal canal, and some surgeons prefer to decorticate and graft before laminectomy for this reason. An isolated fat graft should be placed over the exposed dura.

per cent good or excellent results whereas a more limited midline decompression with only partial facetectomy can be expected to result in a seventy-eight per cent good or excellent outcome (Reynolds 1979). Reynolds and Wiltse are now fusing all patients below sixty-five year of age, but their results have not subsequently been reported.

In the series of patients reviewed retrospectively by Feffer following decompression and fusion (eight patients) or decompression alone (eleven patients), those patients who had a floating fusion had a more favourable outcome than those who were not fused (Feffer 1985). The fusion does not have to extend down to the sacrum provided there is no isthmic defect, and early unrestrained mobilisation can be encouraged post-operatively. These results however are far from conclusive and a larger randomised prospective series is awaited.

The slip occurs predominantly in women older than forty years of age and progresses at an average rate of 2 mm. every four years. The inferior articular facets of the slipping vertebra develop severe degenerative changes and grind their way between the superior facets of the vertebra below in a forward direction. The inferior hook of the superior facets appears to halt excessive progression.

Quinnell and Stockdale demonstrated a significant alteration in the loading curve of the discs on either side of a simulated fusion in an experimental model of spinal dynamics (Quinnell 1981). They concluded that a floating fusion of a single disc generates additional localised loading on the discs immediately below and above the fusion. These experimental findings further justify the earlier warnings of Macnab, Fitzgerald, Newman, and others - that fusion of one segment of a spine with generalised degeneration may aggravate symptoms at a different level and that unless there is significant radiculopathy, these patients are best treated conservatively.

Spinal fusion may relieve the occasional case of segmental instability, but cannot be expected to compensate for inappropriate surgical indications. Neither discectomy nor spinal fusion will cure arachnoiditis, canal stenosis, or neurosis.

(iv) Conclusion

Considerable progress has been achieved over the past thirty years in understanding the concepts which underlie current spinal surgery. The

following three concepts have improved the management of patients with spinal stenosis secondary to degenerative spondylolisthesis.

1. The lumbo-sacral joint is inherently stable, and unless there is an isthmic defect, a lumbar fusion does not have to be extended down to the sacrum.
2. The joint between the fourth and fifth lumbar vertebrae is more superficial and accessible to the surgeon than the lumbo-sacral joint. The additional exposure required for a lateral fusion is negligible once a proper decompression has been done. Paralytic ileus, a common complication at the lowest level, is not so much of a problem at the L4-5 level.
3. Since early unrestrained post-operative mobilisation can be encouraged without compromising this type of fusion, thrombo-embolic complications are rare.

Wiltse pointed out that often the dura is so thickened and scarred and blanched at the level of stenosis that even following decompression it still does not pulsate. Cauchoix found that in those patients with severe spinal stenosis laminectomy was very difficult to perform. He found the easiest and safest way was to remove first the arch just below the slip where the canal was wider, and then carefully to work proximally as an assistant applied traction posteriorly to the spinous process of the slipped vertebra. He also had one patient in whom he stated it was necessary to incise the thickened dura to free the cauda equina. Most authors however do not include opening the theca as a requirement for decompression of the cauda equina.

SPINAL DECOMPRESSION FOLLOWING PREVIOUS SURGERY

Surgery in the previously operated back requires the development of certain special skills and experience to avoid damage to the nerve roots and cauda equina which are adherent to the walls of the canal. Adequate time must be set aside for a meticulous dissection under good lighting conditions, with the use of bipolar coagulation to control bleeding around the dura and nerve roots, and many surgeons find magnifying loupes helpful in defining the anatomy accurately.

The use of sharp curettes to extend the margins of the previous laminectomy opening, or to create such an opening helps to develop planes of cleavage and prevent damage to underlying neural structures. On the

other hand the use of rongeurs or punches before good tissue planes have been developed beyond the scar is extremely hazardous to nervous tissue. It is advisable to enter the spinal canal immediately above or below the level of previous surgery. Once the anatomy of the canal is appreciated proximally and distally, the risk of inadvertently damaging nerve tissue which is intimately adherent to dura and scar tissue is reduced. The bony margins of the neural arch remaining after previous surgery should first be identified. The anatomy of the pre-existing defect should already be known from CT scan images. The remaining constricting bone or soft tissue can then be delicately removed gently separating the adhesions between them and adjacent nerve roots using a blunt probe or a sharp dissector always against the bone, or a small scalpel when the anatomy is clearly seen.

Pulling at fragments of bone and soft tissue which are still securely retained by adhesions must be avoided, since this may easily tear off a flap of dura or even avulse a nerve root. The bony fragments and remains of the ligamentum flavum must be gently teased out of the spinal canal.

When overlying scar tissue is firmly adherent to the dura (usually in the central part of the canal) it is better to leave this undisturbed rather than risk tearing the dura. This problem should become less frequent with the more widespread use of free fat grafts or gelfoam to protect the dura from scarring (*vide infra*).

Finally it may result in less damage to the nerve root if the peri-neural adhesions are disturbed as little as possible for three reasons:

- (i) The adhesions may contribute to the blood supply and nourishment of an ischaemic root which through compression and intra-neural fibrosis has lost much of its intrinsic blood supply, and is no longer nourished by cerebrospinal fluid.
- (ii) Mobilisation, handling, and retraction of the nerve root may further damage its intrinsic blood supply or remaining intact axons particularly when adhesions are extensive and the nerve firmly bound down to the disc. Excessive and rough handling of a nerve root may result in the so-called "battered root syndrome", in which the nerve ceases to function at all during or after surgery increasing the patient's neurological deficit. Interestingly enough the patient's severe sciatic pain may be replaced by numbness which is of little concern to the patient and so offer relief of symptoms. Loss of motor power, however, is not always as easily accommodated by the elderly patient.

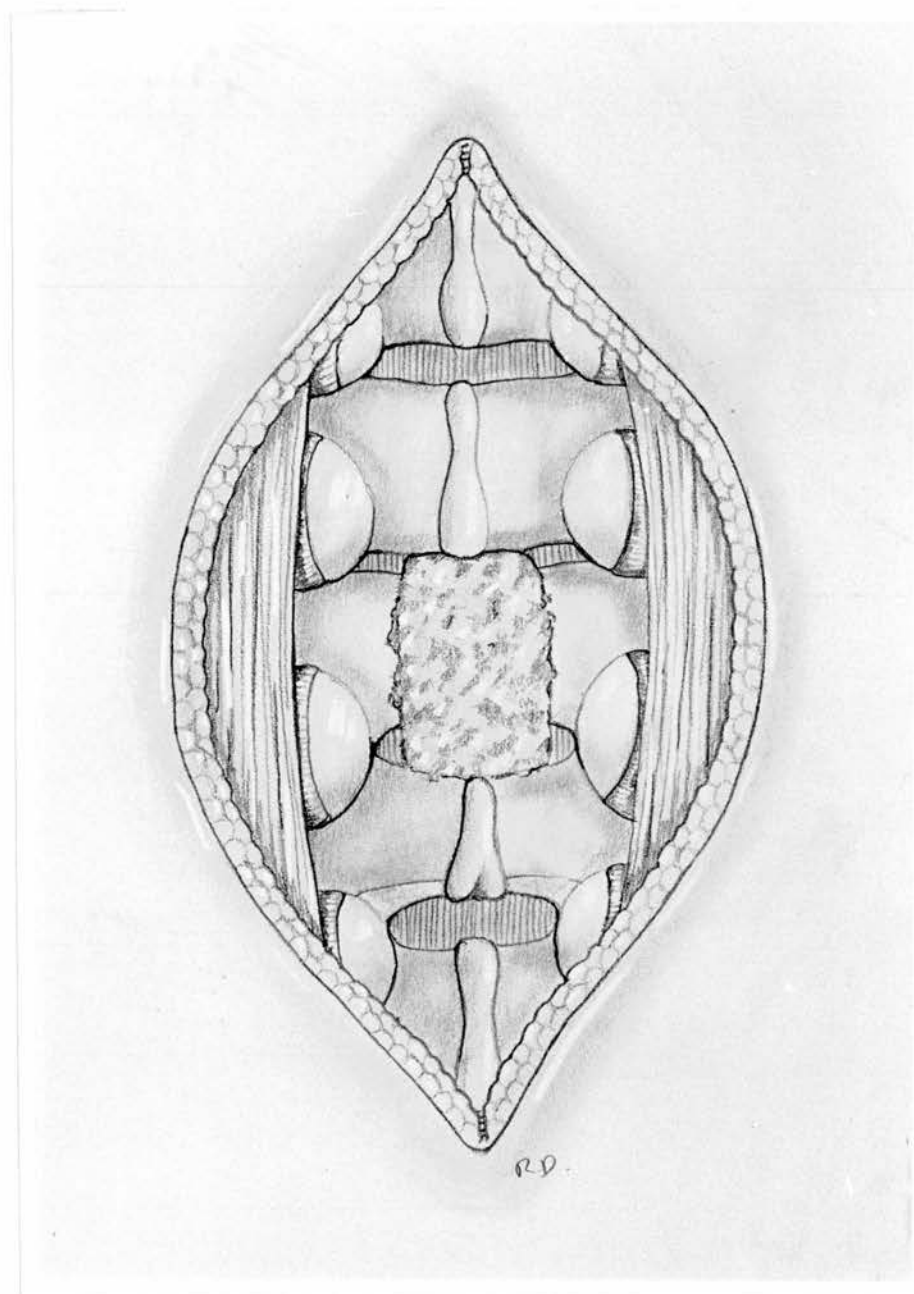


Figure 20:34. A dense scar occupies the site of previous partial laminectomy. This scar is densely adherent to overlying muscle and underlying dura and no attempt should be made to incise or excise it. It is also firmly adherent to surrounding lamina and ligamentum flavum. The first task is to define by meticulous dissection the bony and soft tissue margins of the previous surgical procedure. This is not an exploratory approach but implies pre-operative understanding of these margins based on CT studies.

If an isolated fat graft was used during closure at the previous operation then re-operation is technically much less demanding. The fat graft can be simply lifted out of the wound leaving the dura exposed such that further decompression can proceed unimpeded.

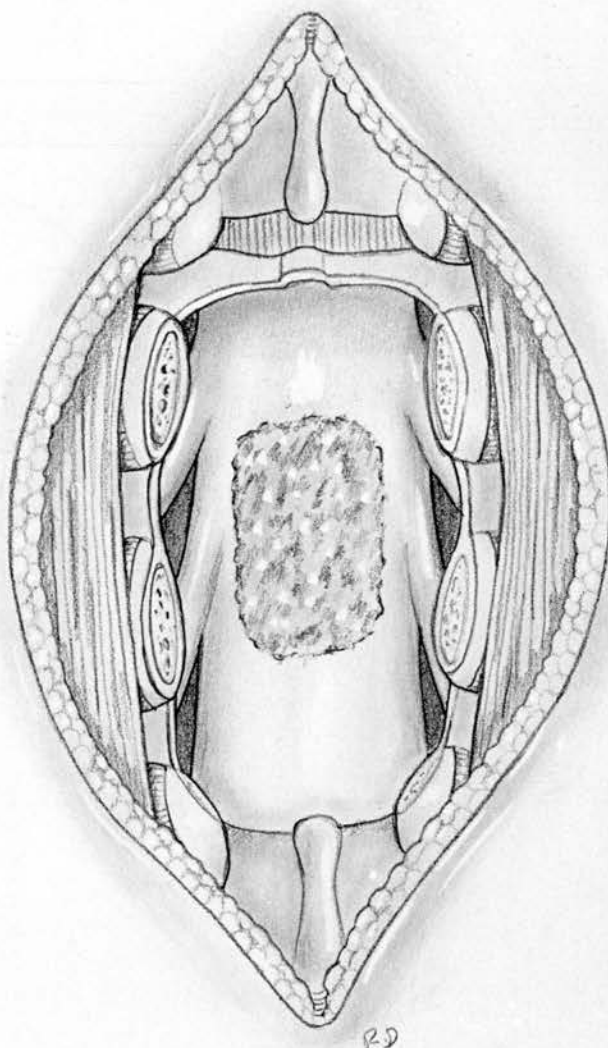
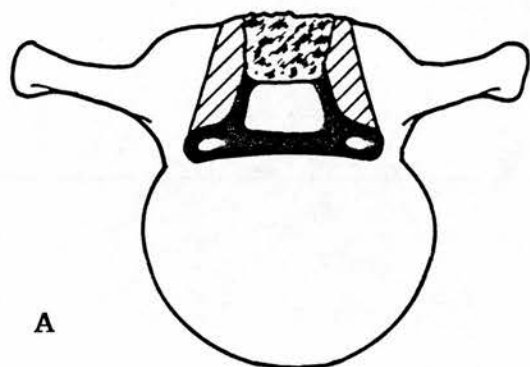
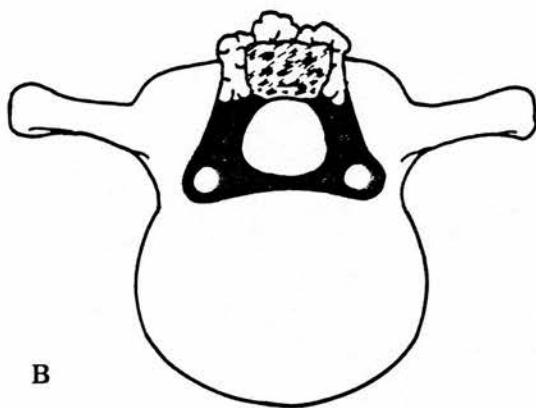


Figure 20:35. The scar is carefully separated from its bony attachment with a Cobb elevator or an osteotome using a twisting motion keeping the instrument firmly against bone at all times. Forceful introduction of the instrument between scar and bone may damage underlying neural tissue. Pulling at the scar may tear the dura and avulse a nerve root and incision directly into the scar will inevitably result in the dural sac being breached. Occasionally scar tissue can be removed from dura by blunt dissection, but when it is firmly adherent no harm results from leaving it in situ. Having defined the bony margins, further decompression may be performed as described above. Division of nerve root adhesions and excessive nerve root mobilisation should be avoided since this may devitalise and traumatise an already ischaemic nerve root resulting in the so-called "battered root syndrome", when the patient recovers from the anaesthetic to discover an increased neurological deficit.



A



B

Figure 20:36. Scar tissue present in the laminectomy defect is firmly adherent to surrounding bone and underlying dura. Only by carefully separating this scar tissue from bone is it then possible to resect the bone (shaded) responsible for lateral recess stenosis (A). The scar is left in situ adherent to underlying dura and the interval between scar and the freshly cut bony surface is filled with an isolated fat graft (B).

- (iii) Extensive nerve root mobilisation is usually unnecessary, since the source of continuing nerve root compression is usually dorsally situated. Prominent marginal body osteophytes or fragments of sequestered disc material may, however, need to be punched flat or removed.

Figures 20:34-20:36 illustrate the technique used by the author when re-operating for persistent symptoms. This must always be clearly identified pre-operatively and correlate with the patient's presenting features. There is no place for exploratory surgery in these patients.

Nerve roots are usually bound down by scar tissue to discs previously operated upon, and the lateral walls of the canal should be handled gently and the nerve freed with great care. It is helpful to decompress the nerve root distally before attempting to retract it towards the midline to expose the disc. It is wise to decompress the stenotic spinal canal before attempting to explore the disc and in fact it is often unnecessary to carry out further removal of disc material since bony stenosis in the lateral recess and nerve root foramen is frequently the reason why further surgery is necessary (Brodsky 1976). The results of re-operation will be considered in detail in Chapter 21.

COMPLICATIONS OF SPINAL DECOMPRESSION

Generalised complications such as paralytic ileus, deep vein thrombosis, urinary retention, and hypostatic pneumonia, and localised complications such as wound infection, haematoma, cerebrospinal fluid leak, or visceral damage will not be discussed in detail. Some have already been considered.

The three specific complications which will now be considered are firstly the laminectomy membranes, secondly arachnoiditis, and thirdly post-operative spinal instability including the indications and techniques of spinal fusion.

1. The Laminectomy Membrane

Studies of histological preparations of eighteen dogs which had undergone lumbar laminectomy showed a characteristic pattern of development (La Rocca 1974). On the third day a haematoma completely filled the laminectomy defect and was in contact with the surface layers of the erector spinae muscles. The haematoma surrounded the posterior and

lateral surfaces of the dura and extended for a variable distance under the intact neural arches above and below the level of the surgical defect.

At the end of the first week, fibroblastic activity was noted at the deep surface of the erector spinae. Fibroblasts could be seen to follow the extensions of the haematoma. A thick fibrous scar gradually formed starting from the erector spinae muscle and extending over the lateral aspect of the dura to the nerve roots. If at laminectomy the nerve root was exposed as far as the foramen, the fibrous scar also extended into the foramen. A dense, tough membrane thus formed to fill the defect, and this was termed "the laminectomy membrane". In seventeen of the eighteen dogs the neural structures did not adhere to the posterior surface of the intervertebral disc in spite of curettage of the annulus. In one dog, however, as a result of interference with the disc there was an extrusion of the nuclear material post-operatively, which was associated with dense scarring which bound the root to the disc in addition to the scar derived from the laminectomy membrane.

In the experimental situation, Gelfoam served as an efficient interposing membrane preventing entry of the laminectomy membrane into the spinal canal. In these animals there was no adherence of the scar to the dura, or to the nerve roots. Silastic sheeting had a similar effect when used as an interposing membrane.

Histological examination following the introduction of Gelfoam indicated the following sequence of events. Initially the interstices of the foam filled with the cellular elements of blood. By the third day, the foam began to fragment and a leucocyte infiltration occurred. By the third week considerable lysis of the Gelfoam had been accomplished, and the remaining material was irregular and filiform in appearance. At the sixth week, there was no evidence whatever of any remaining Gelfoam. Of significance is the fact that the resorption of this substance is not associated with invasion by granulation tissue, and subsequently no scar tissue replaces it. After six weeks the roots that had been encircled with Gelfoam were all free and mobile in the root canal. In dogs no evidence of adverse reactions to silastic tubing were identified.

Gelfoam itself has been shown in numerous experiments to be of a benign nature when implanted (Correll 1945; Pilcher 1945; Reynolds 1953). It was shown by Key and Ford that peri-neural adhesions might be formed from the annulus after excision of the disc (Key 1948), but the work of La Rocca and Macnab suggests that the major source of peri-neural fibrosis is the raw surface of the muscle overlying the dura.

The use of fat transplants was studied and published by the German, Erich Lexer in 1919 (Lexer 1919). Free transplants of fat were not replaced by scar tissue, but remained as soft fat tissue for months or even years. When it was necessary to re-explore the spine dura was found to be without an overlying scar and was easily exposed by blunt dissection. This difference has in several cases been demonstrated by a myelographic sign (Langenskiöld 1976).

Experimental work by Langenskiöld on one hundred and forty-five rabbits has confirmed the value of an isolated fat graft. In each rabbit a partial laminectomy was carried out on two vertebra with one intact lamina between the laminectomy spaces. In one of the laminectomy sites a piece of subcutaneous fat tissue was placed on the dura. The other laminectomy site was left to fill with blood or serum. The rabbits were sacrificed at one to four months after the operation. The fat tissue was found to have retained a practically normal appearance in all ninety-three laminectomy spaces. When a haematoma or seroma was left on the dura, this was firmly adherent to the scar.

In the clinical situation, Weinstein reported the re-exploration of three patients one year after epidural fat graft had been used at surgery for disc herniation. Although a reconstituted epidural fat layer was not present, adhesions were not dense, and a clear epidural plane of dissection was easily established at the site of previous surgery. (Weinstein P.R. 1983).

The following precautions should therefore be undertaken at operation to avoid the development of a laminectomy membrane:

- (a) The laminectomy should be as restricted as possible consistent with decompression of the involved nerve. There is no place for exploratory laminectomy, and exploratory fenestrations should no longer be required in the advent of water-soluble radiculography and computerised tomography. If there is any uncertainty about the level to be exposed at the time of surgery, then intra-operative radiographs should be used before opening the spinal canal.
- (b) A dry field should be obtained and maintained throughout the procedure. This is best achieved by the correct positioning of the patient on the operating table (*vide supra*) and the use of bipolar coagulation and bone wax as required.
- (c) At the conclusion of decompression the nerve roots and dura should be separated from the exposed surface of the erector spinae muscles by a barrier of impervious material. Either Gelfoam or a free fat graft are effective.

2. Arachnoiditis

(a) Generalised and Localised Adhesive Arachnoiditis

Adhesive arachnoiditis is seen following the introduction of irritant materials into the cerebrospinal fluid. Now that Myodil is no longer indicated and should not be used, adhesive arachnoiditis is less frequently seen. Neuro-surgical procedures such as opening the theca and meticulously dissecting the nerve roots free from each other does not improve the situation since the nerve roots adhere to each other again with time. Spinal stenosis and in particular lateral recess stenosis may damage two adjacent nerve roots producing ischaemia, oedema, and thickening of the roots, and fibrous scar tissue may form between them producing a localised adhesive arachnoiditis. (Fig. 20:37)

(b) Constrictive Arachnoiditis

Constrictive arachnoiditis in which the dura is thickened and fibrotic is much more frequently seen in patients with spinal stenosis of long-standing duration. There is no consensus in the literature regarding its treatment, but the available options include firstly bony decompression alone exposing the thickened dura but not interfering with it. This option is favoured in the orthopaedic literature. Secondly, opening the dura completely by a longitudinal incision and confirming the adequacy of spinal decompression by passing a blunt probe or 2 mm. soft rubber catheter proximally or distally in the intrathecal space. Thirdly, performing a vein or dural graft to open up the volume of the thecal sac at the constricted area, and fourthly numerous parallel longitudinal partial thickness incisions in the dura close to each other around the posterior surface of the dural sac which may sufficiently weaken the thecal sac to allow it to expand. These latter three options are favoured in the neuro-surgical literature.

Epstein reported two patients with thickening of the dura which obscured the diagnosis (Epstein 1978). Biopsy on one patient showed fibrous tissue, and similar fibrous tissue was apparent grossly when the dura was opened in a second patient who was suspected of having an intradural mass. This proved to be focal stenosis with obliteration of the subarachnoid space by an extruded midline disc. Despite the fact that the dura was opened and adhesions not disturbed, recovery was excellent.

Jayson has examined histologically the thickened material surrounding and adherent to the dura of patients with such "fibrous stenosis". He



Figure 20: 37. Adhesive arachnoiditis at the L4-5 interspace allows only a very thin line of contrast material to pass between the roots in the cauda equina which are "glued" together. At the level of the L5 segment contrast enters a constricted thecal sac with blunting of the nerve root sleeves to such an extent that no detail of the roots is possible. The presence or absence of canal stenosis or disc prolapse must be determined using contrast CT scanning sometimes enhanced by injection studies. "Fibrous stenosis" will be enhanced by injection. A sequestered disc will not be enhanced.

identified by polarised light small particles which did not have the appearance of surgical glove talc, but which he thought might be small fragments of gauze used at the previous operation (Personal Communication 1985). Although the evidence is far from conclusive it would be a useful precaution to wipe the latex preservative from one's surgical gloves and be careful not to fragment gauze swabs on sharp spicules of bone.

Arachnoiditis may occur as a complication of spinal stenosis per se with or without previous myelography and surgery, and does not necessarily of itself indicated a poor prognosis.

3. Post-operative Instability

In the patient with simple degenerative stenosis without pre-operative spondylolisthesis, post-operative spondylolisthesis is extremely rare, particularly when there is loss of disc height and especially when there are large marginal osteophytes present on the vertebral bodies. On the other hand when degenerative spondylolisthesis is the cause of spinal stenosis, the slip is likely to progress post-operatively particularly if the facet joints have been removed or fractured during the decompression and a discectomy has been performed, and the patient is young and active.

Wiltse fuses patients below the age of fifty-five following decompression for degenerative spondylolisthesis and stenosis even if the facet joints have been saved "because they fuse well when the pars interarticularis and facet joints are still present"(Wiltse 1976). In patients below the age of sixty who have undergone extensive decompression for degenerative spondylolisthesis including total removal of the articular facets, inter-transverse fusion should be performed. In this situation the area for attachment of the fusion mass to the vertebra is extremely limited and further spondylolisthesis nearly always occurs, either with or without fusion. When a partial facetectomy has been performed a floating lateral mass fusion is easily performed in patients with degenerative spondylolisthesis and not only reduces the frequency of further slip but also reduces back pain.

Grabias correlated post-operative instability with extenuating circumstances such as a primary neural disorder, rheumatoid arthritis, degenerative spondylolisthesis, or recent severe trauma after decompression (Grabias 1980). He analysed one hundred and eighty-two patients in whom thirteen developed a progressive spondylolisthesis following decompression

for spinal stenosis. Three of the patients had been treated for a herniated disc, and subsequently for degenerative spondylolisthesis. When subluxation did occur it was within the first few weeks after operation and progressed for as long as two years. All patients with progression were older than fifty-two and were in more pain than those in whom subluxation did not occur.

Older individuals with advanced degenerative change at the level of the disc as well as involvement of the facet joints tolerate extensive laminectomy better than younger individuals. In particular when the disc is maximally narrowed no further settling of the space is possible and marginal osteophytes appear to offer some protective influence against the development of spondylolisthesis. Further subluxation occurred in sixty-six per cent of patients with degenerative spondylolisthesis reported by White and Wiltse following extensive laminectomy. It was however observed in only two per cent of patients undergoing surgery for spondylosis or disc prolapse (White 1977). The extent of decompression and facet removal must be limited in the patient with degenerative spondylolisthesis and an inter-transverse fusion included as part of the treatment.

Post-operative spondylolisthesis is well recognised following extensive decompressive laminectomy and facetectomy for spinal stenosis (Shenkin 1979). This may occur at one or many levels. There is no convincing evidence that this occurs only in younger patients, but it is frequently assumed that advanced degenerative change affecting the discs of older people reduces their risk of post-operative slipping (Grabias 1980). The alternative surgical approaches reported are (a) limited decompression with preservation of at least fifty per cent of the facet joint (Tile 1984; Weir 1981), (b) extensive laminectomies combined with facetectomies (Lee 1983; Johnsson 1981), and (c) extensive decompression plus spinal fusion in younger patients (Cauchoix 1976; Shenkin 1979).

There is some agreement in the literature that patients with spinal stenosis secondary to degenerative spondylolisthesis are at particular risk of further slipping after extensive laminectomy and this risk rises to about sixty per cent if the disc at the level of the slip is surgically interfered with (Reynolds 1979; Tile 1976; Verbiest 1973).

Forty-five patients were examined at a mean interval of forty-six months following spinal decompression for spinal stenosis, where the myelogram had demonstrated an AP diameter of less than 11 mm.

(Johnsson 1986). Twenty of these patients were operated on for degenerative spondylolisthesis with stenosis and twenty-five for degenerative spinal stenosis. Post-operative slipping occurred in eighteen, but seven of these belonged to the group with a good result. However there was a significantly increased incidence ($p < 0.01$) of post-operative slipping in the poor group which consisted of sixteen patients who were unchanged or worse. There was also a significantly increased risk of further slipping in those with degenerative spondylolisthesis and stenosis ($p < 0.01$) but this did not influence the post-operative result. Post-operative disc height was reduced in all groups and did not correlate with a poor result.

Therefore in degenerative spondylolisthesis, post-operative slipping always corresponded with a poor result. In degenerative spondylolisthesis however, although the risk of slipping was much higher, it did not influence the outcome of the operation.

SPINAL FUSION FOLLOWING DECOMPRESSION

Abnormal or increased mobility at an intervertebral motion segment may result in:

- (i) Pain localised to the back with possible radiation to buttocks and thighs;
- (ii) Pain in the sciatic nerve distribution through mechanical irritation and inflammation of the sciatic nerve roots.

The objective of spinal fusion is to relieve both back and leg pain.

In the absence of an objective neurological deficit and when the myelogram and CT scan fail to demonstrate nerve root compression then fusion alone is required. In the presence, however, of a consistent neurological deficit with myelographic and CT evidence of significant root compression, spinal and nerve root decompression should precede surgical fusion. It may be that decompression alone is required to relieve both back and leg pain, but on the other hand, particularly when degenerative spondylolisthesis is present, the results of combined decompression and fusion appear in a small number of patients to be better than decompression alone (Feffer 1985).

The indications for spinal fusion are important. Good results cannot be expected unless patients are selected carefully. The best results are obtained in spondylolisthesis and in this group up to eighty per cent of

patients obtained a good result, and only six per cent are not improved (Jackson 1985). When fusion is performed as the primary operative procedure for degenerative disease of the spine, only fifty-eight per cent can expect a good result; and when the patient has had a previous laminectomy or discectomy only seventeen per cent obtain a good result. In this group of patients spinal fusion brings about no improvement in sixty per cent.

The results of Jackson were similar to those of Johnson (Johnson 1983). Overall ninety-four per cent of patients with spondylolisthesis were improved by lateral mass fusion, and ninety-four per cent obtained a solid fusion assessed by flexion/extension lateral radiographs and antero-posterior views. Tomography and isotope scanning were used when doubt existed.

Only thirty-four per cent of patients who had previously undergone laminectomy and disc excision were improved by surgical fusion, and only sixty-six per cent of this group of patients obtained a solid fusion. A poor result and pseudarthrosis were statistically more common in the post-laminectomy group ($p < 0.001$). Of all the patients with a poor clinical result, half had undergone previous spinal surgery.

It may be that fusion is more difficult to achieve following discectomy and laminectomy because of increased instability from previous surgery. When pseudarthrosis occurs in patients with spondylolisthesis, or in patients who have not had a discectomy, this does not correlate with a poor result, so it is possible that the pseudarthrosis itself is painless, but residual underlying instability remains painful.

The incidence of pseudarthrosis is greater when two levels have been operated upon compared with one ($p < 0.05$). Failure of fusion nearly always occurs at the upper level. A single level fusion is therefore a more reliable operation, and a floating fusion of the L4-5 level does not appear to de-stabilise or provoke pain at the lumbo-sacral level which is intrinsically more stable.

A postero-lateral fusion is preferable to anterior or posterior fusion for a number of reasons:-

1. A greater risk of complications with anterior fusion (Stauffer 1972)
2. A reduced fusion rate using the posterior approach (Truchly 1962; Watkins 1953)
3. Subsequent spinal decompression is more readily performed if required
4. Post-operative lumbar support is not required and the patient leaves hospital within two weeks

5. A posterior, laminar fusion may stimulate laminar overgrowth and further stenosis
6. Fusion occurs rapidly in spite of early mobilisation possibly because the graft is close to the axis of motion
7. It is unlikely that the spondylolisthesis will slip any further following lateral mass fusion (Johnson 1983; Jackson 1985)
8. The thickness and density of the fusion mass may continue to increase for up to three years (Jackson 1985).

A transverse "bikini"-type incision gives a much better cosmetic result than the two "hockey-stick" incisions described by Wiltse (Wiltse 1968).

(a) Wiltse Fusion

The technique of inter-transverse and lateral mass fusion will be briefly described. Although Wiltse initially described two curve hockey-stick shaped incisions and a paraspinal sacro-spinalis splitting approach to the lateral mass and transverse process, the bikini transverse incision is perfectly adequate with a better cosmetic result. Lateral mass fusion has a number of advantages over other types of fusions:

- (i) There is less risk of causing neurological damage in patients who have previously had a wide midline laminectomy
- (ii) In patients with spondylolisthesis the loose element is included in the fusion mass, so that it will not rock back and forth with each muscle contraction, and possibly traumatise the cauda equina causing pain
- (iii) Bone is readily available through the same incision from the adjacent posterior superior iliac spine
- (iv) Because the supra-spinous and inter-spinous ligaments are left intact there is less pain post-operatively and increased slipping of a spondylolisthesis is less likely, and it is also less traumatic than the midline approach to the transverse processes
- (v) Access is gained laterally to achieve further lateral decompression of the nerves
- (vi) Vigorous retraction is not necessary.

The posterior primary divisions of the spinal nerves arising in the segment operated upon are always cut when one approaches the transverse processes from the midline or lateral to the sacro-spinalis or by the paraspinal sacro-spinalis splitting approach. Since however the sacro-spinalis

muscle is segmentally innervated, it seems that paralysis of a segment or two where the spine is to be fused does little harm. Fortunately the posterior primary division of the fourth and fifth lumbar nerves have no sensory component to the skin, so numbness does not result. The posterior primary division of the first sacral nerve does have a sensory component to the skin, but in Wiltse's series this nerve was injured no more frequently by the paramedial incision than by the midline approach.

Only the lateral surface of the superior articular process of the topmost vertebra to be included in the fusion should be denuded. Care should be taken not to detach the capsule or damage the adjacent joint above or below the fusion segment or to expose any of the vertebra immediately above the fusion area. Within the fusion area the lateral surface of the superior articular process, the pars interarticularis and the facet joints are exposed, and the articular cartilage from the posterior two-thirds of each facet joint is removed.

The graft bed is prepared in a classic Hibbs fashion. Ordinarily one iliac crest will supply enough bone for both sides, and the availability of bone from a bone bank has the added advantage of reducing operative time and exposure. Bone is transferred to the fusion site and cancellous bone is tamped between the denuded articular processes and strips of iliac cancellous and cortical bone are tamped into place over the area to be fused.

(b) Interbody Fusion: Posterior Approach

Hutter reported one hundred and forty-two patients with the common types of spinal stenosis who were treated by posterior lumbar interbody fusion (Hutter 1985). The majority of the patients had one or more decompressive procedure prior to fusion. The results were excellent or good in seventy-eight per cent. These patients were followed for a minimum of three years before being included in this study. The rate of fusion was ninety-one per cent, as determined by superimposing films taken with the patient standing. These lateral projections were of the spine in full flexion and full extension, with the pelvis fixed to the table. Motion between all segments except the fused level was found to be as reliable an indication of fusion as any other method tested by this author.

A successful outcome did not always correlate with the presence of a fusion, except that every patient whose result was classified as excellent demonstrated a solid fusion. The anterior interbody fusion does not provide

the opportunity to decompress the lumbar nerves and correct the stenosis. The posterior approach does.

In Hutter's experience the posterior approach produced a fusion rate similar to that accomplished by the anterior procedure with ninety-one per cent fused. The long-term success rate was similar, with eighty per cent excellent or good results. Cloward (1963) and Yamaguchi (1964) reported a similar percentage of satisfactory results and Lin reported a fusion rate of eighty-eight per cent and satisfactory clinical results in eighty-two per cent (Lin 1983).

Posterior interbody fusion requires an extensive laminectomy to allow access to the disc space. Considerable nerve root and cauda equina mobility is required to permit removal of the disc and insertion of the graft. When the nerve root is already ischaemic and at high risk of further operative damage it is probably inadvisable to attempt such full mobilisation because of the risk of increasing the neurological deficit. Hutter unfortunately provided little information on the neurological status of the patient pre- and post-operatively.

One advantage of the posterior approach however is that the graft forces the vertebrae apart and may offer some protection from nerve root canal stenosis developing over subsequent years. The vertebral interspace is usually maintained when autogenous bone is used and collapse of the disc space is prevented. A solid inter-transverse fusion does however unload the segment making root canal stenosis unlikely. Also, correction of the forward slip in degenerative spondylolisthesis is possible, and correction remains after the fusion occurs. A delayed protrusion of disc material cannot occur as it may in the presence of a solid posterior column fusion.

Hutter emphasised the importance of two additional factors. Firstly, position of the patient on the table is extremely important. Flexing the hips and knees as much as possible relaxes the nerves and permits displacement of them to the midline. Secondly, hypotensive anaesthesia is important. A systolic blood pressure of around 80-90 mm. of mercury is essential to control bleeding from cut bone surfaces. Administration of hydralazine hydrochloride in small amounts intravenously may be necessary.

EXPERIMENTAL SURGICAL TECHNIQUES

The three techniques described are not recommended for clinical practice and remain to date experimental. They are included as possible

pointers to the future management of spinal stenosis.

The first technique is the introduction of a prosthetic intervertebral disc to increase the intervertebral space. This opens up the nerve root foramen, stretches the ligamentum flavum, and achieves to some extent the same effect as flexion of the lumbar spine thereby relieving symptoms in some patients with spinal stenosis. The second technique to be described is enlargement of the lumbar vertebral canal in lumbar canal stenosis by removal, refashioning and then replacement of the lamina, and the third technique is internal laminar shaving using a sonic curette.

1. The Prosthetic Intervertebral Disc in the Lumbar Region

It has been demonstrated that mechanical stress on the facet joints increases as the disc degenerates or following disc removal. This results in mechanical low back pain and progressive degeneration which may ultimately produce spinal stenosis. In the early stages the symptoms of spinal stenosis can be relieved by forward flexion. This increases the volume of the spinal canal which lies posterior to the axis of rotation involved in flexion. The insertion of a prosthetic disc may achieve the same effect by increasing the length and therefore the volume of the spinal canal. The work of Daimler confirmed that the proper functioning of the intervertebral joint depended upon the height of the intervertebral disc (Daimler 1974). The aims of implantation of a prosthetic disc are that it should be both mechanically and biochemically tolerated, allow physical mobility, and transmit the pressure from one vertebra to another without fragmentation. Lavaste used silicone of medical quality which was injected via the postero-lateral route into the disc space avoiding mixing with air which would have created bubbles (Lavaste 1976). The prosthesis polymerised in five minutes without any noticeable rise in temperature and without releasing harmful products. This operation was performed on fresh cadavers and the mechanical behaviour of the spine with the prosthetic disc conformed fairly closely to that of a normal disc (Markolf 1972). What is important of course, is the long-term behaviour of this prosthetic implant and fatigue measurements were being undertaken at the time of this preliminary report. The chemical and mechanical stability of such a prosthetic disc are of utmost importance if chemical radiculopathy and severe mechanical pressure on the nerve roots are to be avoided.

2. Surgical Enlargement of the Lumbar Vertebral Canal

Kawai reported eight patients in whom the pars interarticularis was removed by using an osteotomy at the time of laminectomy and later replaced (Kawai 1981). The ventral surface of the removed lamina was ground down using a surgical air drill to enlarge the posterior area of the lumbar canal. The lamina was then replaced and fixed with screws to avoid compromising vertebral stability. This technique was said to be suitable where stenosis was limited to one or two vertebra, and although it was time-consuming it was possible to use it in stenosis involving up to three vertebra. Kawai believed this method provided the advantages of firstly reducing the chance of inflammation by leaving no dead space after the operation, secondly avoiding re-stenosis by scar formation, and thirdly did not compromise spinal stability. The soft tissues such as the inter-spinous and supra-spinous ligaments were sutured and it was stated that "a relatively long period of time was required to attain bone union" at the point where the lamina was cut off. But with the use of screws bony union could be achieved within four to five months of the operation. No long-term results of this technique were available when this series of eight patients was reported.

Experimental work suggests that sub-periosteal stripping of the lamina can stimulate the lamina to enlarge on both the dorsal and the ventral surface. This attempt to avoid re-stenosis by scar formation might in fact in the long term result in re-stenosis by abundant new bone formation, not only at the site of bony union, but also a generalised thickening of the replaced lamina over a period of time.

3. Internal Decompression for Multiple Level Stenosis

Wide decompression without regard for the integrity of facets tends to lead to instability and chronic low back pain. In patients with multiple level stenosis it may be possible to achieve adequate decompression by inferior and superior marginal partial laminectomy combined with medial facetectomy. Lin reported that following such limited decompression internal thinning of the thickened lamina can be achieved by the shaving action of a supersonic curette from within the spinal canal (Lin 1982). This technique achieves the necessary internal decompression of the multiple levels of spinal stenosis without interruption of the integrity of the motion segment. The spinous processes and the supra-spinous ligaments

and the lateral half of the facet with its firm fibrous capsules, are scrupulously preserved. The disc is not removed unless it is overtly extruded.

The supersonic curette, because of its high frequency of vibration, does not injure soft tissue or neural tissue. The heat generated on contact with bone is minimal. The hard bony structure can be removed more easily than with a regular curette. However the surgeon must take care that the supersonic curette does not touch the nerve root retractor. Contact of the curette with a nerve root retractor reduces the frequency of vibration and can cause strong mechanical stimulation to the retracted nerve root.

According to Wolf's Law,

"a bone, normal and abnormal, develops the structure most suited to resist the forces acting upon it".

Therefore, on theoretical grounds, because the canal encroachment is the result of bony overgrowth from abnormal stress on the facets caused by spondylosis, the recurrence of spinal stenosis is very likely unless motion is arrested. It is not known how long this process of recurrence takes after internal decompression, but if recurrence does take place it may be possible to re-operate using internal supersonic decompression again without disrupting the integrity of the motion segment.

This technique cannot be expected to provide adequate decompression unless nerve root entrapment is caused predominantly by the proliferative changes of lumbar spondylosis rather than by developmental lumbar stenosis due to congenital shortening of the pedicles and lamina. In such patients, laminectomy and foraminotomy by the standard technique will be required.

The cephalic laminar edge is the site of greatest midline stenosis, especially in patients with a relatively vertical orientation of the laminar arch. The dura mater is often thinned when the sac has been compressed chronically, and considerable caution would be appropriate to avoid dural laceration while under-cutting the antero-superior edge of the lamina during internal laminar decompression without laminectomy. At this level there is no ligamentum flavum separating dura mater from bone. Similarly the insertion of an osteotome, curette, or rongeur is more difficult and hazardous at the cephalic end of the lamina. Post-operative computed tomography would be of considerable value to verify the adequacy of lateral recess and foraminal decompression by the internal laminar approach. Follow-up on this and the previous method is at present very limited.

C H A P T E R 21

THE RESULTS OF SURGICAL TREATMENT OF SPINAL STENOSIS

INTRODUCTION

At the turn of the century Sachs and Fraenkel reported one patient with lumbar and sacral pain relieved by laminectomy, in which there was marked thickness of the lamina (Sachs 1900). In 1925 Parker and Adson reported eight similar cases (Parker 1925).

The clinical and pathological work of the early nineteen thirties was largely stimulated by Schmorl's investigation into the condition of the intervertebral disc at autopsy. The subsequent description of the ruptured intervertebral disc with involvement of the spinal canal by Mixter and Barr (Mixter 1934), and the realisation that this could be treated surgically, resulted in a rapid increase in the number of operations performed on the lumbar spine based upon an improved understanding of pathology. In 1965 Carl Hirsch reported that removal of disc prolapse appears to be a most promising operation, but he noted that it was not successful in all patients. He stated that

"not all patients with sciatica had disc prolapses" (Hirsch 1965).

Carl Hirsch considered that the concept of the "concealed disc" confused the issue for a long time, and contrived both to mislead the surgeon and to bring the operation into discredit. It was in fact this concept however which helped to bring about more widespread recognition of spinal stenosis and its surgical treatment.

Hirsch reported ninety-six per cent improvement after removal of a prolapsed intervertebral disc and a

"seventy per cent improvement after operation on so-called 'concealed discs' regardless of whether the disc was excised or not".

Hirsch was undoubtedly referring to a laminectomy and decompression for spinal stenosis without discectomy. Without mentioning the term "spinal stenosis" at any point in the paper, Hirsch concluded that

"experience during the past twenty-five years has generated a certain optimism in orthopaedics. Our specialty may look back today with satisfaction on a quarter of a century of intensified investigations of the clinical and pathological aspects of this problem. We are now (in 1965) at a stage where further basic investigations are required. We hope new data will provide improved diagnostic measures and help point the way to better therapeutic concepts" (Hirsch 1965).

Further investigations over the past twenty years into the clinical and pathological aspects of spinal stenosis have resulted in considerable understanding of this condition; and during the same period the results of surgery have also improved but only marginally compared with Hirsch's results. An example of research leading to improved surgical treatment was in 1976 when McIvor correlated pathological with myelographic observations in lumbar spinal stenosis (McIvor 1976). He found that the inferior facet caused narrowing of the central canal and the superior facet narrowing of the nerve root canal, and emphasised the importance of the posterior articular processes in producing stenosis. This in turn lead to the development of the partial under-cutting facetectomy, a vital technique in lateral recess and nerve root canal decompression.

Moreover in 1981, Scafuri found that those patients who were evaluated pre-operatively by CT scan and myelography had a significantly higher subjective improvement following surgery than those patients evaluated by myelography alone (Scafuri 1981).

What is clear now however is that spinal stenosis whatever the aetiology is a treatable disease and responds favourably to operative management when indicated. The indications for surgery in spinal stenosis must be strictly adhered to if satisfactory results are to be achieved and patient selection including a psychological assessment at times is most important.

Strict indications for surgery in patients with spinal stenosis are:

1. Pain unresponsive to adequate non-operative treatment
2. Increasing motor weakness
3. Any sign of bowel or bladder dysfunction.

The problem is always to assess the course of a predominantly subjective condition in ageing subjects, with declining functional capabilities. Success or failure therefore is very often based on subjective assessment by the patient.

THE ASSESSMENT OF RESULTS

The success or failure of surgical decompression must ultimately be judged by the patient. The answer the patient gives is influenced considerably by who asks the question, yet it is surprising how few reports use an independent observer to obtain these results. In most reported series the patient directly informs the surgeon of the results of the operation.

LUMBAR SPINE RATING AND ANALYSIS SCALES

The use of an effective rating scale to objectively measure the level of disability experienced by patients with spinal stenosis would assist the clinician in deciding when surgery is required and in accurately assessing the results of surgical and non-surgical treatment. Patients with spinal stenosis with neurogenic claudication, can often be encouraged to state their claudication distance when walking on the level, but personal estimates of distances are notoriously unreliable, and a short claudication distance may be of little concern to an elderly person who has accepted a more restricted way of life, whereas a longer claudication distance may be a severe incumbrance to a younger person who wishes to remain active.

A number of other features hinder the development of a satisfactory rating scale for spinal stenosis:

1. The disability ultimately depends upon the patient's perception of pain. This is a subjective determination which produces difficulties in assessing the benefits of treatment.
2. The severity of pain may vary considerably from time to time, and when reviewing series of medical and surgical treatment for spinal stenosis it is very difficult to know how severely affected subjects were prior to treatment.
3. Many patients with spinal stenosis do improve considerably with time. Symptoms may have been provoked by unaccustomed exercise or lifting and remission may occur spontaneously without specific treatment.

Two major difficulties therefore arise in rating scales. Firstly, controlling severity between groups: is the severity determined by the claudication distance, the severity of symptoms at that claudication distance, the presence of neurological abnormalities, the size of the filling defect on the myelogram, or the appearance on the CT scans?

Secondly, some difficulty arises in deciding at what point treatment has succeeded or failed. Return to work is regarded as the most reliable and clear indicator of the success of treatment; this however is not as reliable as it may appear. In a study performed on a population in an industrial setting with acute low back pain, eighty-five per cent of injured workers can be expected to return to work despite placebo treatment (Berquist-Ullman 1977). If a similar study is performed on a population of workers receiving compensation for chronic low back pain,

the expected return to work with "successful treatment" is only forty-two per cent (White 1966).

Lehman and others reported a one hundred and five point rating scale consisting of eight parameters grouped into three major parts (Lehman 1983).

1. Physical measurement of trunk strength and range of motion (forty points)
2. The patient's perception of pain and dysfunction assessed by an activities questionnaire and a visual analogue pain scale (forty points)
3. The physician's perception of the patient's dysfunction based on a report of pain and the medication usage (twenty-five points).

The authors clearly found great difficulty applying this rating scale, but they reached three conclusions. Firstly, they gained the impression from clinical work that when the patient's condition was stable over time, there was practically no change observed in the rating scale. Secondly, the change in rating scale was not correlated with return to work. Thirdly, the number of patients tested was too small. They had only twenty-nine patients undergoing lumbar surgery, and forty-eight patients in a three week rehabilitation programme.

This was at least an attempt to produce a rating scale modelled after Larson's Hip Rating Scale (Larson 1963). Weinstein and others reported a one hundred points analysis form of patients following decompression for spinal stenosis (Weinstein 1981). In their analysis the pain/function category was given seventy points (forty for pain and thirty for function), whilst the objective category was given thirty points. Only twenty-four patients were followed up for between 1.1 years and 4.2 years after spinal decompression, and on the basis of this they reported nine patients as excellent, seven good, three fair, and three poor. They concluded that surgical treatment yields significant short term benefits in patients who are carefully selected and widely decompressed, but it must again be pointed out that the numbers in this study were small, and the difficulties of allocating points to patients on the basis of pain and function were considerable.

Longer term follow-up of patients following decompression for spinal stenosis revealed significant changes in both the major categories of pain and objective physical findings using this Lumbar Spine Analysis Form (Weinstein 1983). This suggested that patients with "spinal stenosis"

obtained definite, measurable benefit from surgical decompression during the period of one to three years following surgery.

All twenty-four patients in this series were treated by wide decompressive laminectomy in a standard fashion, and only one case required supplementary postero-lateral fusion. An average of three levels were involved in this group of patients, and the L4-5 motion segment was involved in each case. The number of levels decompressed did not influence the quality of the end result.

A method of following up patients many years after back surgery is to request a postal reply to a questionnaire. An example of this was published by Finneson (Finneson 1974), and is as follows:

"Dear (Patient's name)

I am writing to obtain your assessment of the lumbar surgery I performed on (date).

To facilitate your response I have enclosed a self-addressed postcard, please check the number (on the postcard) which most closely describes your present condition.

1. If after surgery your pain was improved, and you were able to function well, please check No. 1.
2. If your pain was improved but you were not able to function without occasional medication and occasional time off from your activities, please check No. 2.
3. After surgery your pain was improved but you still have considerable discomfort that requires medication and time off from you activities, please check No. 3.
4. If after surgery you were either unimproved or worse, please check No. 4.

I have provided a space on the postcard for any additional information you may wish to indicate.

Thank you in advance for your help."

Out of five hundred and ninety-six mailings there were only three hundred and three responses, twenty-three of which were not considered suitable. Clearly this method is inexpensive and time-saving and avoids bringing patients back some distance for review. However it is purely subjective and the answer to the question is considerably influenced by the patient's psychological make-up and outlook on life. Clearly no information can be provided by this means on the return of reflexes or motor or sensory function.

Most series which report the results of spinal decompression for

spinal stenosis include direct questioning of the patient and grade the answers in one of four or five categories. An example of four categories was reported by Surin and was as follows (Suring 1982):

- "1. Excellent: The patient is symptom-free and has resumed all previous activities.
2. Good: The patient has resumed normal activities but may occasionally after heavy work have recurrent leg or back pain.
3. Fair: The patient has had to reduce his/her previous activities because of persistence of some pain symptoms.
4. Poor: The patient is frankly disabled; pain symptoms have not been reduced at all by surgery."

Grading the results into four categories is the most widely used method of subjective assessment with numerous elaborations, for instance Russin included in the excellent and good categories those patients who needed no form of spinal support, whereas in the fair and poor categories patients needed spinal support (Russin 1976). Another definition of "fair" is "improved functional capacity, but with reduced activity" (Choudhury 1977), and the classification of Paine is more detailed with an important time element involved (Paine 1976a). For instance Paine described a "good result" as the patient returning to their normal working activities and some of their recreational activities with minimal restrictions, and back or leg pain lasting for a few days but not occurring more than once or twice a year. Paine describes a "fair result" as the patient who has returned to work either in a lighter employment, or on a part-time basis with restrictions in their outside activities. Recurrence of back pain or leg pain is sufficient to prevent them from working, and other activities may be two or three times a year for a week or two on each occasion, but the patient remains economically independent. This is quite a complex classification, and not all patients could be fitted easily into one of the four groups.

Simplicity in the classification is therefore important and Spangfort's criteria for the evaluation of pain is probably one of the simplest (Spangfort 1972). Spangfort defined a "good result" as one in which the patient had virtually no pain. A "fair result" indicated that the patient had occasional pain relieved quickly by a short term bed rest and analgesics. A "poor result" meant frequent or disabling episodes of low back pain or sciatica that required narcotic medication, additional surgery, or a significant change in job status.

On the other hand a classification involving five gradings was reported dependent upon whether the patients considered themselves:

- "1. Symptom-free.
2. Left with minor persisting symptoms but previous activities unrestricted.
3. With previous activities restricted.
4. With partial improvement or some symptoms only, or
5. Frankly disabled" (Fitzgerald 1976).

Finally a system of points was used by Scafuri to assess the results of surgery for lumbar spinal stenosis (Scafuri 1981). He reported a "back analysis form" which was divided into two sections. The first section concerned itself with the subjective findings of pain and function. There were forty points allotted for the pain response and thirty points allocated for the functional category. The final thirty points were used to evaluate the objective physical findings. The total possible points when the first and second sections were added was one hundred. Based on a total of one hundred possible points on the back analysis form, those patients with post-operative totals of eighty-five to one hundred were graded "excellent", seventy-one to eighty-four "good", sixty to seventy points was a "fair result", and less than sixty points was considered a "poor result". Using this points system Scafuri was able to conclude that patients evaluated pre-operatively by CT scan and myelography had a significantly higher subjective improvement than those patients evaluated by myelography alone.

THE EFFECTS OF QUESTIONNAIRE DESIGN

Studies which make use of subjective criteria for post-operative assessment, such as pain level and the patient's satisfaction with the result of surgery, report consistently better results than those studies using functional criteria such as return to work, return to previous employment, use of analgesics and spinal braces. To illustrate this, two hundred and seven patients were reviewed by Howe at least ten years after a single lumbar disc operation, using fourteen different questionnaires to measure surgical outcome (Howe 1985). The proportion of patients with a satisfactory outcome from surgery varied between ninety-seven per cent and sixty per cent, which is statistically significant. It is therefore theoretically possible to significantly manipulate the results of spinal surgery by careful selection of the criteria used for assessment.

METHODS USED IN THE ASSESSMENT OF PATIENTS
AT THE NUFFIELD ORTHOPAEDIC CENTRE FOLLOWING SURGERY

Seventy-two patients were re-assessed at regular intervals following spinal decompression for stenosis. The three basic categories examined were:

1. Symptoms
2. Functional disability
3. Physical signs.

These were also the major categories examined prior to surgery. The pre-operative assessment was repeated on two occasions, firstly within one month of surgery, and secondly at the final follow-up which varied from one year to ten years following surgery (mean three years two months for males and four years six months for females). In addition a postal questionnaire was sent to all surgical patients enquiring about patient satisfaction with surgery, residual pain and analgesic requirements, and the use of a spinal corset, and finally resumption of work or normal retirement activities. (Fig. 21: 1).

An identical assessment was made post-operatively to the pre-operative assessment such that it was reasonable to assume any differences were the result of surgery. Clearly the patient's mood at the time of re-examination might influence the result together with any tendency for the symptoms and signs to undergo spontaneous remission. However, these influences were considered to be minimal since only severely disabled individuals were offered surgery, following objective confirmation of organic disease. Similarly the patients were asked to assess their own functional disability as the basis of a six point grading system.

In an attempt to observe changes during the years following surgery, the assessment was repeated at the first, or most recent, follow-up. This was then compared with both the pre-operative and immediate post-operative assessment, and provided useful information about continuing recovery of nerve root function for one or two years following decompression in some patients. In some patients it was necessary to obtain this information from the Hospital Case Records only. The proforma used is shown in Figure 21:2 . No matter how complex and comprehensive the grading system, including ones which use points, they all rely upon subjective information to assess symptoms and functional impairment. It is extremely difficult to obtain objective information upon which grading can be based. Such information should include neurological deficit, time



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JN/MPD

10th October 1986

Dear

I am reviewing patients who have had spinal operations at the Nuffield Orthopaedic Centre, and would be very grateful if you could kindly read carefully the questions below and tick the appropriate box. Please then detach the completed questionnaire and return to me using the enclosed pre-paid envelope. Your reply will be treated in the strictest confidence and will provide important information for this review. There will be no further questionnaires sent or contact made if you kindly return the completed enclosed post card to me.

Thank you for your help, which will in turn help others. Your co-operation in this survey is greatly appreciated.

Yours sincerely,

John E. Nixon, M.A., F.R.C.S.
 Clinical Reader in Orthopaedic Surgery

Please cut along dotted line and return to me in the enclosed pre-paid envelope.

.....

1. If you are satisfied with the result of your operation, tick box 1. ☐
2. If you wear a corset, tick box 2. ☐
3. If you take pain killers for leg or back pain, tick box 3. ☐
4. If you have now returned to work or normal activities, tick box 4. ☐

Figure 21:1. The postal questionnaire used (reduced by thirty per cent), which combined subjective criteria (Question 1) with objective criteria (Questions 2, 3, and 4). Seventy-eight per cent of patients returned the completed questionnaire.

nCSFITAL NUMBER _____
 Occupation: _____
 Age at presentation: _____
 Precipitating factor: _____
 Duration of symptoms: _____

Classification

1. Congenital	Developmental	Idiopathic	Achondroplastic
2. Acquired	Degeneration	Central	Lateral
	Combined	Spondylolisthesis	Spondylolysis
		Congen + Develop	Degen + Disc
		Spondylolisthesis	Spondylolysis
		Iatrogenic	Post laminectomy
		Fusion	Chemoneurolysis
		Post traumatic	
	Miscellaneous	Paget's	Fluorosis

I. Presenting symptoms: 1,2,3 (importance)

1. Pain low back	R	C	L
Legs (above knees)	R	C	L
Legs (below knees)	R	C	L
2. Claudication at (yds/mis)	Sensory		
	Motor		
3. Numbness or paraesthesia in thigh, calf or foot	R	C	L
4. Weakness in legs	R	C	L
5. Bladder disturbance	Bladder		

Post Treatment

Cons	Surg
R	C
S	L
R	L
Sensory	
Motor	
R	L
S	L
Bladder	

Follow Up

--

II. Functional disability

Minimal or no discomfort on normal work or recreation.	
Normal work, reduced recreation, pain 1x or 2x/yr.	
Lighter work or past time. No recreation off work 2 or 3 x/yr.	
Out of work. No Recn. Independent.	
Inactive, and housebound. Dependent on others.	
Confined to bed thro' back or leg pain most days	

Presentation

--

After Treatment

--

III. Presenting signs: 1,2,3 (importance)

Spinal movements: Increased/Normal/Decreased

Spinal tenderness: L1/2/3/4/5/S1

Straight leg raising R

S S T + - R L

B. Motor weakness/wasting (MRC grade)

Hip	Knee	Ankle	Foot
R	R	R	R
L	L	L	L
Ext	Ext	Ext	Ext

Anal tone Normal Lax Right Left

Root values

R	L	1	2	3	4	5	S	1	2	3	4
Saddle											

C. Sensory Deficit:

R	L	1	2	3	4	5	S	1	2	3	4
Saddle											

D. Reflexes

(Absent A)	R	Knee	Ankle	Babinski
(Diminished D)	L	Knee	Ankle	Babinski

E. Exercised Induced Signs:

R	Knee	Ankle	Babinski
L	Knee	Ankle	Babinski

Figure 21:2. The proforma used for documentation of the pre-operative and post-operative symptoms, signs and functional disability.

off work, and the use of a corset or analgesia. An attempt has been made with the Oxford proforma to determine as many objective parameters as possible, and to grade these as simply as possible as described below.

When comparing the three assessments (pre-operative, within one month of surgery, and long-term follow-up) four gradings were used. The particular symptom, sign or functional disability had either:

- (a) Returned to normal
- (b) Improved but with some residual pain, weakness, etc.
- (c) No change, or
- (d) Deteriorated.

These results were then compared with a number of factors including the duration of symptoms pre-operatively, the type of surgery performed, the age and sex of the patient, and the type of stenosis present.

THE RESULTS OF OPERATIVE TREATMENT OF DEGENERATIVE LUMBAR SPINAL STENOSIS

Surin reported the results of decompressive laminectomy in twenty-two patients with degenerative lumbar spinal stenosis (Surin 1982). The average follow-up was thirty-nine months (range fourteen to seventy months). Twelve of the fifteen patients with marked stenosis (a minimal antero-posterior diameter of the spinal canal in extension of 10 mm. or less), and all seven patients with moderate stenosis (a minimum antero-posterior diameter between 11 mm. and 14 mm.) obtained relief from leg pain. All measurements of the size of the lumbar spinal canal were made from myelograms performed with the patient in the upright position with hyperextended lumbar spine. These patients initially answered a detailed questionnaire, and then were reviewed for examination of the circulation in the lower extremities, flexion/extension views of the lumbar spine, and a neurological examination.

The relationship between the severity of myelographically demonstrated stenosis and the operative results was studied by Paine (Paine 1976a), and Verbiest (Verbiest 1977). In Paine's series the best results were achieved in patients with relatively large spinal canals (antero-posterior diameter on myelogram between 11 mm. and 14 mm.). Verbiest found no major difference between patients with severe stenosis (absolute antero-posterior diameter less than 10 mm.), and patients with moderate stenosis (diameter 10-12 mm.). In Sortland's series only patients with marked stenosis (antero-posterior diameter on myelogram of 10 mm. or less) were

operated on (Sortland 1977). For moderate stenosis (antero-posterior diameter 11-14 mm.) conservative treatment was reported to be sufficient in all cases.

Of the ninety-five patients reported by Paine with a follow-up of more than one year following decompression for degenerative spinal stenosis, successful results were obtained in eighty per cent, fair results in eleven per cent, and poor results in only eight per cent of patients.

RESULTS OF SPINAL DECOMPRESSION FOR DEGENERATIVE STENOSIS AT THE NUFFIELD ORTHOPAEDIC CENTRE

(i) Classification

Seventy-two patients with spinal stenosis were treated surgically. Seventy-two per cent of the forty seven males and eighty-five per cent of the twenty-five females had degenerative stenosis. The commonest type in the male (twenty-three per cent) was combined disc and degenerative disease, and the commonest type in the female (forty per cent) was degenerative spondylolisthesis (Table 21:1).

	MALES (N=47)	FEMALES (N=25)
Central	15	5
Central and lateral	18	15
Lateral	8	10
Degenerative and disc	23	15
Spondylolisthotic	8	40

Table 21:1. The frequency of the different types of degenerative stenosis in the male and female groups expressed as a percentage of each surgical/sex group.

(ii) Follow-up

Patients were assessed as described above in the initial post-operative period (within one month of surgery) and then at long-term follow-up which was a mean of three years two months for the males and four years six months for the females (Table 21:2).

MALES	3 years 2 months	(13 months - 9 years)
FEMALES	4 years 6 months	(14 months - 10 years)

Table 21:2. Mean follow-up after surgery with the range enclosed in brackets for the male and female surgical groups.

(iii) Number of Level Decompressed

The levels decompressed are shown in Table 21:3 which illustrates that the majority of decompressions (over sixty per cent) included the combined fourth and fifth lumbar levels.

LEVELS DECOMPRESSED	MALE	FEMALE
L 2/3	5	0
L 2/3/4	2	0
L 3/4	5	7
L 3/4/5	22	14
L 4	16	7
L 4/5	34	57
L 5	16	14

Table 21:3. Frequency of levels decompressed expressed as a percentage of each sex group.

Spinal decompression was confined to the region most involved, and no patient has had more than three levels decompressed. It has been stated that the more levels decompressed the less satisfactory the result, but this was not confirmed in this series (Table 21:4).

NUMBER OF LEVELS DECOMPRESSED	SYMPTOMATIC RESPONSE		
	IMPROVED	NO CHANGE	DETERIORATED
1	28	1	2
2	40	7	1
3	19	2	0

Table 21:4. The symptomatic response to surgical decompression compared with the number of levels decompressed.

It is not apparent from Table 21:4 that factors other than the number of levels were involved in the symptomatic response. These included the presence of arachnoiditis, previous surgery, psychosocial difficulties and litigation. These other factors were found in all patients who failed to improve following decompression, and will be discussed in some detail later.

(iv) Duration of Symptoms

Similarly there was no correlation between the duration of symptoms pre-operatively and the success or otherwise of surgery. It might be supposed, and is in fact reported in the literature, that the longer the duration of symptoms of neurogenic claudication or sciatica, the worse the result of surgery because of more severe nerve root damage.

The opposite was noted in this series with patients whose symptoms had been present for ten years, twelve years, seventeen years, and in two patients for thirty years all achieving excellent symptomatic relief of leg pain following decompression. It may be that these patients were of a more stoical disposition and therefore could be expected to progress well following surgery, or had reduced expectations from surgery.

Conversely, some patients who had poor results following surgery had only a short history, but on closer inspection in each patient there were other more important reasons for failure of surgery as described above.

These results indicate that the duration of the history does not influence the outcome from surgery. There is no reason why one patient with a long history of slowly progressive stenosis should have a worse outcome following surgery than another patient with an acute onset of severe symptoms and signs. Clearly, however, the one condition which does demand urgent decompression is the cauda equina syndrome.

(v) Sciatic Pain

All patients operated upon had severe and unremitting sciatic pain which was unresponsive to conservative treatment. This was their main complaint and if they had predominantly back pain rather than sciatic pain they were unlikely to enter the surgical group. It was not possible to measure objectively the severity of leg pain, but each patient was asked within one month of surgery if the leg pain had resolved completely, was improved, was unchanged, or had increased. This was considered to indicate whether

surgery had been appropriate and correctly performed and possibly whether further nerve root damage had occurred at the time of surgery, or the major cause of stenosis inadequately decompressed. The results are shown in Table 21:5.

	INITIAL ASSESSMENT (1 month post-op.)	LONG-TERM ASSESSMENT (13m-10yrs. post-op.)
Total Relief of Sciatic Pain	22	44
Partial Relief of Sciatic Pain	61	39
No Change in Sciatic Pain	15	12
Increased Sciatic Pain	2	5

Table 21:5. The results of surgery on sciatic pain at both the initial and final assessment expressed as a percentage of each assessment group.

Eighty-three per cent of patients reported improvement or relief of leg pain within one month of surgery. Seventeen per cent of patients noted no difference or reported deterioration. On careful review of the patients who reported deterioration, it was always possible to identify a cause, despite apparently adequate and appropriate surgery. The reasons identified for failure of surgery were:

- (a) Psychosocial
- (b) Arachnoiditis
- (c) Litigation
- (d) Multiple operations.

Factors (a) and (c) would clearly influence the patient's response to enquiries about persistent leg pain post-operatively, and factors (b) and (d) would possibly indicate the presence of irrevocable nerve root damage. It is probable that myodil myelograms and previous surgical explorations are capable of inflicting a more lasting insult on the nerve root than the condition of spinal stenosis persisting for many years.

At the final assessment eighty-three per cent of patients still reported total relief or improvement of sciatic pain, but the proportion reporting increased sciatic pain had increased. It must be appreciated however that the above figures hide an ongoing flux of patients, and this is indicated on Table 21:6.

Gradual Improvement in Sciatic Pain	39
No change in Sciatic Pain	42
Gradual Deterioration of Sciatic Pain	19

Table 21:6. Comparison of the initial response of sciatic pain to surgical decompression with the final result expressed as a percentage of the whole group.

Table 21:6 indicates that although forty-two per cent of patients remained stable following decompression, thirty-nine per cent experienced less leg pain, whilst nineteen per cent began to experience more leg pain with the passage of time. Most change with time occurred in the top two groups, such that patients who had no pain during the first month following surgery began to experience leg pain as they became more active. Conversely some patients whose leg pain was reduced, but not resolved completely, following surgery noticed a steady improvement with time, such that at final review their leg pain had completely resolved. This suggests that some degree of nerve root recovery may be possible following decompression. This important flux of patient's symptoms is not apparent when viewing Table 21:5 in isolation from Table 21:6.

(vi) Low Back Pain

Patients were asked about the effect of surgery on back pain at the initial and then final assessment. Once the patient had recovered from the initial discomfort of surgery they were usually able to compare their degree of post-operative back pain with their pre-operative pain. Within one month of surgery, sixty-nine per cent of patients stated that their back pain had either improved or completely resolved (Table 21:7).

	INITIAL ASSESSMENT (1m. post-op.)	LONG-TERM ASSESSMENT (13m.-10yrs. post-op.)
Back Pain Resolved	13	25
Back Pain Reduced	56	37
No Change in Back Pain	26	32
Back Pain Increased	5	5

Table 21:7. The effect of surgery on low back pain assessed on the two occasions described.

At the long-term follow-up assessment, seventy-two per cent of patients stated their back pain was either reduced compared with the pre-operative level or had largely resolved. Clearly at a ten year follow-up it is difficult for a patient to recall the severity of pain pre-operatively. However this does represent a useful monitor of the patients general state of well-being.

There was however during this follow-up period a drift upwards of some patients and a downward drift of others. Roughly half of the patients remained stable whilst twenty-five per cent improved with time, but twenty-five per cent deteriorated. With advancing age, further degenerative disease develops within the lumbar spine, sufficient to account for this twenty-five per cent deterioration (Table 21:8).

Gradual Improvement in Low Back Pain	21
No Change in Low Back Pain	53
Gradual Deterioration of Low Back Pain	26

Table 21:8. Comparison of low back pain experienced within one month of surgery with back pain experienced at long-term follow-up, expressed as a percentage of the entire surgical group.

(vii) Motor Power

Objective neurological findings, such as weakness of extensor hallucis longus, were looked for very carefully in all patients with spinal stenosis. The finding of motor weakness would often be sufficient to move the patient from the conservative group to the surgical group if sufficiently disabled by pain. Patients in the surgical group therefore frequently had motor weakness pre-operatively, and this was assessed post-operatively. Other patients complained of weakness in the legs on walking or simply standing despite the fact that no objective motor weakness could be identified on examination.

Patients who reported subjectively less weakness post-operatively were also found to have recovered power in the lower limbs on objective examination. The following results are a composite of both subjective and objective assessment of muscle power post-operatively (Table 21:9).

	MALE (N=47)	FEMALE (N=25)
Motor Power Returned to "Normal"	13	8
Motor Power Stronger	60	50
No Change in Motor Power	7	8
Reduced Motor Power Post-operatively	13	17
No Pre-operative Weakness	7	17

Table 21:9. The effect of surgery on motor weakness in the lower limbs assessed at the long-term follow-up and expressed as a percentage of each sex group.

It should be noted that about fifteen per cent of patients were either subjectively or objectively weaker post-operatively, and it may be that the patient should be advised of this possibility pre-operatively. The majority of patients (approximately sixty-five per cent) felt stronger in the legs and in forty per cent of males and forty-four per cent of the female there was clear evidence of improved motor power in the lower limbs on examination.

(viii) Sensation

Sensation was assessed post-operatively in a similar way to motor power. That is, the patient was asked if he or she noted any change in sensation in the legs post-operatively, providing a subjective response, and then sensation in the lower limbs was formally tested to provide a reasonably objective response. The two correlated closely and the composite response is shown in Table 21:10.

	MALE (N=47)	FEMALE (N=25)
Sensation returned to normal	35	40
Sensation improved	23	10
No change in sensation	18	10
Sensation diminished	18	20
Normal sensation pre-operatively	6	20

Table 21:10. The effect of spinal decompression on lower limb sensation expressed as a percentage of each sex group.

When examining purely objective criteria such as pin-prick testing of the lower limbs, only thirty-five per cent of males and thirty per cent of females had evidence of sensory impairment post-operatively when compared with the pre-operative sensory deficit. Again, some patients recovered from surgery to discover they had an increased sensory deficit, and this may be the result of intra-operative nerve root damage. Less active patients tended to be more aware of sensory impairment than motor impairment. This may of course influence the observation that a greater proportion of patients claimed that sensation had returned to normal post-operatively than claimed motor power had returned to normal. An alternative explanation would be that motor end plate degeneration occurs in chronic denervation, so if and when nerve recovery does occur there is no possibility of recovery of normal motor function.

(ix) Reflex Changes

The knee reflex was absent in some patients, but this often failed to correlate with the myelogram and CT findings and so was not taken to be of prognostic significance. Changes in the ankle reflex were considered to be a much more reliable indicator of nerve root dysfunction, but again it must be noted that the loss of one or both ankle reflexes in an elderly person is not always of clinical significance.

Although one might suspect initially that the ankle reflex is the most objective parameter of nerve root function which can be easily tested by the clinician, it is surprising how often the ankle reflex varies in the same patient when examined on different occasions. Some patients appear to have stable ankle reflexes which change little from one occasion to the next, but other patients seem to have labile responses. The ankle reflexes therefore were examined on a number of occasions both pre- and post-operatively before the changes observed in Table 21:11 were recorded.

Fifty-seven per cent of males and fifty per cent of females had either diminished or absent ankle reflexes prior to surgery. Fifty per cent of females had normal ankle reflexes before and after surgery, whilst only thirty-eight per cent of males had normal reflexes both before and after spinal decompression.

	UNILATERAL	BILATERAL
IMPROVED		
Absent to Diminished	0	2
Diminished to Normal	7	3
Absent to Normal	12	8
NO CHANGE		
Absent to Absent	4	3
Diminished to Diminished	3	0
Normal to Normal	0	45
DETERIORATION		
Diminished to Absent	8	0
Normal to Diminished	0	0
Normal to Absent	5	0

Table 21:11. Changes recorded in the ankle reflex following spinal decompression as a percentage of all patients in the surgical group.

The details of Table 21:11 can be summarised to form Table 21:12 which indicates overall changes in the ankle reflex comparing the result at long-term follow-up with the pre-operative observation.

	TOTAL GROUP (N=72)	EXCLUDING NORMALS (N=40)
Improvement in Ankle Reflex	32	58
No Change in Ankle Reflex	55	18
Deterioration of Ankle Reflex	13	24

Table 21:12. Changes in ankle reflex following spinal decompression expressed as a percentage of the entire surgical group (seventy-two), and therefore including forty-five per cent of patients who had normal ankle reflexes pre- and post-operatively. When this group of normals is excluded it can be seen that of the remaining forty patients, fifty-eight per cent were noted to have improved ankle reflexes post-operatively, whilst in twenty-four per cent there was loss of an ankle reflex unilaterally.

It was found that fifty-eight per cent of patients with a diminished or absent ankle reflex pre-operatively would recover some reflex activity post-operatively, and in a large proportion (over fifty per cent) the ankle reflex or reflexes would return to normal. This was considered to indicate that

the nerve root retains some potential for recovery despite severe stenosis. It is considered that electrophysiological studies would be required to demonstrate conclusively nerve root recovery following decompression, but in this series the number of such studies was too small to be of significance.

(x) Spinal Mobility

Spinal mobility was judged purely on clinical grounds and flexion/extension radiographs were not routinely performed. The Schroeber index was found to be useful when doubt existed on pure inspection. Spinal mobility in this series refers principally to spinal flexion. It is well recognised, and confirmed in this series, that spinal extension is almost invariably restricted in spinal stenosis. It is less often appreciated that lateral flexion to the side of the symptoms is frequently restricted in patients with lateral recess and nerve root canal stenosis. Similarly axial rotation of the spine is commonly accompanied by pain at the extremes of motion most likely because this is the movement which loads maximally the degenerate facet joints on firstly one side, then the other side.

The increased spinal mobility reported in some series was not observed, and conversely seventy-four per cent of patients had restricted, often painful, spinal movements. Pain was usually experienced in the back, but spinal extension sometimes caused pain to shoot down the legs in a sciatic nerve distribution. In the males with combined stenosis due to degenerative and disc disease, forward flexion was markedly restricted as seen in patients with disc prolapse. The change in spinal mobility following surgery is shown in Table 21:13.

Restricted to Normal	19
Restricted to Restricted	43
Normal to Normal	16
Normal to Restricted	22

Table 21:13. The effect of surgery of spinal mobility expressed as a percentage of the total surgical group.

It can be seen from Table 21:13 that the majority of patients had stiff spines before surgery and stiff spines after surgery (forty-three per cent),

whilst twenty-two per cent had stiff spines after surgery only. In total sixty-five per cent of patients had restricted spinal motion following surgery and in thirty-five per cent of patients spinal motion was reported as normal. In general patients tended to be more stiff following surgery than before. However many patients had worn corsets for many months prior to surgery and some also used corsets post-operatively.

(xi) Results of Surgery: Functional Disability

The functional grading system used six levels of disability which indicated time off work, change of job, loss of job, loss of recreational activities, dependence on others, and whether the individual was housebound as a result of spinal stenosis. The details of this system are shown in Figure 21:2.

The majority of patients treated surgically were in one functional disability group lower than those treated conservatively. Forty-six per cent of the conservatively treated patients belonged to group 3, whilst forty-eight per cent of the surgically treated group belonged initially to group 4. The main difference between group 3 and group 4 was whether or not the individual could manage a regular job, even a light job. Patients in category 3 were in work but did have to take time off two or three times a year through their leg and back pain, whilst patients in category 4 were out of a job, through spinal stenosis, but yet maintained their independence.

The majority of patients improved by one or two functional disability grades following treatment as shown in Table 21:14: but most important of all, eighty per cent of patients in group 4 were able to return to some form of gainful employment or recreational activities if retired following spinal decompression. Recreational activities included golf, gentle gardening, country walks, and playing with grandchildren.

Severity of Pre-operative Functional Disability	6			2	2						
	5		5	5	2		1				
	4	4	16	5		3	1				
	3	10	4		2	1					
	2	7									
	1										
		1	2	3	4	5	6				
		Severity of Post-operative Functional Disability									

Table 21:14. The change in functional disability grading after surgery. The ordinate is pre-operative disability and the abscissa post-operative disability. Patients on the stippled squares showed no change following surgery whilst those below and to the right deteriorated. Patients above and to the left of the stippled squares (eighty-eight per cent of patients) reported functional improvement following surgery.

Forty-five per cent of patients improved by two functional grades, twenty-five per cent improved by one functional grade, and fifteen per cent of patients improved by three functional grades. Only thirty per cent of patients returned to full and normal employment with normal recreational activities totally unimpeded by occasional recurrence of sciatic or back pain, and no patient below functional disability grade 4 achieved this result. The more disabled a person is pre-operatively the less likely they are to resume a full and normal life post-operatively, but the large majority of patients were satisfied with the progress made following surgery.

(xii) Results of Surgery: Patient Satisfaction

All patients were asked by means of a postal questionnaire (Fig. 21:1) whether or not they were satisfied overall with the long-term results of surgery. Seventy-two questionnaires were despatched and fifty-eight were returned. Seventy-five per cent of females replied and eighty-five per cent of males replied. The results indicated that sixty-five per cent of females were satisfied and eighty-five per cent of males were satisfied. The case records of the six dissatisfied females and the five dissatisfied males

were reviewed. In each case there was an obvious reason for dissatisfaction. These are indicated in Table 21:15.

Multiple Spinal Operations	4
Psychosocial including Depression	3
Arachnoiditis	2
Lost Job	1
Litigation: Case Pending	1

Table 21:15. Reasons for patient dissatisfaction with results of surgical decompression. Patients with arachnoiditis or following multiple spinal operations had residual numbness or weakness and functional disability. Patients with psychosocial disorders or litigation pending had persistent incapacitating pain and functional disability.

It is clear from this analysis that careful patient selection is essential if satisfactory results are to be achieved. Numerous studies have indicated, and this series confirms, that operating on patients who have had numerous previous operations, or who have psychosocial difficulties, or who have arachnoiditis or with litigation pending should not be recommended. There are some circumstances in which surgery may result in some improvement for patients with arachnoiditis, but these are uncommon and will be considered in detail in Chapter 22.

(xiii) Results of Surgery: Post-operative Reliance on Corset

Many patients become accustomed to and dependent upon a corset pre-operatively and continue this habit post-operatively. Other patients use a corset following spinal decompression to help relieve persistent backache when the symptoms of neurogenic claudication have been relieved. Patients may use a corset only intermittently post-operatively when they know the back will be under additional stress, for instance at work, to maintain the garden, or for a round of golf.

Post-operatively forty per cent of females and fifty per cent of males used a corset either regularly or intermittently. In an elderly population this practice was not actively discouraged since it often gave the patient confidence to continue their everyday activities. In the younger patients persistent use of the corset was discouraged and the patients advised to lose weight and build up abdominal and paraspinal musculature by isometric exercises.

(xiv) Results of Surgery: Analgesic Requirements

Despite the observation that non-steroidal anti-inflammatory drugs had little influence on the symptoms of spinal stenosis pre-operatively (Chapter 19), the majority of patients persisted in taking analgesic medication post-operatively. This was usually for backache, but it is surprising how many elderly patients, particularly females, become accustomed to taking regular analgesic medication rather like drinking cups of tea.

Seventy per cent of females and fifty-five per cent of males continued to take analgesic medication regularly post-operatively for leg or back pain. It is difficult to ascertain whether or not the patients needed this post-operatively or whether they swallowed the tablets from force of habit, or simply in the hope of avoiding a recurrence of pain.

(xv) The Results of Surgical Intervention in the Elderly

With improved life expectancy it is probable that previously uncommon syndromes afflicting an older population have become more prevalent, and lumbar spinal stenosis is one of those now frequently encountered in orthopaedic practice.

Once the syndrome is well established, conservative management rarely improves the quality of life, offering at best symptomatic relief. Improving the quality of life is a paramount consideration for aged stenotics: as many of these patients live alone and fare for themselves, severe walking claudication and pain in the prone position can make life intolerable. Hood reported that twenty out of twenty-one patients aged fifty to seventy-five had subjective pain relief following spinal decompression as well as functional improvement, indicating that decompressive laminectomy offers an improved quality of life to the older person using a relatively safe, simple procedure which has few post-operative complications (Hood 1983). Wide decompressive laminectomy is a safe and effective surgical procedure, offering the otherwise severely incapacitated older patient an improved quality of life and reduced morbidity.

Fast noted that the symptoms of lumbar spinal stenosis usually do not improve with time. Despite the advanced age of some patients, surgical decompression may offer significant relief. Of nineteen elderly patients who underwent lumbar decompressive laminectomy, eighteen showed sufficient improvement to return to normal daily activities (Fast 1985).

Lassale reported the long-term results of surgery for lumbar stenosis (Lassale 1985). Among one hundred and sixty-three patients who underwent surgery for degenerative lumbar stenosis, seventy-nine per cent were re-examined and evaluated retrospectively (two to fourteen years following surgery), using a functional grading scale. The grading scale (up to twenty) assessed limping, radicular pain at rest and with effort, back pain, motor deficits, sphincter dysfunction, medication requirements, and quality of life. Satisfactory results were obtained in eighty-three per cent with eighty-seven per cent reporting substantial functional improvement. Limping and radicular pain at rest responded most rapidly to surgical intervention. Subsequent disappearance of residual radicular pain occurred in thirteen per cent whether present at rest or with effort. Episodic radicular pain with effort persisted however, in approximately one-quarter of all patients, generally in those with more pronounced pain before surgery. One out of four patients had complete relief of back pain and most often without performing a spinal fusion. Major neurological deficits resolved extremely slowly but completely in six out of ten patients. On the grading scale of twenty, four recovery profiles could be identified, a perfectly stable result (sixty per cent), regular improvement (fourteen per cent), improvement with episodic aggravation of symptoms (nineteen per cent), and subsequent worsening (eight per cent). Overall, a second surgical intervention had to be performed in five per cent of patients with complete bony excision and arthrodesis (for vertebral slippage or for back pain).

Other series report questionable results, for instance in one series all patients who were operated upon were

"entirely relieved of intermittent dysaesthesiae and pain; and all returned to work, including two labourers and a farm hand" (Blau 1961)!

In the Oxford series, age did not influence the result of decompression. Elderly patients who were fit enough to be treated surgically were particularly grateful for the relief obtained from decompression which often enabled them to retain their independence and dignity.

FACTOR ASSOCIATED WITH A FAVOURABLE RESULT FOLLOWING SURGERY

The size of the stenotic spinal canal has been related to the results of decompressive surgery by three authors (Paine 1976a; Verbiest 1977; and Sortland 1977). Unfortunately the authors all used quite different

methods of measurement to establish the size of the stenotic canal. Paine reported the best results in patients with large canals, whilst Verbiest found no difference in the results between severe and moderate stenosis. Sortland on the other hand only operated on patients with severe stenosis (antero-posterior distance on myelograms of 10 mm. or less). Paine reported satisfactory results in eighty-five per cent of patients with involvement of only one or two levels.

Getty noted that it was important to advise patients before operation, that they are likely to have some pain afterwards. He found that patients who are thus prepared psychologically do have a much more balanced approach to their situation post-operatively (Getty 1980). Scafuri found that patients who were evaluated pre-operatively by CT scan and myelography had a significantly higher subjective improvement than those patients evaluated by myelography alone (Scafuri 1981).

Froning examined motion of the lumbo-sacral spine following laminectomy, and in some patients spinal fusion (Froning 1968). He found that in those patients where movement was restricted at the level of laminectomy (possibly indicating a more advanced degree of degeneration) and where motion at the levels adjacent was increased, the result was better initially. In the long-term however the increased mobility adjacent to the stiff segment accelerated degenerative change giving rise to increased back pain in the long-term.

FACTORS ASSOCIATED WITH A POOR RESULT FOLLOWING SURGERY

Paine reported that when three or more levels were involved by degenerative spinal stenosis, that only sixty per cent of patients had a satisfactory result following decompression (compared with eighty-five per cent with one or two level involvement) (Paine 1976a). In these patients, extensive degenerative disease limited their activities. Surin agreed with these findings and reported that patients with more severe and more widespread stenosis tended to have poorer results (Surin 1982). In his series twenty per cent of patients with a spinal canal diameter of 10 mm. or less had fair and poor results, whereas no such results were found in patients with a spinal canal diameter of 11mm. to 14 mm. Patients with stenosis at three or more levels had thirty-three per cent (two out of six) fair and poor results, whereas patients with more localised forms of stenosis had only seven per cent (one out of fifteen) fair and poor results.

In Paine's series, eighty per cent of patients with degenerative and developmental spinal stenosis continued to suffer persisting back pain following decompression. This compared with seventy-four per cent following removal of a herniated nucleus pulposus. Paine also found no great difference in the results whether one or two or more levels were involved by degenerative stenosis, and found that seventy per cent of forty-seven patients achieved a satisfactory result following decompression at an average of three and a half years and a mean of two and a half years following surgery. Froning found that persistence of mobility following laminectomy, when compared with that expected in the normal individual, was usually found in patients judged to have a poor result (Froning 1968). This was based on flexion/extension radiographs in fifty-two patients following laminectomy.

Getty characterised poor results as persistent low back pain, sciatica usually with a sensory or motor deficit or both in the L4 and S1 root distribution, and by persistent claudication (Getty 1980). There was little or no relief of symptoms in the convalescent period or subsequently. He correlated this with inadequate decompression, the presence of very marked degenerative change, and inadequate lateral decompression at the initial procedure. Patients with a poor result had not been prepared psychologically before surgery for the presence of some post-operative pain.

PROGNOSTIC CRITERIA IN THE NUFFIELD ORTHOPAEDIC CENTRE SERIES

Numerous conflicting prognostic criteria appear in the literature and text books. This is hardly surprising because of different population groups in different areas, the lack of standard criteria for the selection of patients for surgery, and assessment of results. Also until recently some confusion has persisted in the terminology used in spinal stenosis. Careful patient selection is one of the most important factors in determining surgical outcome.

Three groups of patients were selected from the seventy-two reported in the Oxford series. The criteria for selection were simple:

- Group A. Twenty-five patients who had no claudication pain and no neurological deficit following surgical decompression.
- Group B. Ten patients who had no back pain, or only very minor discomfort following decompression.

Group C. Fifteen patients whose back pain and leg pain was no better and sometimes worse following decompression. Back pain and claudication pain persisted in the same patients, and it was not possible to divide Group C into two sub-groups.

It was considered that by selecting these three groups of patients who were at the extreme ends of the spectrum of response to surgery, and by comparing one group with another and secondly with the entire surgical group, it might be possible to identify certain factors which would indicate pre-operatively a good or poor prognosis following surgery.

The following factors were examined: age, occupation, type of stenosis, delay in presentation, and operative details such as levels involved and the extent of decompression. The results of this analysis will now be discussed.

(a) Age at Presentation

The ages of patients at presentation are shown in Table 21:16.

	GROUP A	GROUP B	GROUP C
MALES	57 (39-83)	54 (39-66)	53 (29-68)
FEMALES	47 (12-71)	55 (12-71)	53 (43-70)

Table 21:16. The ages of patients given as means and range, for the three selected groups.

No difference was observed between groups and between any particular group and the total unselected surgical group. Each group contained patients across a broad age group.

(b) Occupation

It was noted in Chapter 10 that patients treated surgically for spinal stenosis occupied predominantly the sedentary occupational groups (Fig. 10: 4 and 10: 5). This was true also for patients in the three selected groups (Table 21:17).

OCCUPATIONAL GRADE	GROUP A	GROUP B	GROUP C
1	34	25	30
2	14	25	10
3	19	25	40 *
4	14	12	10
RETIRED	19	25	10 *

Table 21:17. Occupational grading (see Fig. 10: 4 for details) of patients in the selected group, expressed as a percentage of each group.

The only marginal difference between groups is that fewer patients in group C had retired and more were involved in heavier occupations which involved lifting. It will be seen also from the next paragraph that there was a high incidence of combined disc/degenerate stenosis in group C.

(c) Type of Stenosis

Classification of patients in each selected group resulted in Table 21:18.

TYPE OF STENOSIS	GROUP A	GROUP B	GROUP C
Congenital + Developmental	7	8	5
Degenerative: Central	23 *	8	10
Central + Lateral	23	23	5 *
Lateral	7	15	5
Combined Degenerative + Disc	20	15	40 *
Degenerative Spondylolisthesis	13	23	10
Post-laminectomy	7	8	25 *

Table 21:18. Classification of spinal stenosis patients in each selected group expressed as a percentage of each group.

It is immediately apparent that group C (poor result) contains a very high proportion of patients who have had previous surgery (sometimes numerous operations), and a high proportion of patients with combined degenerative and disc stenosis. At the same time there are disproportionately few patients in group C with central and lateral stenosis which raises the

possibilities that either patients in group C belong to a different population type or that the diagnosis was not fully appreciated prior to surgery.

(d) Delay in Presentation

The delay in presentation was found to be no different between any of the selected groups and the entire group (Chapter 10) or between the selected groups themselves (Table 21:19).

	GROUP A	GROUP B	GROUP C
DELAY IN PRESENTATION (YEARS)	5.4 (0.3-17)	4.5 (0.4-12)	5.5 (0.2-15)

Table 21:19. Mean delay in presentation in years together with range for each of the selected groups.

The range of this delay was enormous in all groups and no significant differences were identified.

(e) Operative Details: Longitudinal

Two factors were examined; firstly the number of levels decompressed, and secondly the actual levels involved. Table 21:20 gives the results for the number of levels decompressed.

NUMBER OF LEVELS DECOMPRESSED	GROUP A	GROUP B	GROUP C
1	21	20	19
2	58	50	62
3	21	30	19

Table 21:20. The number of levels decompressed expressed as a percentage of each selected group.

A two-level laminectomy and decompression was most frequently performed in all groups, and this was most commonly the L4-5 levels (Table 21:21).

LEVELS DECOMPRESSED	GROUP A	GROUP B	GROUP C
LUMBAR 1	0	0	0
LUMBAR 2	0	5	3
LUMBAR 3	6	0	20 *
LUMBAR 4	45	42	39
LUMBAR 5	41	37	35
SACRAL 1	8	16	3

Table 21:21. Frequency of decompression of lumbar and sacral levels indicated and expressed as a percentage of each group.

There is little difference between the numbers of levels decompressed, but when examining which levels were decompressed it is clear that patients with a poor result (group C) had a higher level of decompression (lumbar 3) more frequently. This figure may be influenced by the larger number of repeat operations in group C and the surgeon's attempt to "get above" the lesion before decompressing it.

(f) Operative Details: Transverse

The CT scanner was introduced to Oxford during the ten years of this review. Its introduction has clearly influenced surgical management, and it must be remembered that many of the patients reported were treated before the CT scanner arrived. This section examines the extent of decompression in the transverse or "horizontal" plane and compares the three groups. The results are displayed in Table 21:22.

SURGICAL PROCEDURE IN ADDITION TO LAMINECTOMY	GROUP A	GROUP B	GROUP C
Partial Facetectomy	24	40	11 *
Total Facetectomy	8	0 *	11
Foramenotomy	52	30	0 *
Discectomy	32	30	67 *
Spinal Fusion	8	20 *	11

Table 21:22. Details of the surgical procedure performed in addition to laminectomy in each group expressed as a percentage of all procedures in each group.

(i) Firstly it was postulated that the state of the nerve root on inspection (whether swollen, injected and irritable, or small white and fibrotic or irritable) would influence the outcome of surgery, since the objective of surgery is to decompress the nerve root without de-stabilising the spine. This, however, was not confirmed by this study, and it appears that nerve roots in all the above conditions have the potential for recovery and the potential for infarction.

(ii) Secondly it was postulated that if the dural sac expanded and pulsated at the end of spinal decompression then the result of surgery would be favourable, since it indicated full and complete decompression. If, on the other hand, the dural sac was thickened and scarred and retained its hour-glass constriction post-operatively, then the result of surgery would be unfavourable since despite bony and ligamentous decompression, the dural sac would still constrict the cauda equina and nerve roots. This assumption was also found to be incorrect. The condition of the dura, and the presence of dural expansion and pulsation at the end of surgery did not appear to influence the outcome of surgery provided, of course, that arachnoiditis had not been diagnosed pre-operatively.

(iii) Thirdly an operative dural tear with leakage of cerebrospinal fluid was found to be associated with a poor prognosis. The dural tear itself if adequately treated, the patient given antibiotics and if no traumatic meningocoele develops is without consequence. It does appear however, that a dural tear indicated a difficult surgical decompression usually with abundant adhesions and possibly previous surgery (Table 21:23).

	GROUP A	GROUP B	GROUP C
DURAL TEAR	0	0	20

Table 21:23. The incidence of dural tear at surgery as a percentage of patients in each group.

There were in the entire surgical group of seventy-two patients, seven dural tears, giving an overall incidence of ten per cent. There were however, no dural tears in either group A or group B, and when one takes out group C (poor response) from the whole group then only four tears occurred in fifty-six patients who responded well to surgery, an incidence of seven per cent. This is significantly different from the twenty per cent incidence in group C.

One observation is that no patient in group B (no back pain) had a total facetectomy. The most important observation, however, is that sixty-seven per cent of patients in group C (poor result) were treated by laminectomy and discectomy, with only eleven per cent having either a partial or a total facetectomy, or any attempt to decompress the lateral recess. No patient in group C was treated with foramenectomy. Spinal decompression in the majority of patients in group C was therefore inadequate, largely prior to the arrival of the CT scanner which provides considerably improved detailed analysis of the lateral recesses and nerve root canals. The proportion of patients in group C should therefore now decline.

(g) Operative Details: Operative Findings and Complications

Certain operative findings were common to most groups. These have already been described (Chapters 5 and 6), and include:

- (i) No extradural fat
- (ii) Non-pulsatile dura
- (iii) Scarred whitish dura
- (iv) Persistent hour-glass constriction of dura
- (v) Nerve root irritability
- (vi) Oedematous injected nerve roots
- (vii) Thinned whitish nerve roots
- (viii) Nerve root adhesions
- (ix) Fragments of old sequestered disc material
- (x) Bulging annulus fibrosus
- (xi) "Thickened" ligamentum flavum
- (xii) Thickening of lamina
- (xiii) Osteophytic ridges on bodies and facets
- (xiv) Mucoid cystic degenerate products from facet joints
- (xv) Subluxed facet joints
- (xvi) Increased intervertebral mobility.

An attempt was made initially to classify these observations, but it soon became apparent that any one or combination of the above factors could be present in each different type of stenosis and were therefore totally non-specific. The importance of listing the observations here is so that the surgeon will recognise each finding in turn. Three specific observations were, however, examined in some detail.

POST-OPERATIVE SPONDYLOLISTHESIS

Surin performed flexion/extension radiographs of the spine in all twenty patients following surgery (Surin 1982). They revealed that vertebral slip occurred post-operatively in four patients after decompression for degenerative lumbar spinal stenosis, in two out of the fifteen patients without and in two of the five patients with some degree of degenerative spondylolisthesis pre-operatively. The slip never exceeded 5 mm. He concluded that the tendency for vertebral slip following laminectomy is greater in patients with previous degenerative spondylolisthesis. There was no clear evidence that a post-operative slip caused more back symptoms. Tile reported forty-two patients with central and lateral degenerative stenosis (Tile 1976). Two patients in this group showed further slip following wide decompression, and five patients appeared to have instability in extension, but he did not define this. He also reported no cases of further slip in patients with root canal stenosis, who were treated by wide lateral decompression, but he does not describe in detail the extent of surgery (Fig. 21:3 to 21:7). There was again a tendency for further slip in patients with degenerative spondylolisthesis.

THE RESULTS OF DECOMPRESSION COMPARED WITH DECOMPRESSION AND FUSION

Tile reported little difference in the end result between laminectomy alone, and laminectomy and spinal fusion (Tile 1976). Surin did not perform vertebral fusion in any of the patients he decompressed for degenerative spinal stenosis (Surin 1982). He noted a minimal vertebral slip (2 mm. to 5 mm.) which occurred post-operatively in four out of twenty patients on flexion/extension radiographs of the spine, but this was not associated with a higher incidence of post-operative low back pain.

LONG-TERM RESULTS OF SPINAL DECOMPRESSION FOR SPINAL STENOSIS

Getty noted that symptomatic improvement following decompression was maintained in all but three patients for the whole of the follow-up period which extended as far as thirty years (Getty 1980). In these three patients pain in the leg recurred spontaneously at one, three and



Figure 21:3. Antero-posterior radiograph of a forty-five year old female (E.B.) complaining of severe back pain. Two years previously she had undergone L4-5 spinal decompression consisting of L4 laminectomy and removal of the L4-5 facet joints bilaterally. She had gained eighteen months relief of symptoms following this wide decompression.



Figure 21:4. Lateral radiograph of the same patient (E.B.) as Figure 21:3 showing post-operative spondylolisthesis present for eighteen months after removal of the facet joints of L4-5 bilaterally to achieve wide spinal decompression.

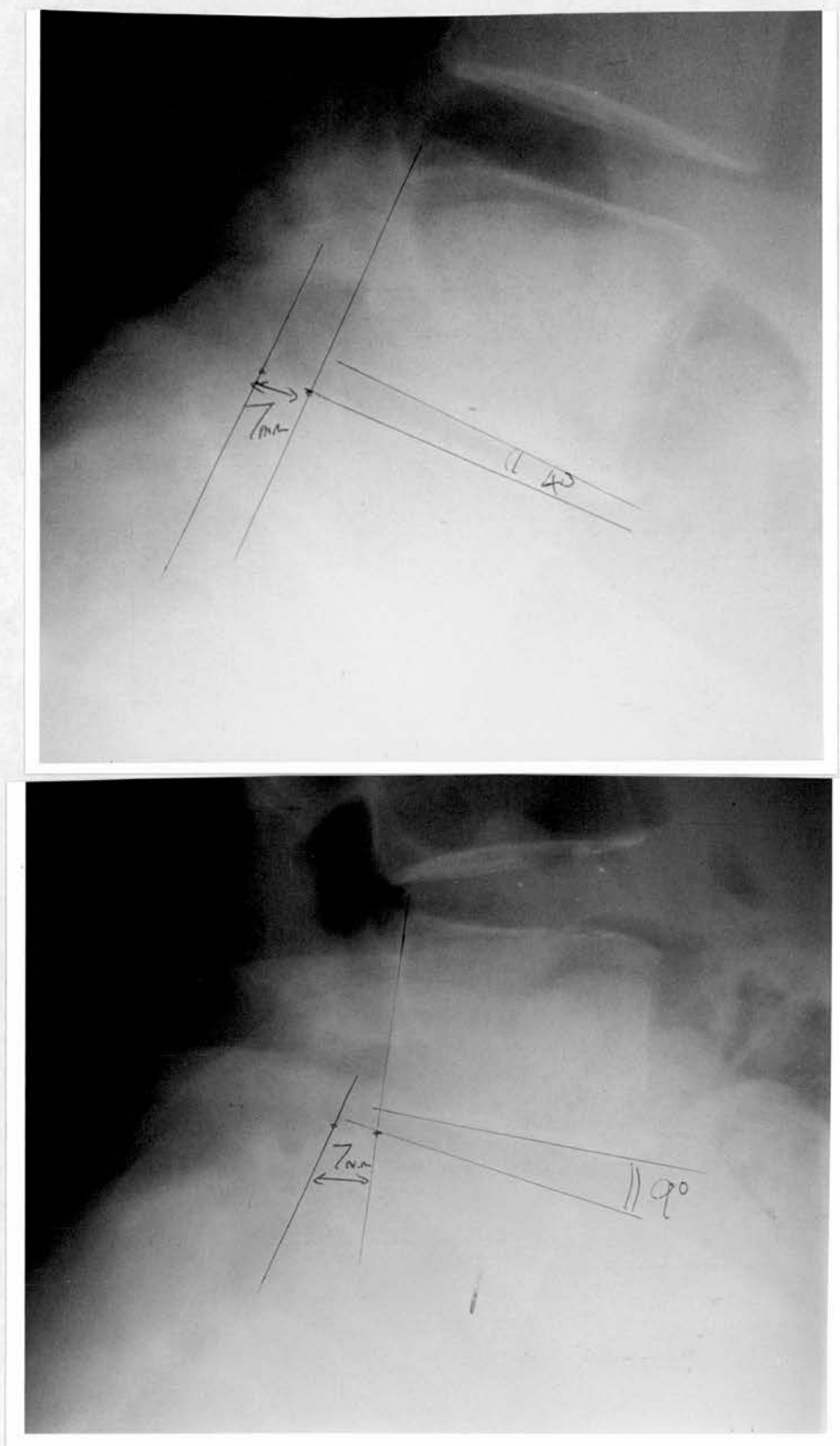


Figure 21:5. Same patient (E.B.) flexion and extension views showing 13° of intervertebral rotatory movement but no increase of translocation or spondylolisthesis. This is clear evidence of instability.



Figure 21:6. A radiculogram of patient E.B. showing increase in transverse diameter of dural sac following wide decompression. Two years after this decompression, the patient was unable to walk because of pain and numbness in the legs and back pain. She could obtain relief of leg symptoms only by lying still and obtained no relief from a plaster jacket or spinal brace. Traction helped to relieve the leg pain and numbness.



Figure 21:7. Patient E.B. underwent lateral mass inter-transverse floating fusion from L4 to L5 not including the sacrum. This completely relieved her leg and back symptoms and she returned to work as a matron of a boy's school six months following surgery.

eight years after treatment. He found no specific reason for these relapses, but their symptoms were at the time of reporting insufficient to warrant further investigation. Getty therefore concluded that in patients over the age of fifty who have degenerative changes causing lumbar spinal stenosis, there is a good prognosis in the long-term after adequate primary decompression, and it was his experience that a rapid resolution of pain in the leg following surgery indicates a good surgical result.

Nineteen patients were re-assessed by Surin during a follow-up period of up to seventy months. All had had initially substantial relief of pain. During the long-term follow-up, ten described sustained lasting relief of pre-operative pain, but six experienced a slight recurrence of painful symptoms (Surin 1982). Russin's reported long-term follow-up of over fifty-eight months attributed poor results in some patients to (a) psychosomatic reasons, (b) insurance and medico-legal problems, (c) incomplete surgical decompression, and (d) poor selection of patients (Russin 1976).

LONG-TERM FOLLOW-UP OF PATIENTS AT THE NUFFIELD ORTHOPAEDIC CENTRE: THE STABLE AND UNSTABLE RESULT

In the series of seventy-two patients followed up at the Nuffield Orthopaedic Centre following spinal decompression, an assessment was made within one month and again at the long-term follow-up which extended to ten years (Table 21:2). These two assessments were then compared to determine the influence of passage of time on the result of surgery. Two distinct groups of patients were identified and were of roughly equal size; those with stable and those with unstable results.

- (i) Stable Result: Forty-two per cent of patients stated that there had been no change in the sciatic pain, or absence of sciatic pain between the two assessments (Table 21:6). Fifty-three per cent of patients stated their back pain, or lack of it, was unchanged (Table 21:8). Clearly the memory may not be so reliable over a ten year period in an elderly group of patients but in the absence of more objective criteria, this will have to suffice.
- (ii) Unstable Result: The symptoms may either improve following the initial assessment or deteriorate. Thirty-nine per cent of sciatic

pain and twenty-one per cent of low back pain improved during the long-term follow-up (Table 21:6 and 21:8), but nineteen per cent of patients reported deterioration of sciatic pain and twenty-six per cent reported increasing back pain during follow-up.

The small group of patients with an unstable deteriorating result on long-term follow-up is a difficult group to manage. They return frequently to orthopaedic and low back clinics and are often convinced that another operation will relieve their symptoms. This is probably because they enjoyed a period of months or even years following surgery without symptoms or only minimal disability. The surgeon should, however, remain circumspect and aware of the development of arachnoiditis and further degenerative change. Only in the presence of a new neurological deficit is further investigation considered justifiable. This will be discussed further in Chapter 22.

CONGENITAL AND DEVELOPMENTAL STENOSIS

Paine reported eight patients at an average of four years following decompression for congenital and developmental stenosis (Paine 1976a). These patients had only minimal degenerative change. They underwent a minimum of three level laminectomy sometimes four or five levels, and seventy per cent of them had good results following this. Tile reported no tendency to further slip in patients following decompression of developmental stenosis (Tile 1976). Reale reported satisfactory results of around eighty per cent in thirty-seven patients operated on for developmental stenosis of the lumbar spinal canal (Reale 1978). This was based on an assessment not only of the patients verdict on surgery, but also on improvements in neurological signs and the appearance of new deficits. He also stated that "the diagnostic certainty of stenosis suspected on the basis of clinical and radiographic data is reached only at the operating table", which must bring his report into question.

In 1977 Verbiest reported twenty-seven years of experience between 1948 and 1975 when one hundred and forty-seven patients were treated surgically for developmental stenosis of the lumbar vertebral canal. In fact he measured the mid-sagittal diameter of the area of stenosis in one hundred and sixteen of these patients during the operation (Verbiest 1977). Ninety-two of these patients were followed up for periods varying between one and twenty years. About two-thirds were

completely relieved of symptoms and signs. Sciatica and intermittent claudication were more frequently cured than radicular deficit and lumbago, the latter being the most frequent persisting symptom. A permanent neural deficit as a result of the surgical procedure was noted in two cases. In seven cases there was either an increase in previous symptoms or appearance of new symptoms or radicular deficit which was permanent in two cases.

In Verbiest's series no case of vertebral displacement was observed after extensive laminectomies, even when combined with excision of disc protrusions and clearance of the corresponding disc spaces. Laminectomies combined with foramenotomies did not result in vertebral displacement, if not combined with disc excision in that area. Combined laminectomy bilateral foramenotomy and disc excision at the same level resulted in vertebral displacement in one case only. Post-operative ossifying arachnoiditis was observed in two patients. An annular non-ossifying arachnoiditis was observed in one patient.

Pre-operative paraplegia was present in two patients and did not recover after surgery. Sciatica whether or not accompanied by a radicular deficit was the symptom most frequently relieved. It persisted in only one case of pure relative stenosis. Intermittent claudication responded the next most favourably. Only four of the twenty-four patients were not completely relieved.

A radicular deficit was cured six times out of seven in cases of pure absolute stenosis, about four times out of five in cases of mixed stenosis, and in five out of six cases of pure relative stenosis; in only two cases was it a new and persistent post-operative finding.

Low back pain as a new symptom after operation did not develop; it persisted in one out of five of the cases of pure absolute stenosis, and in about one of the three cases of mixed and pure relative stenosis. The rate of complete recovery was highest with pure absolute stenosis, and lowest with pure relative stenosis, and intermediate with mixed stenosis.

Other reports confirm that the extent of laminectomy influences the result (Getty 1980). A satisfactory result is reported in seventy per cent or more of patients decompressed at one or two levels, whereas when three or more levels were involved the percentage of satisfactory results was lower.

CONGENITAL AND DEVELOPMENTAL STENOSIS
AT THE NUFFIELD ORTHOPAEDIC CENTRE

Seven patients of the seventy-two in the Nuffield Orthopaedic Centre series had either congenital or developmental stenosis. In no patient was spinal stenosis recognised at birth, and so there was no true case of congenital stenosis. However one girl aged twelve presented with a congenital non-incarcerated hemi-vertebra at the second lumbar level and symptoms of reduced running distance. Myelography and tomography demonstrated the hemi-vertebra to be intruding into the spinal canal, indenting the contrast column anteriorly (Fig. 21:8). Following anterior decompression and rib strut grafting she made an uneventful recovery and was able to return to normal sporting activities without leg pain on a seven year follow-up.

An eighteen year old male (T.D.) with developmental stenosis of the entire spinal canal reducing the antero-posterior diameter to 10 mm. developed a small disc prolapse at the L3-4 level which reduced the antero-posterior diameter further to 8 mm. He required a three-level laminectomy and discectomy at the L3-4 and L5-S1 levels. At operation no extradural fat was present, and numerous adhesions were found around the L4, L5 and S1 nerve roots on the left side. He was relieved of leg pain on a six year follow-up but continued to experience mild lumbar discomfort (Fig. 21:9).

A thirty year old male suffered a minor back injury during a game of football and subsequently developed severe pain in the right leg on exercise, together with weakness of the extensor hallucis longus muscle. A myelogram revealed sagittal flattening of the spinal canal particularly at the L4-5 level, and at surgery one year after injury no disc prolapse was found but the spinal canal was shallow and the facet joints protruding into the canal. Decompression including partial facetectomy completely relieved his leg pains on exercise.

The other patients in the series with developmental stenosis were males aged forty-five, fifty-three, fifty-five, and fifty-nine. The average age of the developmental group was thirty-eight. The four oldest members of the group had combined developmental degenerative stenosis, and two also had disc disease. The duration of symptoms at presentation for the whole group was 1.3 years (range 0.6 to 2 years) which is considerably shorter than for patients with degenerative stenosis.



Figure 21:8. Myelography of a twelve year old school girl with "congenital" stenosis resulting from a non-incarcerated hemi-vertebra at the second lumbar level. The canal was decompressed by anterior resection and grafting resulting in complete relief of symptoms.

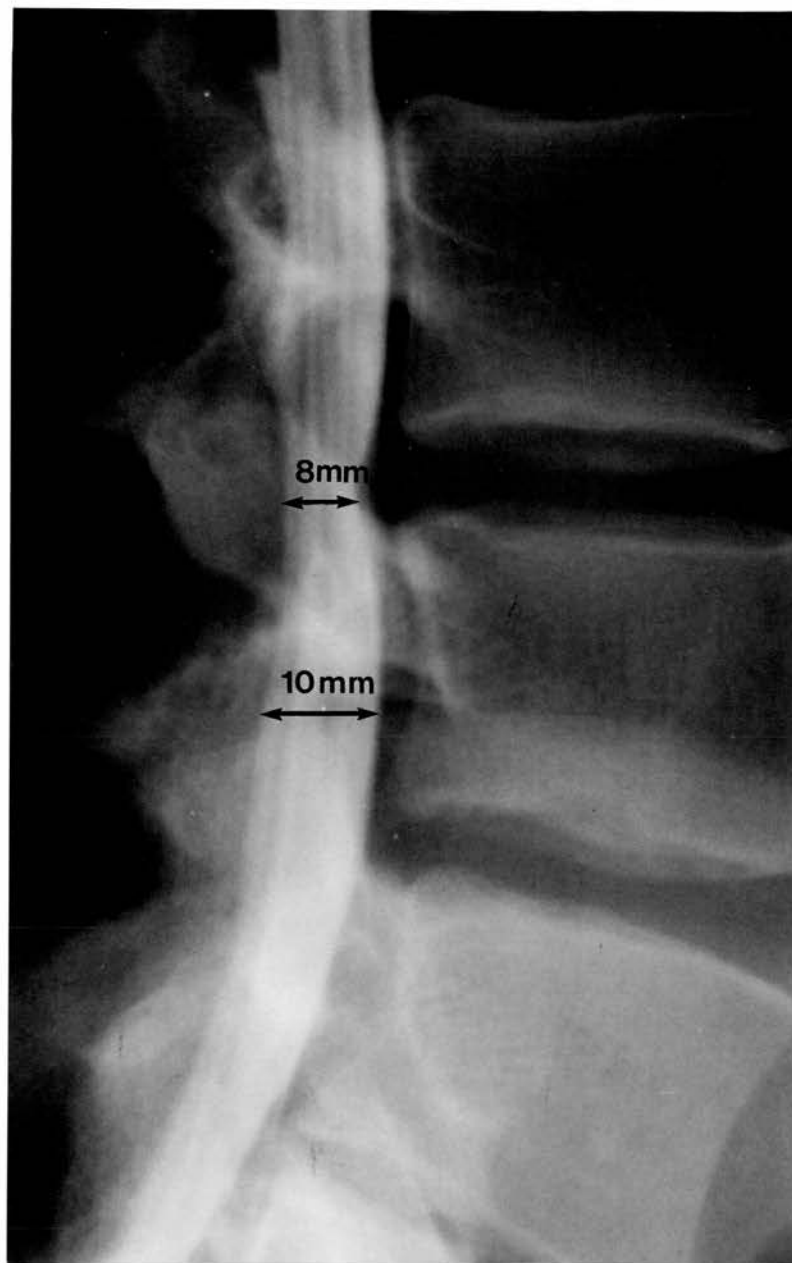


Figure 21:9. Lateral view of the radiculogram of an eighteen year old male with developmental stenosis. The antero-posterior dimension of the canal was reduced from 10 mm. to 8 mm. by a small disc prolapse.

Four out of the seven were completely relieved of leg pain (sixty per cent) following decompression, whilst two had minimal symptoms, and one patient who had had a previous decompression was no better following an L2-3 laminectomy and discectomy, presumably the result of previous scarring.

It is the author's opinion that surgery in patients with developmental stenosis should be confined to the level or levels identified as responsible for the symptoms and signs. When developmental stenosis is caused by anomalous facet joint development, the level of surgery is clearly defined. But when developmental narrowing involves the entire lumbar canal it is essential to correlate detailed radiological and CT studies with the clinical presentation, and only when the clinical and radiological findings correlate closely should surgery to that level or confined area be considered. Decompression of the entire lumbar canal in a combined therapeutic and prophylactic approach is not recommended.

Four achondroplastic patients have been treated for spinal stenosis at the Nuffield Orthopaedic Centre (Fig. 21:10). Stenosis was evident myelographically involving the cervical spine in one patient, the thoracolumbar junction in one patient, and the lumbar spine in two. Three were managed conservatively with bed rest, traction and plaster jacket support, and one required surgical decompression for progressive weakness and numbness of the legs. A three-level laminectomy was performed in the upper lumbar region, but this occurred before the period of this survey. However twenty-three years following decompression the patient remains comfortable and stable with intermittent exacerbations of back pain and leg pain requiring bed rest. She walks with the aid of two sticks, presumably to reduce the exaggerated lumbar lordosis (Chapter 4).

THE RESULTS OF DECOMPRESSION OF ROOT CANAL STENOSIS

The dimensions of the intervertebral foramen is determined to a major extent by the height of the intervertebral disc space. A small number of patients may present with unilateral sciatica, with segmental conduction defects in either the L5 or S1 nerve roots, and they will be found to have isolated disc resorption and lumbar nerve root canal stenosis (Crock 1976). At operation in such cases the disc space is virtually empty, despite the presence of nerve root compression. The results of surgery in this situation are excellent in eleven out of fifteen



Figure 21:10. Lateral radiograph of the cervical spine of an achondroplastic patient with symptoms and signs of spinal stenosis. Myelography demonstrated stenosis at the level of the cervical spine.

patients reported after an interval of between six months and five years (Epstein 1972).

In patients with a long history a significant functional impairment may persist despite adequate decompression because of persisting spondylosis and perineural and intraneural scarring. Removal of the roof of the foramen brings about enlargement of the nerve root canal without sacrifice of the superior articular facet. In the patients reported by Epstein (Epstein 1962), and those of Hanraets (Hanraets 1959), no specific impairment of function could be attributed to excision of the facets that did not exist before surgery. Munro reported one hundred and thirty patients in whom the facets were damaged or removed and stated that

"the loss of a pair of intervertebral facets and their intervening joint space is of infinitely less importance than the continued root compression and inadequate exposure that would result from their retention or undamaged condition" (Munro 1956).

Post-operative spondylolisthesis is uncommon, unless there is already a pre-operative degenerative spondylolisthesis, or operative interference with the disc itself. Tile reported that unroofing of the lateral recess is extremely important (Tile 1976) and he condemned the so-called "key hole" laminectomy approach to these patients.

In the Nuffield Orthopaedic Centre series of patients nerve root canal decompression when performed was part of a more extensive decompression. It has already been shown in this series that nerve root canal decompression was frequently performed in those patients with an excellent or good result from surgery. In those patients with a poor result, nerve root canal decompression had not been performed.

DECOMPRESSION OF STENOSIS CAUSED BY DEGENERATIVE SPONDYLOLISTHESIS

Tile reported that all patients with degenerative spondylolisthesis in his series showed further slip following surgery (Tile 1976). He noted though that if the lamina of L4 was removed with decompression of the fifth lumbar root, then the end results were "quite satisfactory". He pointed out that the facet joints at the L4-5 level were "quite abnormal", but also that non-operative treatment gave very poor end results, and the patients continued to have symptoms usually with L5 root involvement, unless surgery was performed.

The importance of decompression rather than simple fusion has been emphasised (Fitzgerald 1976). Intermittent claudication of the cauda equina when treated by fusion alone persisted in the series of Fitzgerald and Newman in all but a single case as might be expected. On the other hand, when decompression was performed all the neurological symptoms were relieved by surgery, with the exception of one patient. Three patients in this series were graded as unsatisfactory because of persistent back symptoms. In two of these there was obvious degeneration and instability above the level of decompression and fusion but in the third patient the cause of persistent symptoms was uncertain.

Three patients in this series were treated by decompression alone. The slip did not increase in one and there were no symptoms of instability. In the second the slip did not increase but there were definite symptoms of instability, and in the third the slip increased dramatically from twenty per cent to forty per cent following decompression alone, a degree not otherwise seen. The treatment of choice is therefore decompression combined with a lateral mass fusion.

Degenerative spondylolisthesis was the commonest type of stenosis in females (forty per cent) in the Nuffield Orthopaedic Centre series. In only eight per cent of males however, was stenosis attributed to degenerative spondylolisthesis. The total number in the series of seventy-two was therefore fourteen, and in each patient the slip occurred at the lumbar four-five level. Treatment was by decompression and fusion as described in Chapter 20.

The results of decompression and fusion at the Nuffield Orthopaedic Centre are shown in Table 21:24.

	COMPLETELY RESOLVED	IMPROVED BUT NOT RESOLVED	NO DIFFERENCE
Sciatic Pain	50	40	10
Low Back Pain	60	20	20

Table 21:24. The response of patients with degenerative spondylolisthesis to decompression and fusion expressed as a percentage of the fourteen patients.

In one patient who failed completely to respond to treatment, no cause could be found, but some years later evidence of a long-standing personality

disorder became apparent. One patient was completely symptom-free post-operatively provided she wore a corset, and in two other patients although symptoms were considerably improved their activity was still restricted for other reasons: one patient had angina of effort and the other an osteo-arthritic hip joint.

One patient with spondylolytic spondylolisthesis at the lumbo-sacral junction was treated surgically by decompression and lumbar four to sacral one fusion. Following this she was able to return to work as a nurse.

DECOMPRESSION OF POST-FUSION SPINAL STENOSIS

Following nine years experience of two hundred and thirty-one patients with post-laminectomy and post-fusion spinal stenosis, Brodsky emphasised the importance of recognition and adequate decompression of such lesions (Brodsky 1976). Special surgical techniques are required for decompression of these lesions and spinal fusion may be advisable. The indications for fusion however are few and require further investigation and evaluation.

In patients who have already had one operative procedure on the spine, one must take into account factors of secondary gain, psychoneurosis, arachnoiditis, the presence of permanent damage to nerve roots either surgical or through prolonged severe compression, since it is these factors which are highly likely to influence the results of further surgery.

Continuing research into the causes of low back pain and persistent sciatica is required to help these patients overcome disabling pain and at times drug dependence. When, in patients with post-operative stenosis, a clear cause of persistent symptoms and signs exists adequate decompression of the spinal canal and nerve root canals gives good or excellent results in most cases when other factors such as secondary gain, psychoneurosis and arachnoiditis have been excluded (Brodsky 1976). This can in practice prove extremely difficult.

NON-SPECIFIC COMPLICATIONS OF SPINAL DECOMPRESSION

Out of four hundred and fifty-seven patients treated surgically for herniations of the nucleus pulposus, degenerative and developmental spinal stenosis, Paine reported one death from pulmonary embolus occurring approximately ten days after discharge from hospital (Paine 1976a). A

second patient in this series suffered a pulmonary embolus but recovered. Deep vein thrombosis and wound infection also occurred (Paine 1976a). Eighteen out of the four hundred and seventy-three patients treated surgically by Russin developed wound haematomas and thirty-six had urinary tract infections (Russin 1976). Three out of these four hundred and seventy-three patients developed intra-discal infections. In Paine's series a persistent sinus occurred in one patient, and continued for approximately eighteen months. Another patient developed a post-operative haemorrhage causing further cauda equina compression with only slight recovery after evacuation of the haematoma. Two other patients were noted to have increased cauda equina lesions following surgery for developmental and degenerative spinal stenosis which emphasises the care required in handling instruments close to nerve tissue. Paine reported a slight increase in root signs in a few patients but he stated that most recovered fully. Residual complaints following surgery were much more likely to be due to extensive degenerative disease in the lumbar spine than to persistent cauda equina compression.

SUMMARY

It can be seen therefore that spinal stenosis, whatever its aetiology, is a treatable condition which responds favourably in carefully selected patients to operative management. The important consideration necessary to achieve a satisfactory result from spinal decompression is to scrupulously correlate the patient's clinical picture with the local anatomy and pathology as demonstrated radiologically. The most frequent and persistent complaint following adequate spinal decompression is of recurrent attacks of low back pain. These may resolve but tend to recur. Attempts to relate the prognosis to the presenting features have been disappointing.

This chapter identifies a number of useful prognostic indicators and emphasises the importance of wide meticulous decompression, following the "road map" of the myelogram and CT scan to obtain the best results. Mathematical analysis of radiographs has been found to provide no clue to the prognosis. The way forward should become clearer when we can accurately identify the lesion or lesions responsible for continuing low back pain following an otherwise successful decompression for spinal stenosis.

C H A P T E R 22

THE "MULTIPLE-OPERATED" LUMBAR SPINE

INTRODUCTION

The optimum time to achieve a good or excellent result from surgery is at the first operation. The importance of full investigation cannot be over-emphasised since it eliminates the need for exploratory surgery. Careful pre-operative planning of the exact procedure required, and its performance using a meticulous surgical technique ensure that optimum results are achieved at the first operation. Re-operation because of failure at any one of these three stages is much less likely to succeed, particularly when the patient is already dissatisfied with the results of the initial procedure. The Nuffield Orthopaedic Centre series and numerous other reports indicate that inadequate decompression of spinal stenosis particularly of the lateral recess and nerve root foramen is an important cause of poor results following surgery.

Symptoms and signs may persist in a small proportion of patients even following adequate decompression for two main reasons. The first reason is poor patient selection, and the second the presence of permanent nerve damage in the form of intraneural fibrosis or constrictive perineural fibrosis.

It is not unusual for sciatica to be relieved, but for back pain to persist because of severe degenerative change in the lumbar spine. Other patients after initially good or excellent results from surgery may then deteriorate owing to the development of post-operative adhesions, spinal instability or post-operative spondylolisthesis, with further irritation of nerve roots caused by abnormal movements at the intervertebral joints. It must be added, however, that a larger group of patients continue to improve for some time following decompression.

When symptoms are not improved by the first operation, or they recur, and the reasons for surgical failure are not identified or the causes of recurrence not investigated, such patients tend to seek referral from one centre to another, and may in fact be subjected to multiple spinal operations in their search for "a cure" and in the process may deteriorate and become progressively disillusioned and depressed. It is as important to explain to a patient with arachnoiditis or permanent nerve root damage that no further surgery is indicated as it is to identify the small proportion of patients who may benefit from further surgery.

Surgical intervention should be reserved for those few individuals in whom a clearly defined and surgically remediable lesion is identified. This group represents probably one out of twenty new patients with persistent symptoms following previous surgery (Rothman 1981).

THE OBJECTIVES OF TREATMENT

The primary objective is to ensure that the patient's persistent low back pain and leg pain is not a manifestation of another disorder which was not recognised at the time of previous surgery. There are four steps in approaching a second operation.

- (i) Firstly, it is essential to recognise, diagnose and treat if possible any psychosocial problems. Since eighty per cent of people suffer low back pain at some stage in their life, it is hardly surprising that the lumbar spine remains one of the favourite focuses of attention for patients who are suffering from depression or some form of personality disorder. The patient with difficulties at work may attribute these to low back pain. On the other hand, certain occupations genuinely aggravate low back problems, and it may be considerably more beneficial for the individual to change occupations than to undergo re-operation on the spine.
- (ii) Secondly, certain medical and surgical disorders may be the source of continued low back pain and leg pain. These must be considered and treated before any consideration of further surgery to the spine. Such disorders include peripheral vascular disease, peripheral neuropathy of for instance a diabetic or alcoholic nature, long tract signs from syringomyelia, spinal cord tumour, or vitamin B₁₂ deficiency. Leg pain on exercise may be caused by metabolic disease of bone particularly in the elderly, or osteo-arthritic change in the joints of the lower limb.

Continued back pain may be related to urological or gynaecological causes. The presence of a ureteric calculus may cause pain referred to the upper thigh increased by activity and exercise. An atherosclerotic abdominal aortic aneurysm may cause both back pain and leg pain on exercise. Metastatic malignant disease involving the lumbar spine may simulate spinal stenosis as may infection such as tuberculosis, acute infective discitis, prolapsed intervertebral disc, and in rare instances myeloma and lymphoma. The patient must be thoroughly screened to rule out such medical or surgical disorder requiring treatment.

- (iii) Thirdly, patients who present for consideration of further surgery on

the spine must have failed to respond to all methods of conservative treatment maintained for adequate lengths of time. These include periods of bed rest, analgesia, sedation, traction, isometric spinal exercises, corset, plaster jacket, heat treatment and other forms of physiotherapy, and epidural injections.

(iv) Fourthly, the patient who is found to have no psychosocial problems and no associated medical or surgical disorders should then be admitted to full spinal investigation to identify the cause of persistent or recurrent symptoms. This includes plain radiographs, flexion/extension radiographs, computerised tomography preferably combined with radiculography, and at times supplemented by nerve root injections, and facet joint blocks, and a technetium diphosphonate bone scan.

INDICATIONS FOR FURTHER INVESTIGATION

It is essential by means of investigations to distinguish between sciatica caused by mechanical compression of the nerve root, and sciatica caused by irritation through abnormal motion of the intervertebral segment (instability).

In patients with sciatica definite abnormalities on neurological examination must be demonstrated before contrast studies are undertaken. Pain itself is an inadequate justification for myelography (Rothman 1981). The presence of a new neurological deficit is an essential pre-requisite to further investigation, since stable or residual neurological deficits may simply be the result of prior surgical intrusions, or the presence of permanent neurological damage.

In the absence of a new or evolving neurological deficit, an unequivocally positive root tension sign elicited by means of the straight leg raising test or sitting root stretch test, must be present before proceeding to myelography. If neither a new neurological deficit nor a tension sign is present, then no further investigation should be performed and conservative treatment only advocated. The absence of a new neurological deficit rules out significant mechanical compression, and the absence of a positive root tension sign rules out significant nerve root irritability from instability. In this situation the cause of pain is arachnoiditis or perineural fibrosis, neither of which is amenable to current surgical treatment.

When low back pain continues following spinal fusion the further

investigations required are flexion/extension views and computerised tomography of the fusion mass with overlapping cuts to demonstrate the continuity of the graft and its attachment to the vertebra. If low back pain continues despite an anatomically successful fusion, then treatment should be discontinued.

The diagnosis of post-operative instability of the spine when used as an indication for further back surgery must be rigidly confined to patients in whom there is translatory motion of the vertebra on flexion/extension radiographs, reversal of the disc space angle, or true traction spurs as described by MacNab (MacNab 1971).

THE RESULTS OF SURGICAL INTERVENTION IN THE SYMPTOMATIC MULTIPLE-OPERATED BACK PATIENT

Finnegan reported in 1979 a series of sixty-seven patients who had had multiple operations on the back (Finnegan 1979). Several patients with objectively demonstrated poor results considered the operation to have been enormously worthwhile, but on the other hand two patients with "acceptable results" claimed that they would not repeat the operative experience. Of the seventeen patients claiming total disability including inability to do housework in many cases, eight were involved in on-going litigation or compensation claims at the time of operation and follow-up evaluation. There was a net improvement in the post-operative neurological status assessed by reflex change and muscle testing in ten per cent (seven patients) but three patients (five per cent) had an increased neurological deficit post-operatively. However, from the entire group ten patients (fifteen per cent) had complete recovery of pre-operative motor and reflex abnormalities. In this series changes in sensation were not evaluated.

Women out-numbered men by a ratio of nearly 3:1. The average age was forty-nine years, and the mean number of operations was slightly less than three. All patients were evaluated on two occasions. The first examination was conducted at a minimum of one year post-operatively (range one to five years, mean two years follow-up), the second interval followed two years later. The physician who reviewed the patients had not participated in any of the surgical procedures. Overall eighty per cent of patients claimed to have gained enough relief to consider the procedure worthwhile. Despite this, only eight patients fulfilled the fairly stringent criteria of a good result, and there were forty-six fair results and thirteen poor results.

ANALYSIS OF THE REASONS FOR AND RESULTS OF RE-OPERATION AT THE NUFFIELD ORTHOPAEDIC CENTRE

Twelve patients required re-operation at the Nuffield Orthopaedic Centre. The first operation or operations were often performed elsewhere, so details are sometimes sparse, but in each patient sufficient information was available to indicate clearly the reasons for failure of the first operation. The reasons for re-operation were usually obvious on retrospective analysis, and as always it is easy to be wise after the event.

Many similar series report psychosocial reasons and litigation as prominent causes of patient dissatisfaction. In this series, however, patients were very carefully selected for re-operation with such patients excluded. The series consisted of ten males and two females. Both females were aged forty-three and the average age of the males was fifty-one (twenty-nine to sixty-five), so that middle aged working people were commonly affected, and some lost their jobs as a result of time off work. Only one patient was retired. The patients belonged to the occupational groups shown in Table 22:1.

1	2	3	4	RETIRED	UNEMPLOYED
25	8	17	34	8	8

Table 22:1. The occupational groups of the patients requiring re-operation expressed as a percentage of this group (N=12). For description of the group please see Figure 10:4.

The extent of previous surgery was determined from the operative records, and these were compared with the pre-operative myelogram, subsequent CT scans and repeat radiographs and myelography. It was then possible by careful examination of the patient to determine the reasons for failure of previous surgery (Table 22:2).

Inadequate Decompression	75%
Failure to recognise Developmental Stenosis	17%
Inappropriate Surgery (Wrong Level)	8%

Table 22:2. Reasons for failure of first operation or operations, expressed as a frequency percentage of the group (N=12).

The average number of operations performed per patient was 2.3 (range two to four) including re-operation at the Nuffield Orthopaedic Centre. The average interval between operations was five years (range three months to twelve years), but there were essentially two groups:

(i) Early Re-operation

In the first group the patient was no better and frequently deteriorated following the first operation, and within a matter of months further investigations and reassessment occurred followed by re-operation. There were five patients in this group and the average interval between operations in group one was six months (range three to twelve months).

(ii) Late Re-operation

In the second group patients often experienced a satisfactory result from the first operation, which usually lasted for between three years and eleven years (average five years). All subsequently deteriorated (some rapidly) either spontaneously or following a minor twisting or lifting injury, and required further surgery. Three patients in this group had no relief from the initial operation and slowly and gradually deteriorated over the following years until they were investigated further and came to re-operation. The interval between operations in group two was on average seven years (range three to twelve years). This is summarised in Table 22:3.

A. No Improvement or Rapid Deterioration (N=5)	➡	(i) Early Re-operation at 6 months (3-12m.) (N=5)
B. No Improvement or Slow Deterioration (N=3)	➡	(ii) Late Re-operation at 7 years (3-12yrs.) (N=7)
C. Temporary Improvement lasting 5 years (3-11yrs.) but Subsequent Deterioration sometimes rapidly (N=4)	➡	

Table 22:3. The three modes of failure following surgery which result in two re-operation groups.

The groups described in Table 22:3 will now be examined in detail.

GROUP A NO IMPROVEMENT OR
RAPID DETERIORATION: EARLY RE-OPERATION

Four patients in this group had inadequate decompression at the first operation, and one had inappropriate surgery. The reasons for describing the decompression as inadequate or inappropriate are given in Table 22:4.

Case 1	L4/5	Laminectomy	: Large sequestered disc missed
Case 2	L4/5	Laminectomy	: Myelographic block at L3/4
Case 3	L5/S1	Discectomy	: Bony stenosis
Case 4	L3/4/5	Discectomy	: Bony stenosis
Case 5	L1/2	Discectomy	: L2/3 disc and bony stenosis

Table 22:4. The surgical procedures performed at the first operation in group A patients together with their reasons for failure.

Case 1

A forty-three year old female employed as a school nurse was admitted under the neurosurgeons with low back pain and sciatica. A myelogram showed a block at the L4-5 level. She was treated by L4-5 laminectomy but post-operatively developed increasing saddle anaesthesia. She was seen by the neurologists who excluded a demyelinating disease and then transferred to the Nuffield Orthopaedic Centre because of difficulty walking. Further myelography revealed a large sequestered disc fragment at the L4-5 level and this was removed three months after the first operation, and discectomy and lateral recess decompression performed. Sensation improved post-operatively and she returned to work, but she remained dissatisfied with surgery because of persistent weakness in the legs.

Case 2

A forty-three year old female presented at another hospital with leg pain and numbness. After myelography she was decompressed with an L4-5 laminectomy. Post-operatively leg pain and numbness persisted and she developed a drop foot, weakness of knee extension and bladder symptoms. Some months later she was referred to the Nuffield Orthopaedic Centre and further myelography revealed a complete block at the L3-4 level. Ultrasound examination showed the dural sac to be patent below the level of the block. Twelve months after the first operation she was decompressed

again by L3 laminectomy and discectomy at the L3-4 level. Following this bladder symptoms improved but weakness, pain and numbness persisted in the right leg and four years later she still required a caliper.

Case 3

A fifty-seven year old male civil servant had no symptomatic improvement following a right L5-S1 discectomy with removal of a sequestered fragment. Six months later the symptoms were increasing and after further investigation at re-operation an L5 laminectomy, lateral recess and nerve root canal decompression was performed. He obtained symptomatic relief from this second procedure and despite minimal residual leg pain was satisfied with the result but seven years following the second operation he had still not returned to work. Over the age of forty most patients require bony decompression in addition to simple discectomy.

Case 4

A fifty-eight year old male University Bulldog with low back pain and left sciatica was diagnosed from the myelogram to have large disc prolapses at the L3-4 and L4-5 levels, with "cut-off" of the nerve roots. A registrar removed both discs surgically but the patient complained of increasing pain and weakness in both legs. Diabetes was diagnosed and his weakness was initially considered to be the result of diabetic neuropathy. As indicated in Case 3, however, discectomy alone is inappropriate in this age group, and after further myelography the spine was formally decompressed by L4-5 laminectomy, L4-5 discectomy and lateral recess decompression. A large sequestered fragment of disc was also removed from the stenotic canal. One year later he was satisfied with the result of the second operation. He had less pain, improved sensation and power, his ankle reflex had returned and he had dispensed with a drop-foot appliance. His diabetes was also well controlled.

Case 5

A fifty-nine year old clerical worker had an L1-2 discectomy but suffered persistent numbness of the left leg post-operatively. Review of the radiographs and myelogram indicated that he had had an L1-2 discectomy for an L2-3 disc prolapse. Three months after the initial procedure the L2-3 disc was removed together with the lower half of the L2

lamina and the upper half of the L3 lamina. He improved, but six years later still had numbness of the left leg with occasional sharp pains in the thigh. The knee and ankle reflexes were diminished and pin prick sensation was reduced in the left lumbar 3, 4, 5 and sacral 1 and 2 dermatomes. He did not return to work. It is possible that at the second operation removal of the upper half of the L3 lamina essentially removed the cephalad attachment of the L3-4 ligamentum flavum. The ligament would then shorten and bulge into the canal below the decompression. It may subsequently calcify. This procedure is therefore not recommended and may account for persistent symptoms.

GROUP B NO IMPROVEMENT OR
 SLOW DETERIORATION: LATE RE-OPERATION

One patient in this group had repeatedly inadequate decompression in the transverse or horizontal plane, and two patients had developmental stenosis which was not recognised at the first operation.

Case 6

A forty-eight year old welder and storeman had no symptomatic improvement despite three operations under the care of the neurosurgical department. The first operation at the age of thirty-five was a partial laminectomy. Five years later he had a left sided L4-5 laminectomy, and again five years later an exploratory procedure. He was then referred to the Nuffield Orthopaedic Centre and six years later had a total L4-5 laminectomy. A narrow spinal canal and numerous adhesions were noted, and a dural leak occurred. Little relief of symptoms followed, however, and one year following surgery he was considered to have a "functional overlay". Seven years later he was unable to stand for long, walked with crutches, unable to work, and needed his wife to dress him from the waist down. He had had one year of relief of symptoms over the previous twenty years, and this was following two epidural injections: strong confirmation that his basic problem was arachnoiditis.

Case 7

A twenty-nine year old motor mechanic had a left L4-5 discectomy and partial removal of the L4 lamina elsewhere. It was noted at surgery that he had a small trefoil shaped spinal canal. Post-operatively he developed a left sided drop foot, which failed to improve with time. He

gradually developed more leg pain and numbness in the left leg. A repeat myelogram revealed pronounced developmental spinal stenosis affecting particularly the lower lumbar spine from L3 downwards, and an L4-5 laminectomy was performed. At operation a very constricted canal was noted. He did not improve significantly afterwards. The foot drop persisted, sensation was diminished in the left lumbar 4 and 5 dermatomes, and he complained of considerable back pain and stiffness. Both ankle reflexes could not be obtained after the second operation. He began to walk with two sticks and was reported to have a "supratentorial component" to the symptoms. A repeat myelogram revealed arachnoiditis. Seven years following the second operation he remained dissatisfied with both operations. A number of problems occurred in this patient's management. Firstly and foremost he clearly had developmental stenosis initially, but this was not recognised. In the presence of a narrow spinal canal considerable nerve root mobilisation and retraction would be required to remove the disc if formal spinal decompression was not performed. This might account for his post-operative foot drop. Three years later a repeat myelogram revealed stenosis from L3 downwards, but an L4-5 decompression only was performed. This might account for his failure to improve after the second operation. The third myelogram revealed only "arachnoiditis" but this might co-exist with persistent stenosis at the L3 level. The management of this patient should have been straightforward initially, but is certainly now very complex.

Case 8

A thirty-nine year old business man with back pain and sciatica was only marginally improved by an L4-5 and L5-S1 disc exploration. No disc prolapse was found and the lower half of the L4 lamina was removed and the ligamentum flavum excised. The dura was pulsatile with the spine flexed on the operating table. Eight years later a further myelogram was performed because of persistent symptoms. This showed a reduced antero-posterior diameter and indentation of the spinal canal by arthritic facet joints. Developmental stenosis was diagnosed, and L4-5 laminectomy performed with partial facetectomy. Four years later he had no leg pain and only occasional back pain. If developmental stenosis had been recognised at the first operation, he might not have required a second decompression. The fact that the dura is pulsatile does not exclude stenosis when the spine is flexed.

GROUP C TEMPORARY IMPROVEMENT WITH
SUBSEQUENT DETERIORATION: LATE RE-OPERATION

Each of the four patients in this group had an initially good result from their first operation, but they all subsequently required further surgery some years later. Should it have been possible to predict this* at the time of the first operation and modify surgery so that a second operation became unnecessary? These four case reports indicate, in my opinion, that it should since the horizontal extent of decompression was inadequate in each case.

Case 9

A sixty-five year old retired builder had altered sensation below T10 which was the site of an old war wound and discectomy. At the age of fifty-four an L4-5 discectomy was performed which gave a satisfactory result for eleven years. He then suddenly developed a rapidly progressive neurological deficit and an emergency myelogram revealed a block at L4-5 for which he had an L4-5 laminectomy and lateral recess decompression. Two years later his leg pain and weakness was considerably reduced, but he wears a corset and takes analgesics for back pain. A simple discectomy in the sixth decade of life cannot be expected to provide lasting relief of symptoms.

Case 10

A fifty-five year old had an initially good result from a right L4-5 discectomy. Two years later he twisted his back and the symptoms recurred, and three years post-operatively an L4 laminectomy and left L4-5 discectomy was performed for focal stenosis. A four year follow-up confirmed that his leg pains had resolved and he was satisfied with the result of surgery and back at work with occasional support from a corset.

Case 11

A forty-two year old bakery worker was pleased with the result of an L4-5 discectomy and nerve root canal foramenotomy for three years. He then suffered a back injury from a fall with recurrence of sciatica. Symptoms continued intermittently for six further years when an L5 laminectomy and lateral recess decompression relieved his sciatica. He returned to work in the bakery and three years following the second operation he remained satisfied with the result, with no leg pain and only occasional

back pain relieved by analgesics. The dimensions of the lateral recess can often not be determined at fenestration and discectomy, but he probably had lateral recess stenosis at the time of the first operation. Would a more complete decompression at the first operation have prevented a recurrence of sciatica following the fall?

Case 12

A fifty-nine year old engineer responded well to an L4-5 discectomy and exploration of the L5-S1 level and was satisfied with the result for twelve years. His symptoms then recurred and an L4-5 laminectomy and repeat L4-5 discectomy was performed. The major cause of neurological compression was from grossly enlarged L4-5 facet joints. Numerous adhesions were present and a dural leak occurred. Post-operatively the sciatica resolved and two years later he was very pleased with the result and was back at work despite persistent numbness under the ball of the left forefoot. At the first operation, why was the L5-S1 level explored? The answer is probably that the disc prolapse found at the L4-5 level was not impressive and so the next level down was exposed. The initial diagnosis was probably lateral recess stenosis from enlarged facet joints, but this was not recognised. Lateral recess stenosis was also not recognised by the radiologist who reported the second myelogram as a "disc recurrence". Fortunately for the patient, the surgeon did not fall into the same trap.

SUMMARY OF RESULTS

Seven patients were satisfied with the long-term results of re-operation but five patients remained dissatisfied. One patient had four operations for the same focal stenosis, three of which were inadequate, but the fourth operation (which was adequate) was too late because focal constrictive arachnoiditis had developed. Each case is described above in some detail since each patient should have required only a single effective operation to relieve focal or widespread stenosis. Fortunately the majority of patients (sixty per cent) responded favourably to re-operation. The cases are summarised in Table 22:5.

The success rate of spinal decompression therefore falls from eighty per cent patient satisfaction for the primary procedure to sixty per cent for re-operation. Critical analysis of the cases of re-operation reported, however, would suggest that this figure could be improved upon. However

CASE NUMBER	AGE AT FINAL OPERATION	INITIAL OPERATION	REASON FOR FAILURE	FINAL OPERATION	INTERVAL BETWEEN OPERATIONS	TOTAL NUMBER OF OPERATIONS	FINAL RESULT
CASE 1	43	L4-5 laminectomy	Inadequate transverse decompression	Discectomy and lateral recess decompression	3 months	3	Dissatisfied at 5 yrs.
CASE 2	43	L4-5 laminectomy	Inadequate longitudinal decompression	L3-4 laminectomy and discectomy	1 year	2	Dissatisfied at 4 yrs.
CASE 3	57	L5-S1 discectomy	Inadequate transverse decompression	L5 laminectomy and lateral recess decompression	6 months	2	Satisfied at 7 yrs.
CASE 4	58	L3-4 and L4-5 discectomy	Inadequate transverse decompression	L4-5 laminectomy and lateral recess decompression	6 months	2	Satisfied at 1 yr.
CASE 5	54	L1-2 discectomy	Inappropriate surgery	L2-3 discectomy and partial laminectomy	3 months	2	Dissatisfied at 5 yrs.
CASE 6	48	L4-5 partial decompression	Repeatedly inadequate decompression	L4-5 laminectomy and lateral recess decompression	6 years	4	Dissatisfied
CASE 7	29	L4-5 discectomy	Developmental stenosis not recognised	L4-5 laminectomy	3 years	2	Dissatisfied at 7 yrs.
CASE 8	39	L4-5 and L5-S1 negative exploration	Developmental stenosis not recognised	L4-5 laminectomy	8 years	2	Satisfied at 4 yrs.
CASE 9	65	L4-5 discectomy	Inadequate transverse decompression	Emergency L4-5 laminectomy + lateral recess decompression	11 years	3	Satisfied at 2 yrs.
CASE 10	55	Right L4-5 discectomy	Inadequate transverse decompression	L4-5 laminectomy and left L4-5 discectomy	3 years	2	Satisfied at 4 yrs.
CASE 11	42	L4-5 discectomy + foramenotomy	Borderline inadequate decompression	L5 laminectomy and lateral recess decompression	9 years	2	Satisfied at 3 yrs.
CASE 12	59	L4-5 discectomy + L5-S1 exploration	Inadequate transverse decompression	L4-5 laminectomy and lateral recess decompression	12 years	2	Satisfied at 2 yrs.

Table 22:5. Summary of the cases reported. For details of surgery and the reasons for dissatisfaction at the final result, please refer to the text.

as patient selection improves and the first operation is tailored more closely to the patient's requirements then the proportion of patients who require re-operation should decline. This would result in a change in the pattern of patients presenting for further surgery, and presumably with conditions more resistant to surgery. Re-operation is unlikely therefore in the future to achieve the same high standard of results now obtained following the first operation. However fewer patients should require a second operation.

FACTORS ASSOCIATED WITH A FAVOURABLE PROGNOSIS FOLLOWING RE-OPERATION

Four factors can be identified before re-operation which are associated with a favourable result from surgery.

- (i) When a diagnosis of mechanical compression of a nerve root from either spinal stenosis or a disc fragment is made pre-operatively, the patient is more likely to obtain a good result from surgical relief of this compression. The cause of mechanical compression may have been unrecognised at the initial operation resulting in inadequate decompression, or may have developed some years after a previously successful operation.
- (ii) Secondly, when instability can be demonstrated, for instance progression of a degenerative spondylolisthesis or the development of a pseudarthrosis after spinal fusion for spondylolisthesis, the outcome is better with re-operation (Finnegan 1979).
- (iii) Thirdly the presence of a pain-free interval lasting one year from the date of the previous operation correlated highly with the presence of a surgically remediable lesion.
- (iv) Fourthly, the myelographic demonstration of a complete block indicating persistent or recurrent significant compression on the cauda equina, was associated statistically in Finnegan's series with an acceptable outcome from re-operation.

The importance of the relatively pain-free interval lasting approximately one year from the date of previous surgery was also noted by Hirsch and Nachemson in 1963 (Hirsch 1963). They noted a positive correlation between the early return of symptoms, that is in less than one year and quite often around six months following surgery, and the presence of dural scarring in a group of fifteen patients. The work of Finnegan confirmed the findings of Hirsch and Nachemson.

FACTORS ASSOCIATED WITH AN UNFAVOURABLE PROGNOSIS FOLLOWING RE-OPERATION

A diagnosis of perineural or intraneural fibrosis pre-operatively or intra-operatively portends a poor result. Patients without at least one year interval of freedom from pain tended to do poorly with re-operation (Rothman 1981). Their diagnosis is often arachnoiditis and scarring, and on a statistical basis they are the most resistant group to benefits of re-operation. Three principle factors therefore are associated with a poor result:

- (i) Firstly psychosocial instability
- (ii) Secondly lack of a pain-free interval, and
- (iii) Thirdly multiple previous operations .

These are amongst the most ominous factors to be found in most series. Finnegan reported that in a series of sixty-seven patients subjected to re-operation poor results were obtained when neurolysis was the major operative procedure and objective, and perineural fibrosis was the predominant diagnosis made at re-operation (Finnegan 1979). He also emphasised the importance of no pain-free interval or an interval of less than one year as signifying a poor prognosis. When the patients had a history of psychiatric treatment or were currently involved in compensation or litigation claims, or had previously undergone two or more operations on the lumbar spine, the results of further surgery were poor.

Some difficulty may exist in distinguishing between those patients who had no relief of symptoms following the initial operation because of permanent nerve root damage, from those patients who have no relief of symptoms because the main cause of their pain and disability was not addressed through inadequate surgery at the first operation. If in doubt it is mandatory to investigate these patients fully before reaching any conclusions.

AVOIDING SURGICAL PITFALLS IN SPINAL DECOMPRESSION

Two major problems were identified in the Nuffield Orthopaedic Centre series as responsible for the majority of patients requiring re-operation. The first was inadequate decompression usually in the horizontal or transverse plane, and the principle error was to simply remove the disc of a patient who required central and lateral recess and/or nerve root canal decompression. The second problem was that the correct operation was

performed at the wrong level. The third problem of failure to recognise developmental stenosis should be avoidable by increasing awareness now of this condition. We must therefore examine the methods which can be deployed to avoid both inadequate decompression and operating on the wrong level.

(a) Inadequate Decompression

The most important question is:

"Does this patient require simple fenestration and discectomy or formal decompression including the lateral recess and nerve root canals?"

- (i) This decision must be made pre-operatively on the basis of myelography and in difficult cases CT scanning. Myelography tends to under-diagnose lateral recess stenosis, and CT scanning to over-diagnose lateral recess and nerve root canal stenosis because of artefacts imposed by slice thickness.
- (ii) The finding of a pulsatile dural sac at operation and the surgeons ability to pass a probe proximally or distally in the canal does not exclude lateral recess or nerve root canal stenosis.
- (iii) The absence of extradural fat is strongly suggestive of spinal stenosis.
- (iv) With the patient's lumbar spine flexed on the operating table to open the interlaminar space, the volume of the spinal canal is increased (since the axis of intervertebral flexion/rotation lies anterior to the spinal canal), to conceal the fact that developmental or degenerative stenosis is present.
- (v) Dural abnormalities such as thinning, thickening and scarring, hour-glass constrictions and adhesions between dura and ligamentum flavum are strong indicators of spinal stenosis.
- (vi) Failure of the dural sac to pulsate either before or after the surgical decompression suggests the possibility of cephalad stenosis. However if the dura is thickened and scarred it may still not pulsate even after adequate decompression.
- (vii) If the nerve root is not visible or cannot be exposed by simple fenestration then lateral recess stenosis is probably present. In these cases to avoid excessive mobilisation and retraction of the nerve root, partial facetectomy and lateral recess decompression should be performed before mobilisation is attempted.
- (viii) Following decompression the intervertebral motion segment should be

moved to the extremes of its range and the nerve root observed.

If the nerve root is compressed or put under tension by this manoeuvre then decompression is inadequate. This applies particularly in patients with degenerative spondylolisthesis when abnormal inter-vertebral motion is present. Further decompression may be necessary and fusion required to restrict abnormal motion. Patients with degenerative spondylolisthesis routinely require segmental fusion following decompression.

- (ix) Discectomy alone is usually sufficient in patients under forty provided there is no developmental stenosis. In patients over fifty discectomy alone is inadequate and lateral recess and nerve root canal decompression are required because of degenerative hypertrophy of the facet joints.

(b) Inappropriate Surgery

This term usually implies poor patient selection, but in this context it indicates the correct operation has been performed at the wrong level. This is one of the commonest errors of spinal surgery. The problem usually occurs in the upper lumbar spine, and when operating in this region an operative radiograph is advisable. Even this is open to misinterpretation and must be viewed very carefully (and not from the far end of the operating room as the radiographer holds up the film against the window!) because of the changing spatial relationship of spinous processes with disc levels throughout the lumbar spine.

The majority of surgical procedures for spinal stenosis occur in the lower lumbar spine, and at this level the sacrum should always be exposed to verify the level. The following technical points should be noted to avoid operating on the wrong level:

- (i) At least two segments of the sacrum should be exposed since with a high incision the upper margin of the L5 lamina may be mistaken for the upper margin of the S1 lamina. Only when the solid fusion is seen between the laminae of S1 and S2 can the surgeon be certain of identifying the sacrum.
- (ii) In patients with transitional lumbo-sacral vertebrae there may be segmentation of the bodies only, segmentation of the neural arches only, or asymmetric segmentation. In this instance the operative findings must be correlated with the radiological (and CT) findings to determine the correct level. If in doubt, an operative radiograph is required.

- (iii) The shapes and sizes of the spinous processes are usually quite different at the L4-L5-S1 levels. These can often be easily identified from the antero-posterior radiograph. The L4 spinous process is often long and thick, the L5 spinous process shaped like an inverted "V" or even bifid, and the S1 spinous process fused to the S2 spinous process.
- (iv) The lower edge of the L5 lamina is usually prominent and sharp and angles up into the wound.
- (v) The percussion note obtained by tapping the sacrum is quite distinct (if the operation room and anaesthetic equipment is quiet) from that of the lumbar vertebra. It is higher pitched and less resonant.
- (vi) The application of towel clips to the spinous processes of L5 and S1 will allow the surgeon to check for mobility, and by working caudally, the last mobile segment can be identified. It is necessary to have a dry operative field and a clear view of the lamina and ligamentum flavum to observe minor degrees of movement. This technique can also be used to identify hyper-mobility in patients with degenerative spondylolisthesis.

These points are summarised in Table 22:6.

- | |
|---|
| <ol style="list-style-type: none"> 1. Identify two segments of sacrum 2. Correlate spinous processes with radiographs 3. Distinctive shape of L5 lamina 4. Percussion note of sacrum 5. Check mobility of segment 6. Beware transitional vertebrae 7. Operative radiograph if in doubt |
|---|

Table 22:6. Methods used to determine the correct level for surgery. One of the commonest errors of spinal surgery is to perform the right operation at the wrong level.

SUMMARY

It is essential that the clinician should not advise the patient who is unfortunate enough to have already suffered from one unsuccessful operation to undergo yet another operative procedure which again fails to bring about relief of symptoms. Hence the importance of patient selection and choice of operation. On the other hand it is essential he recognises that there is a small group of patients who will benefit from further operative intervention.

This remains a difficult decision requiring a considerable degree of clinical acumen, a thorough knowledge of the individual's personality and psychological make-up, and some insight into their domestic and working environment, in addition to a very careful thorough and methodical examination and investigation of the patient.

By appropriate pre-operative studies it should be possible to identify those patients with spinal stenosis, lumbar or lumbo-sacral instability, or pseudarthrosis which are amenable to further surgical treatment. On the other hand neurolysis alone yields poor results. The relief of mechanical compression from disc protrusion or bony impingement provides gratifying results. Similarly surgical stabilisation when appropriate often proves satisfactory. The importance of the "pain-free interval" is emphasised by a number of reports. The lack of a pain-free interval correlates strongly with significant intraneural and perineural fibrosis. Occasionally however the lack of a pain-free interval indicates inappropriate or inadequate surgery.

Compensation and litigation compromise the outcome of surgery. Evidence of psychosocial instability such as alcoholism, drug dependence or depression should be sought since this also adversely influences the results of surgery. Patients are often satisfied despite some residual disability particularly if their pain is relieved or reduced. However even satisfied patients may not be willing or able to work. Finnegan found that the overall results of re-operation were essentially unaltered between two and four years post-operatively (Finnegan 1979) and this is confirmed by the long-term follow-up after re-operation reported from the Nuffield Orthopaedic Centre.

Figures 22:7 and 22:8 illustrate two algorithms to assist in unravelling the complex problem of the patient who fails to respond to spinal decompression. Figure 22:7 is for patients whose predominant symptom is sciatic pain and Figure 22:8 for those with predominantly back pain. With improved understanding of the aetiology and management of patients with spinal stenosis, the proportion of patients requiring re-operation should diminish.

Only when organic pathology (which correlates with the clinical presentation) has been clearly defined and is surgically remediable, should the patient be offered further surgery. The surgeon must seriously consider the degree to which any psychosocial disorder or ongoing litigation is influencing the clinical presentation before opening any discussion with the patient on the possible benefits of re-operation.

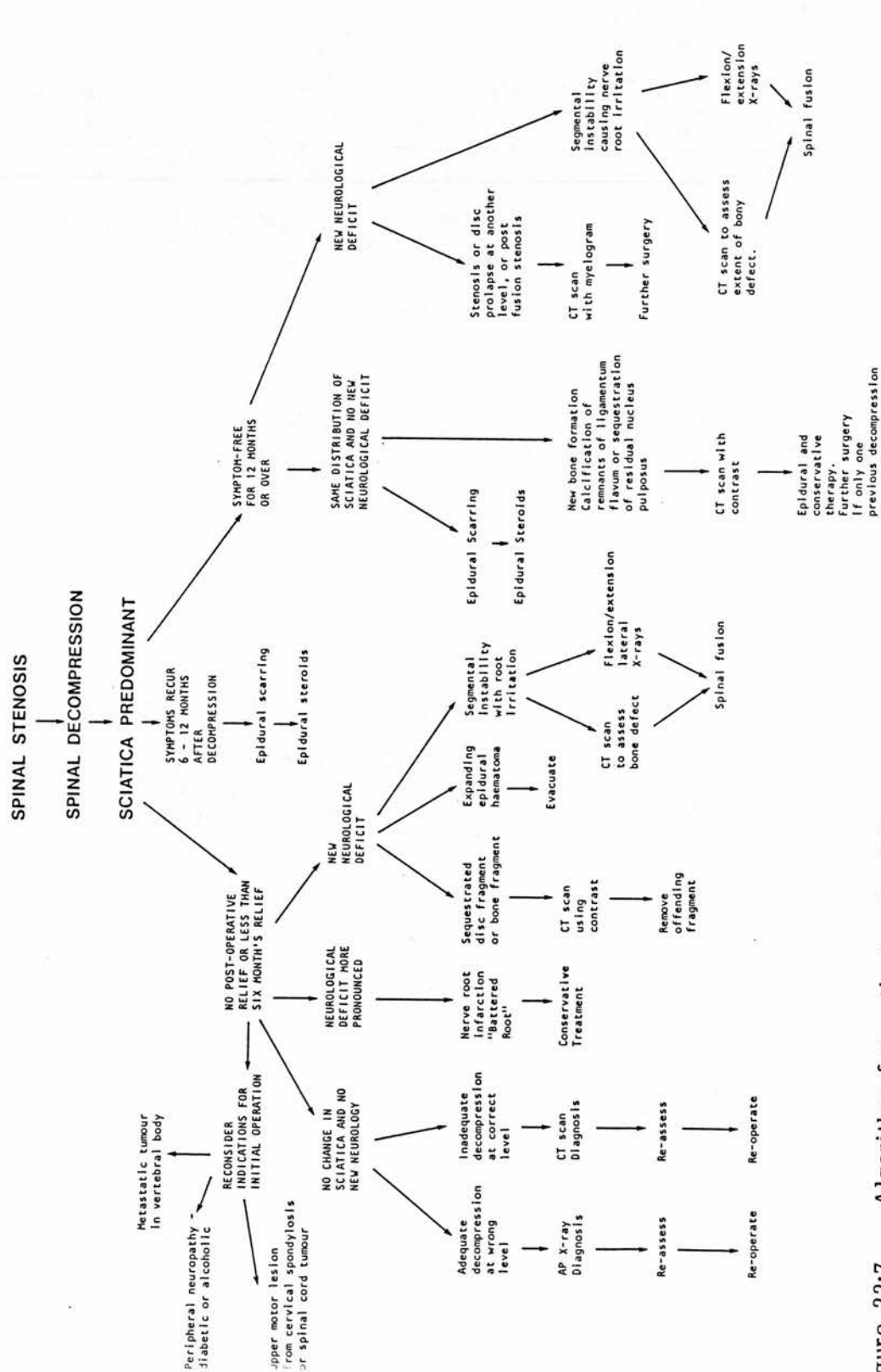


Figure 22.7. Algorithm for patients who fail to respond to spinal decompression because of persistent or recurrent sciatic pain, indicating which category of patient may be suitable for re-operation

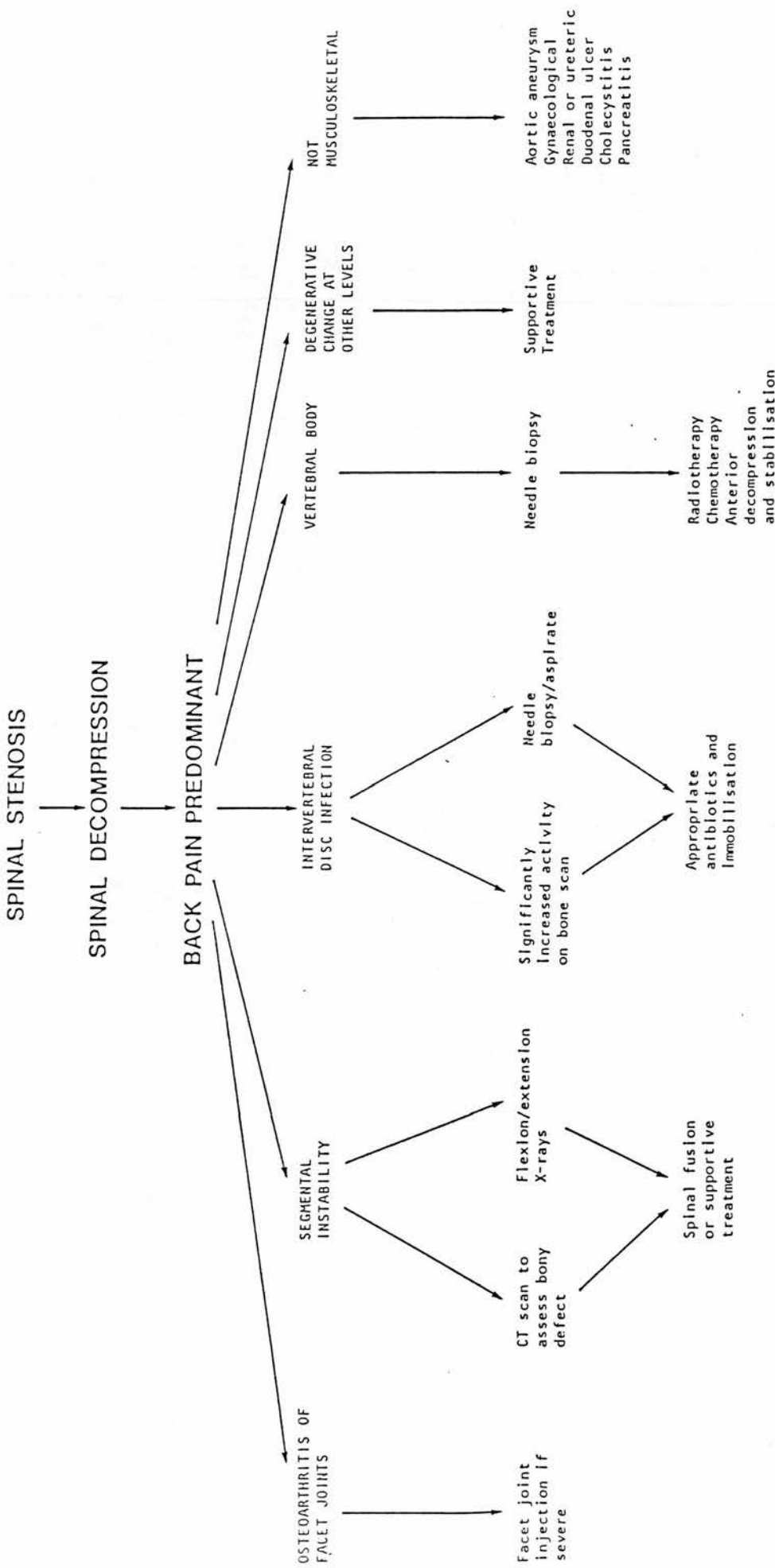


Figure 22:8. Algorithm for patients who fail to respond to spinal decompression because of persistent or recurrent back pain, indicating which patient may be suitable for re-operation

CHAPTER 23

SUMMARY

Spinal stenosis is narrowing of the spinal canal, lateral recess and/or nerve root canals which occurs secondary to developmental, degenerative, or deforming disorders of the spine. This narrowing is of little importance until the critical point is reached at which the neurological contents of the canal are compromised, resulting in the clinical syndrome of spinal stenosis. The clinical presentation, diagnosis and treatment of two hundred and twenty-one patients with spinal stenosis treated at the Nuffield Orthopaedic Centre was reviewed and analysed. Initially neurological compression occurs only after exercise or during spinal extension and is rapidly relieved by spinal flexion, but as compression increases the patient may experience sciatica on standing (postural claudication) even night pain.

The characteristic presentation in the early stages is neurogenic claudication which can be distinguished from vascular claudication by a careful history, but in the later stages severe unremitting sciatic pain develops with progressive loss of motor power and sensation to the lower limbs and subsequently loss of bladder and bowel control. Two-thirds of patients with spinal stenosis can be managed conservatively, but one-third require surgical decompression.

Spinal stenosis occurs when there is disproportion between the volume of the spinal canal and nerve root canals and the volume of their contents. Measurements of the antero-posterior and transverse diameters of the spinal canal either radiologically or at operation provide only an approximate guide to the condition and will consistently under-diagnose degenerative and lateral recess stenosis and nerve root canal stenosis in which the spinal canal shape is trefoil and the antero-posterior diameter preserved. The antero-posterior diameter of the dural sac measured on myelography is however a useful indicator of the presence of developmental stenosis. Inspection of the dorso-lateral aspect of the contrast column as seen on the oblique projection (opposite the nerve roots) provides invaluable information on laminar and/or ligamentum flavum indentation of the canal. Computerised tomography is the most valuable investigation at present for all forms of spinal stenosis, and permits measurements of cross-sectional area of the spinal canal and neurological contents, from which the "spinal reserve capacity" (or difference between the two) can be measured. This is one

of the most helpful indicators of spinal stenosis, but false negatives occur in lateral recess and nerve root canal stenosis. Computerised tomography, using either intrathecal or intravenous contrast materials, provides useful information particularly if re-operation is being considered.

Computerised tomography provides little information about the dynamics of the spinal canal, and in this respect radiculography provides more information. Using the latest radiographic equipment it is possible to perform erect/supine/prone and flexion/extension erect screening of the spine focussing on the filling and emptying of individual nerve root dural sleeves during these manoeuvres. The volume of contrast required to fill the dural sac and the pressure at which contrast must be injected to overcome a "block" provide invaluable information on the important dynamics of the spinal canal.

The volume of the spinal canal increases on spinal flexion and is reduced during extension. At the same time on extension the nerve roots of the cauda equina become shorter and their diameter increases. In borderline cases of stenosis only radiculography in extension will detect a spinal "block". Screening should be performed with the patient erect since the diameter of the degenerate annulus is increased during loading. During spinal extension the superior articular facet moves cephalad into the nerve root canal to guillotine the nerve root and the inferior articular facet intrudes into the central canal behind the bulging ligamentum flavum. Erect spinal flexion and extension views should therefore be routinely performed at radiculography.

Magnetic resonance imaging of the spine is likely to supercede computerised tomography only when the software permits sections of comparable thickness to be obtained. At present the section thickness is too great to permit detailed inspection of the spinal canal. When it becomes possible to image the nerve roots using magnetic resonance, this will provide the ultimate investigation, since nerve root oedema and inflammation should be obvious.

The structures responsible for canal narrowing are either soft tissue, or bony, or both. The spinal canal may not have grown to its full dimensions owing to familial, or constitutional factors, or childhood trauma to the neurocentral growth plate. In such patients developmental stenosis occurs with only minor soft tissue (a disc prolapse) or bony (degenerative osteophytes) change and usually presents in the third, fourth, or fifth decade. Patients with degenerative stenosis are usually in their sixth

decade, but there is clearly considerable overlap between the different groups (Fig. 23:1).

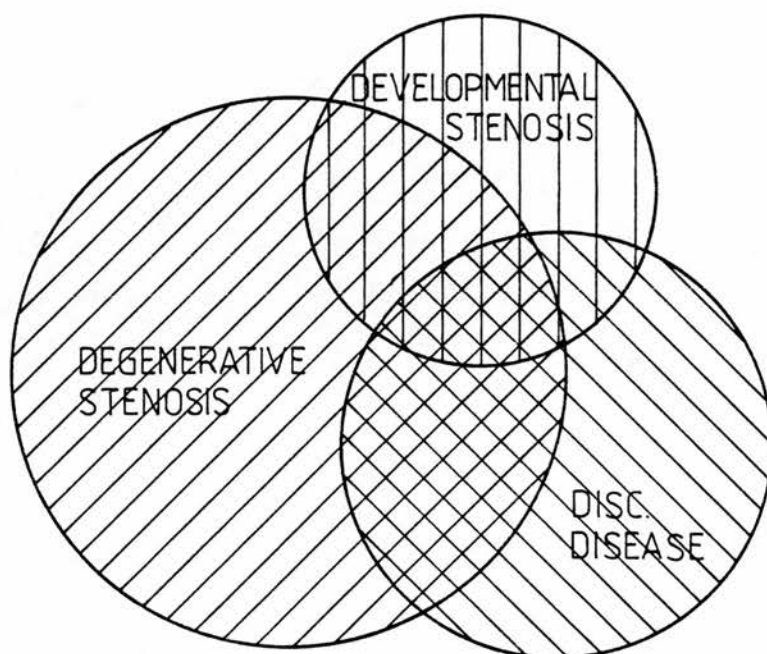


Figure 23:1. The groups of degenerative stenosis and developmental stenosis overlap considerably. Degenerative disc disease overlaps with both groups separately and together.

Why do some patients with considerable degenerative disease of the lumbar spine have no symptoms of spinal stenosis whilst others with only minor degenerative disease have severe stenosis? The answer is probably that the critical point of neurological compression is reached much earlier when the spinal reserve capacity is less than normal at the end of skeletal growth. It would clearly be unethical to examine the spinal reserve capacity of a normal population of young adults, but it is important to consider what factors may result in failure of the spinal canal to achieve its normal reserve capacity. Trauma, for instance, may damage the neurocentral growth plate between pedicle and body resulting in short pedicles. There are no reports however of the effect of sub-laminar wiring in the juvenile on the growth and development of the spinal canal. This is important in view of the more frequent use of sublaminar segmental spinal instrumentation in the correction of spinal deformities and in stabilisation of the lumbar spine.

An animal model was developed using thirty-four eight week old New Zealand white rabbits. Sublaminar wiring was performed at three levels, with the wire tight at one level, slack at the next with the ends long to encourage movement of the wire as the animal moved, and at the third level

the lamina was deliberately fractured and the wire tight. Other levels were exposed but not instrumented to act as ipsilateral controls and the contralateral side was neither exposed nor instrumented to act as normal controls.

The rabbits were allowed to grow to twenty-four months before sacrifice and harvesting of the spines. Radiographs of the spine confirmed the macroscopic appearance that sublaminar wires had resulted in longitudinal overgrowth of the lamina to produce a kypho-scoliosis, convex to the instrumented side.

The instrumented segment of spine with two normal segments above and below was then preserved and vacuum fixed in L.R. White Resin. This is a low viscosity resin which permeated the whole specimen without the necessity for further dissection. After curing it was hard enough for 2 mm. sections or discs to be cut without any wire movement or pulling out.

An Ibas Kontron Analytical Image Analysis Computer was used by courtesy of the Department of Human Anatomy at the University of Oxford for morphometric analysis of the effects of sublaminar wiring on growth and development of the lamina and spinal canal. These effects included significant laminar thickening on the instrumented side of up to four times both series of controls ($p < 0.001$). Significant intrusion of the thickened lamina into the spinal canal was also noted ($p < 0.001$). The overall cross-sectional area of the spinal canal was however not consistently and significantly compromised ($p < 0.1$).

This suggests that during growth and development the spinal canal is able to compensate for significant bony intrusion in one dimension by expansion of the canal in other dimensions. This work supports the concept proposed for the embryological development of the spinal canal, that the sliding or gliding movement of the neurological structures combined with the pulsatile action of the dura and blood vessels within the canal influence the shape and volume of the canal during growth and development. Indirect evidence for this is the groove on the under-surface of the enlarged pedicle of the fifth lumbar vertebra which is created by the fifth lumbar nerve root. Sublaminar wiring of the immature spine is therefore unlikely to result in developmental stenosis.

The morphology of a lumbar nerve root is different in a number of important respects from that of a peripheral nerve. The supporting connective tissue, lymphatics and blood supply of the lumbar roots are

unique. Focal nerve root compression or ischaemic neuritis which produces nerve root oedema result in intraneural fibrosis, since nerve root lymphatics are inadequate to remove interstitial oedema. Intraneural fibrosis and loss of Schwann cells may permit the electrical impulse of a motor efferent to short circuit to the low threshold pain afferent producing a type of "artificial synapse". This provides yet another explanation of sciatic pain on exercise in patients with spinal stenosis. Since intraneural fibrosis is irreversible it also explains why some patients following adequate surgical decompression continue to suffer neurogenic claudication.

Two-thirds of the two hundred and twenty-one patients reviewed were managed conservatively. A spinal corset was superior to all other methods of conservative treatment. Seventy-two were managed surgically by central decompression, lateral recess decompression, nerve root canal decompression, and fusion when indicated. All patients with stenosis secondary to degenerative spondylolisthesis requiring decompression were fused primarily. The disc was preserved when not contributing to stenosis to preserve intervertebral height and maintain stability. The facet joints were seldom removed, but a partial under-cutting facetectomy was invariably performed. The results of surgery were inferior when lateral recess decompression was not performed.

Eighty per cent of patients obtained relief or reduction of sciatic pain following surgical decompression. The initial results of surgery within one month of the operation were compared with the long-term follow-up which extended to ten years but averaged three years and ten months. Forty per cent of patients reported further improvement of sciatic pain during follow-up and in some further recovery of sensation and reflexes occurred.

Motor recovery occurred less frequently although patients often reported that their legs felt stronger. Overall pin prick sensation improved in fifty per cent of patients and the ankle reflex was restored in thirty per cent of patients following surgical decompression. This suggests that despite intraneural fibrosis the nerve root retains some potential for recovery following decompression. Subjective improvement was considerably greater than objective improvement with eighty per cent patient satisfaction following surgery. Twenty per cent of patients who failed to respond to surgery had an operative dural tear (cf. five per cent in the satisfactory results). This represents technical difficulties encountered during surgery in some patients particularly with nerve root adhesions and

adhesions between the dural sac and ligamentum flavum in severe stenosis.

Twelve patients were treated surgically for post-laminectomy stenosis. These patients were usually referred to the Nuffield Orthopaedic Centre after failure to respond or following relapse post-operatively. The reasons for re-operation were analysed. Two principle groups were identified: firstly those in whom decompression had been inadequate in either the horizontal or longitudinal dimension, and secondly those in whom developmental stenosis had not been recognised resulting again in inadequate decompression.

Only sixty per cent of patients were satisfied following re-operation, partly because of pre-existent arachnoiditis and possibly because of permanent nerve root damage. Patient selection is crucial if good results are to be obtained, and to assist in this process two algorithms, one for persistent sciatic pain, and one for persistent back pain, have been formulated from the above analysis. Careful electrophysiological studies both pre-operatively and intra-operatively may be useful in the management of this group of patients.

The surgical techniques employed for spinal decompression, lateral recess decompression, nerve root canal decompression, post-laminectomy decompression, and for spinal fusion are all described and illustrated in detail.

Improved understanding of the aetiology of spinal stenosis has enhanced surgical management and results. The extent of surgical decompression must be precisely planned pre-operatively from radiographic and CT studies, and the surgeon must be able to execute this plan at operation. There is now no place for spinal exploratory operations. The objective of surgery is adequate nerve root decompression without spinal de-stabilisation, and when this is achieved re-operation is redundant.

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