Certificate identifying Exhibit 'HVC-6'

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Date:	11 September 2012

This is the exhibit marked 'HVC-6' referred to in the affidavit of Henry Vernon Crock sworn / ~~affirmed~~ at ~~T~~oorak in Victoria on 11 September 2012.

Before me: ____________________

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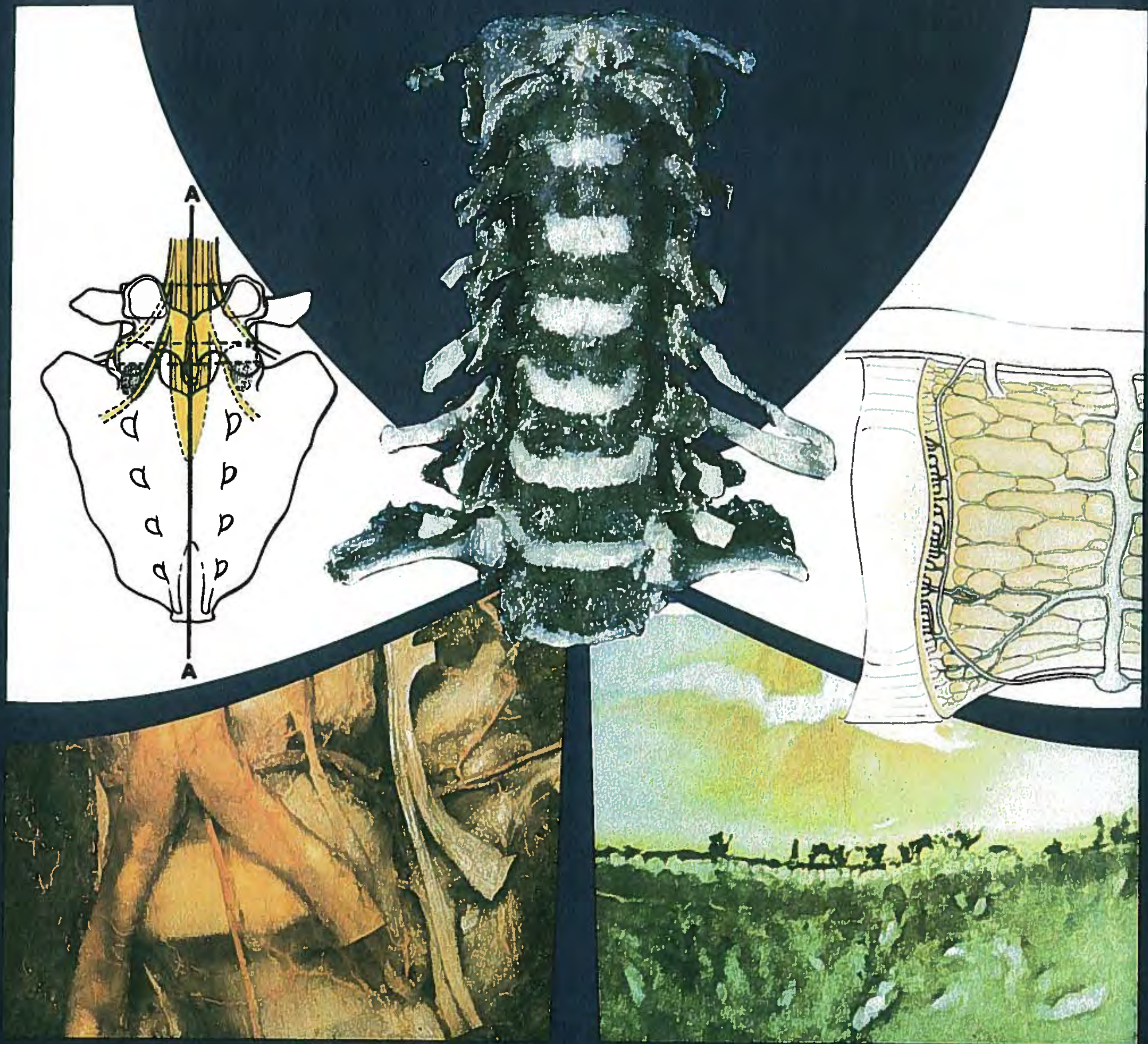
H. V. CROCK PRACTICE OF SPINAL SURGERY

With a Contribution on The Management of Spinal Injuries by Sir George Bedbrook



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H. V. Crock

Practice of Spinal Surgery

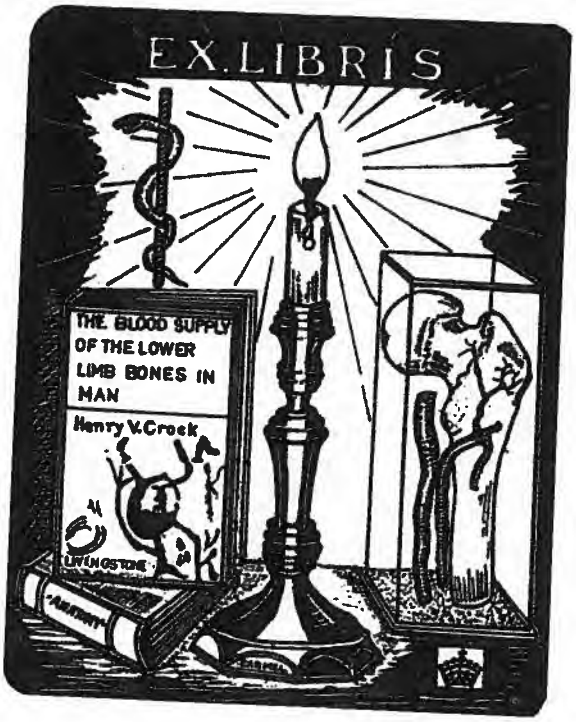
With a Contribution on The Management of Spinal Injuries by Sir George Bedbrook

This book presents the management of major spinal problems in a new light. Emphasis is placed on the recognition and treatment of the disabling forms of disc disease and disc injury, which can now be distinguished from the less common problems of disc prolapse.

The relevance of surgical anatomy is highlighted in relation to individual pathological problems, and applied anatomy is integrated with descriptions of surgical techniques in each chapter.

Disc disorders, spondylolisthesis, spinal canal and nerve root canal stenosis, spinal infections, the surgery of the cervical spine, and the management of failed spinal operations, are subjects covered by Dr. H. V. Crock. Disc prolapse is placed in a new perspective, and this contribution alone may save many patients from unnecessary or even disastrous operations.

Spinal surgical techniques are described and illustrated in considerable detail in each chapter.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THE BLOOD SUPPLY OF THE LOWER LIMB BONES IN MAN
Henry V.Crock
LIVINGSTONE

The First Copy of this book
received in Melbourne on
Monday September 19. 1983.

for Carmel

with all my love.

Harry.

Henry V. Crock

Practice of Spinal Surgery

With a Contribution on
The Management of Spinal Injuries
by Sir George Bedbrook

Springer-Verlag
Wien New York

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Foreword

It is not long since surgery of the spine dealt with fracture-dislocation and tuberculosis, little else. With the advent of contrast X-ray and anatomical study a wide range of disease entities has been categorized and become the subject of corrective and ameliorative treatment.

The principal author of the present book has played a distinguished part in widening knowledge of the anatomy of the bones, ligaments, blood vessels, neural features and the natural history of diseases relevant to hard structure disorder. He has done this in relation to the development of highly refined surgical techniques based strictly upon structural requirements in relation to the disease processes under treatment. The result is a comprehensive account of his integrative conceptualisation and the relevant principles of the methods used. His component, the major part of the book, is in the tradition of John Hunter, Bland Sutton, Kanavel and others who improved their understanding and treatment by the discipline enforced by the discipline of basic investigation. In the era of proliferation of specialties and books of single author chapters it is refreshing to meet one man's mind extended.

By Sir George Bedbrook adding the fruits of his years of experience and thought about the treatment of spinal injury the book is enriched. As the best of two investigative practitioners, it reflects the best features of the surgical calling and should be studied not only for its material but especially for its reflection of high professional endeavour.

Melbourne, June 1983

Professor Emeritus Sir Douglas Wright
Chancellor, University of Melbourne

Preface

In writing this book I have attempted to prepare a document which may prove of practical use to surgeons in what I see as a phase of transition in spinal surgery.

This book will be published nearly fifty years after Mixter and Barr's historic description of intervertebral disc prolapse–an entity now in eclipse.

Since the mid 1950s emphasis has moved to the more common problems of spinal canal and nerve root canal stenosis–the latter being caused in some cases by quite a different form of disc disease–isolated disc resorption.

Let us not forget that there are two laboratories from which progress in medicine may emanate: the laboratory of the field–clinical practice, the chief investigator being the busy practitioner; and the other–laboratories of our great medical scientific institutions.

In this book I have attempted to focus attention on a particular clinical problem described in Chapters 2 and 7 as Internal Disc Disruption. I believe that the study of the histochemistry and immunology of internal disc disruption presents a formidable challenge for science in the 1980s. This is a challenge which will only be met effectively by the joint efforts of clinicians who recognize this disabling entity and who can provide fresh disc tissues from their patients for analysis and study by those qualified to identify biochemical abnormalities in living tissues.

Perhaps that will be the direction of the next leap forward.

Melbourne, June 1983 *Henry V. Crock*

Acknowledgements

This book is based on experience gained in the past twenty years in busy practice and in orthopaedic research carried out at St. Vincent's Hospital, in the University of Melbourne. I am deeply grateful to the Sisters of Charity for their help in supporting my work.

During that time it has been my pleasure to have many visiting international fellows work with me, to all of whom I express my thanks. Among this group I single out for special thanks:

Dr. S. Sihombing (Indonesia), Professor P. R. Chari (India), Dr. S. K. Kame (India), Dr. A. Fujimaki (Japan), Mr. Robert Venner (Scotland).

Dr. H. Yoshizawa (Japan), co-author of one of my books, has continued to inspire me.

I wish to thank my orthopaedic colleagues throughout Australia, especially from Tasmania, who have referred many difficult cases on which my clinical experience has been built. Many of my ideas on the nature of intervertebral disc disorders evolved during my association with a remarkable physician, the late Dr. Joseph Silver Collings, to whose memory I wish to pay homage.

The following surgeons have kindly given me illustrations for use in this book; Messrs. B. J. Dooley, J. Cloke, B. Davie, C. Haw, J. K. Henderson, and K. Mills.

Experience with the use of special surgical techniques such as those required for anterior interbody fusion operations, can only be acquired slowly, with help from anaesthetists, general and thoracic surgeons. I thank my anaesthetic colleagues for their patience, Drs. E. Kenny, J. Forster, W. Stanisich, I. Sutherland, and D. Taylor who, from his vantage point at the head of the operating table, has designed an excellent retractor for use during these operations.

I am deeply indebted to the following general surgeons; Messrs. P. K. Steedman, I. Vellar, B. Collopy, J. L. Connell, and the late E. Ryan. I wish to thank Messrs. J. K. Clarebrough and A. Wilson for teaching me the principles of thoracic surgery applied to spinal operations.

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The Frontispiece was prepared by Tate Adams of Melbourne, one of the greatest living woodblock artists. The author's portrait on the jacket was drawn by Louis Kahan, an old family friend.

Most of the drawings in this book have been prepared by Dayle Howat. I thank him sincerely for his splendid work.

A number of drawings have been prepared by one of my international Fellows, Dr. Hideki Matsuda from Osaka, Japan. He has inherited an artistic talent from his father, a talent which he put to good use on my behalf. I thank him sincerely for his contributions.

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To my colleagues in Paris, Professor Jean Cauchoix and Dr. J. Zucman, I express particular thanks for their help in translating and facilitating the publication of my work on nucleus pulposus calcification.

Professor R. C. Bennett, Professor of Surgery, St. Vincent's Hospital, Melbourne, has continued to support my work over many years.

The tedious process of criticism on which the final quality of a manuscript depends so heavily has been undertaken once again by my friend, Dr. W. McCubbery. The manuscript has also been checked carefully by my wife, Dr. M. C. Crock, and by Dr. Paul DiMartino from New York.

My wife has performed some of the anatomical dissections, photographs of which are reproduced in this book. For fifteen years she has assisted at surgery during all my private operations. Without her help and the forbearance of my children, this book may never have been published.

My children, Elizabeth and Damian, have helped with secretarial work, Vernon with photographic work and Catherine and Carmel with constant encouragement.

I owe a special debt of thanks to my identical twin brother, Professor G. W. Crock of Melbourne.

The preliminary typing of the manuscript was done by my secretary, Mrs. Sandra Koukouras. However, the real burden of preparation of this manuscript has fallen on Mrs. Beverley Vaudrey.

I am grateful to Professor Emeritus Sir Douglas Wright, Chancellor of the University of Melbourne, my former teacher, mentor and friend, who has kindly agreed to write the Foreword.

Finally, I wish to thank my Publishers, Springer-Verlag in Vienna, particularly Mr. Frank Chr. May for his untiring help and careful attention to details, and especially Dr. W. Schwabl for his constant encouragement.

Henry V. Crock

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Introduction

Nineteen hundred and thirty four marked a turning point in the history of the understanding of sciatica when Mixter and Barr's paper on rupture of the intervertebral disc was published in the New England Journal of Medicine. In 1927 Putti had drawn attention to the importance of facet osteoarthritis as a cause of sciatica. His work was overshadowed by the impact of the description of prolapse of the intervertebral disc. Indeed the entity of prolapsed disc soon emerged as the only intervertebral disc lesion which was considered in dealing with the clinical problems of sciatica.

Dandy (1941) hinted at the need for a wider understanding of intervertebral disc pathology in his short paper on "Concealed Ruptured Intervertebral Discs", but once again the profound influence of the concept of disc prolapse held sway and his work also was overshadowed. In 1957 Morgan and King drew attention to the derangement of movement which may occur between adjacent vertebrae due to circumferential and incomplete radial annular tears within the discs, as a cause of backache. This paper presented an important new concept in the understanding of disc pathology applied to clinical practice, yet it failed to receive wide acclaim. The biophysical basis of their observations has since been expounded by Farfan *et al.* (1970) in their paper "The Effects of Torsion on the Lumbar Intervertebral Joints: The Role of Torsion in the Production of Disc Degeneration."

Without doubt, Mixter and Barr's work, viewed in historical perspective over the past 48 years, has exerted a profound effect on the practice of medicine relating to the diagnosis and treatment of sciatica. They presented for the first time a simple concept to explain the basis of this age-old scourge.

The impact of this work has been such, that, since its publication, every medical graduate in the world has had some familiarity with prolapse of the intervertebral disc.

Paradoxically the powerful psychological impact of this work on medical practitioners has had a number of adverse reactions. Their acceptance of the concept has tended to be blind, so that clinically, they recognize no other disc pathology apart perhaps from the vague entity of disc degeneration, widely held to be a cause of back pain. By adopting this exclusive view of disc pathology some are apt to develop aggressive attitudes and behaviour towards patients whose problems they have diagnosed as being due to disc prolapse. This is particularly so if the patient continues to complain of pain after surgery for suspected disc herniation, when none was actually found.

Even among radiologists attitudes have been strongly conditioned, so that many think of intervertebral disc pathology exclusively in terms of its capacity to produce space-occupying lesions within the vertebral column. Many are not aware of the existence of non-prolapsing disc disorders. Likewise, many neurologists have adopted a purely mechanical view of disc pathology; as a result, their concept of sciatica due to disc disease relates strictly to nerve-root impingement, pain without "signs" being beyond their imagined view of the pathology.

In the 1950s the view prevailed that prolapse of the intervertebral disc was the most common cause of low back pain and sciatica, a view which became tradition to the detriment of many thousands of patients. *Disc prolapses may be the cause of back pain and sciatica in only a small percentage of all the patients who complain of those symptoms.* Sciatica from this cause is usually unilateral and if surgery is indicated, the result of excision of the disc fragments is usually excellent. What deserves to be recognized is the fact that the results of operations for suspected but non-existent disc prolapses are often disastrous.

The recognition in recent years of a range of disorders of the intervertebral discs has made a significant difference to the results of their surgical treatment. Lesions such as prolapsed intervertebral disc and isolated disc resorption produce their adverse clinical effects mechanically, while others, such as post-traumatic internal disc disruption and nucleus pulposus calcification have complex biochemical abnormalities which probably cause pain at histochemical levels.

The four principal disorders of intervertebral discs discussed in the following chapters will be presented in order of their frequency in clinical practice.

1

Nerve Root Canal Stenosis

1.1. Isolated Lumbar Disc Resorption

This condition is characterized by gross narrowing of one affected disc space, with sclerosis of the adjacent vertebral bodies. Occurring commonly as an isolated affection in an otherwise normal lumbar spine, even late in life, it is seen most commonly at L5/S1, occasionally at L4/5 and rarely at L3/4.

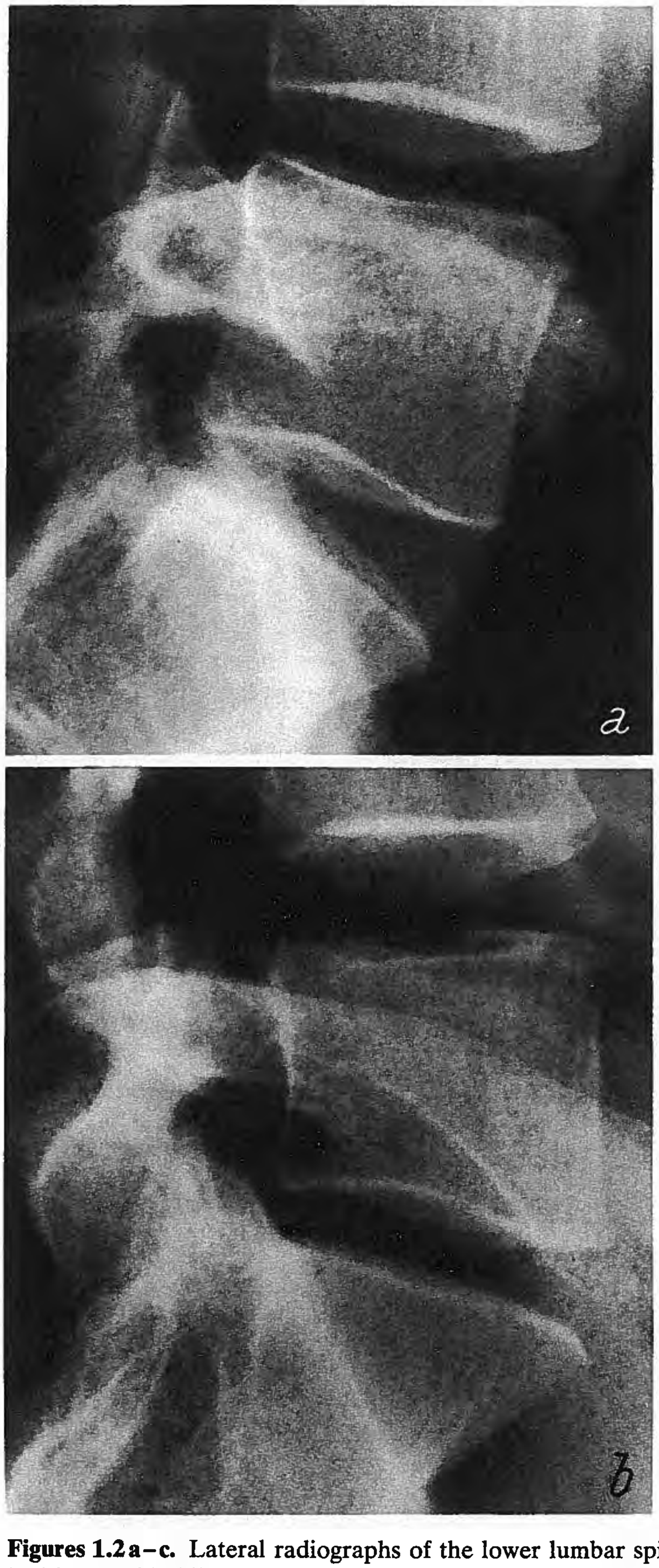
Attention was drawn first to the importance of "reduced lumbo-sacral joint space: its relation to sciatic irritation", by Williams in 1932. The term *isolated disc resorption* was coined by Crock in 1970, though he was unaware of the existence of Williams' paper at that time.

Isolated disc resorption causes back and leg pain more commonly than does prolapse of an intervertebral disc. This condition therefore assumes great clinical importance and warrants identification as a specific form of disc disease. By combining observations on the pathological findings in isolated disc resorption with a sound knowledge of surgical anatomy, different forms of surgical treatment can be planned to suit individual cases. When these cases are treated by the standard operation of "laminectomy" used in the management of disc prolapse, the results are often poor, whereas excellent results may be obtained by performing *bilateral nerve root canal decompressions* or more rarely by performing some form of local spinal fusion.

a) Natural History

This condition of narrowing of a single lumbar intervertebral disc space usually progresses slowly over a number of years, the clinical course being punctuated by repeated bouts of acute low back pain lasting for three to four days and then resolving completely. Following trauma, particularly a fall on to the buttocks, the symptoms may extend to include severe bilateral buttock and leg pains. In some cases buttock and leg pain may be aggravated by physical exercise or walking. The description *nerve root claudication* may then be used to describe this particular symptom pattern.

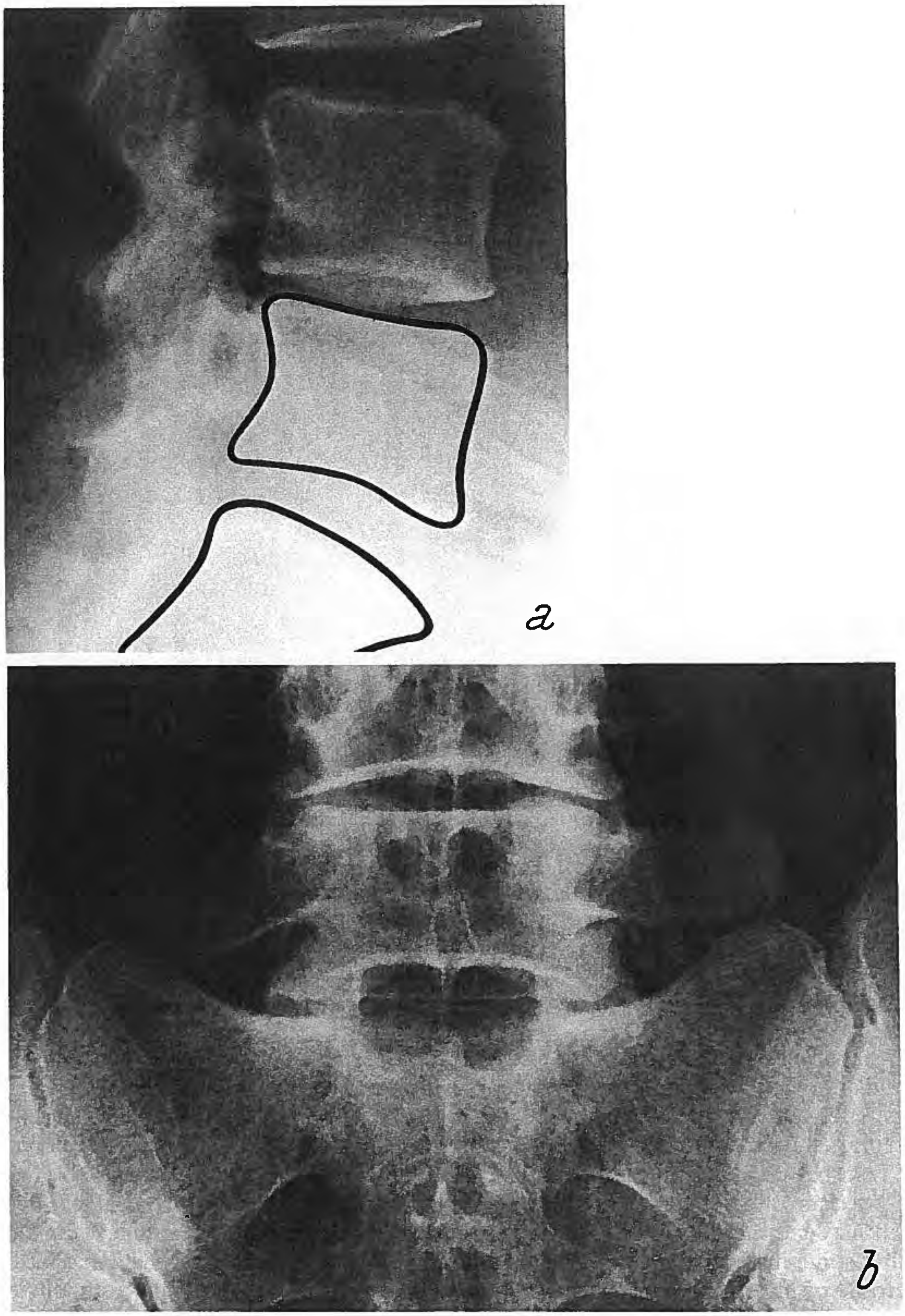
Figure 1.1. A lateral radiograph of the lumbar spine of a 48 year-old man showing the classical features of isolated disc resorption at the lumbo-sacral junction



Figures 1.2 a–c. Lateral radiographs of the lower lumbar spine in a 39 year-old woman who had intractable bilateral buttock pain and unilateral leg pain. Films taken in 1970 **a,** 1972 **b** and 1974 **c** illustrate the progressive narrowing of the lumbo-sacral disc in a case of isolated lumbar disc resorption

Figure 1.2c

Figure 1.3



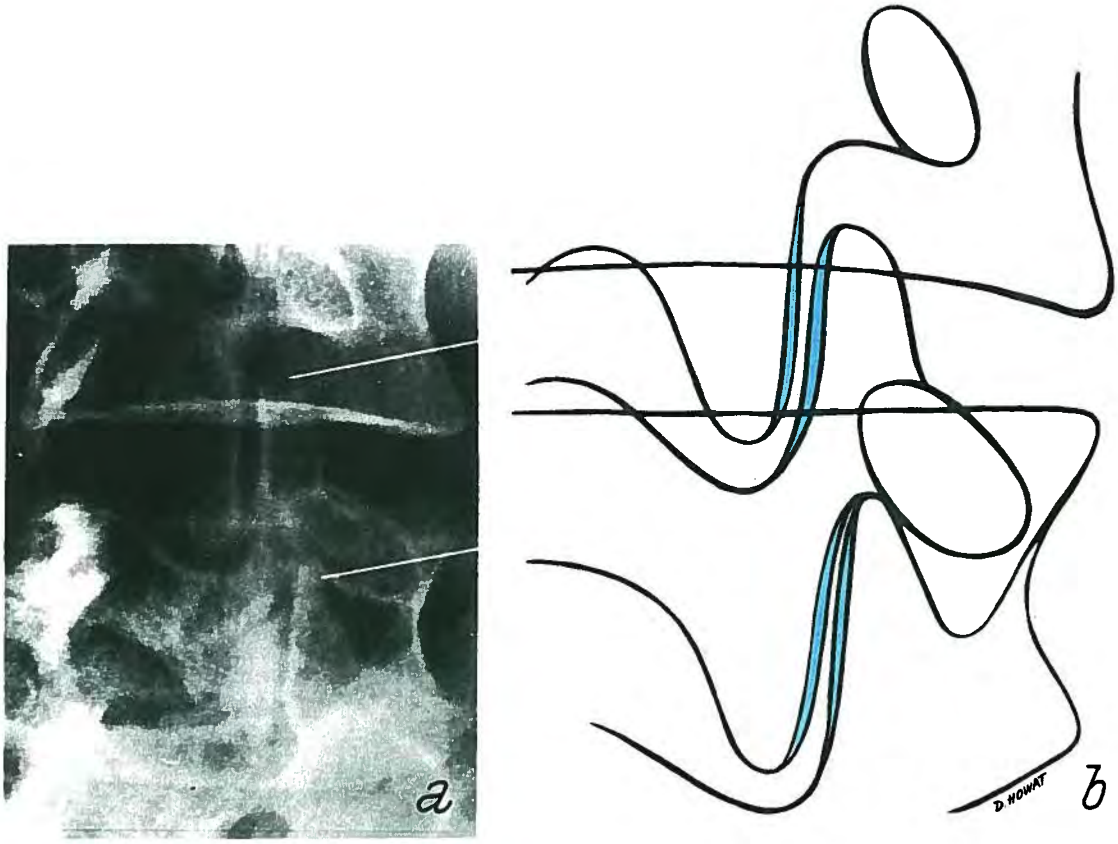
Figures 1.4 a and **b.** Isolated disc resorption at L4/5. A 48 year-old woman had longstanding back pain, with bilateral leg pain. She was treated by bilateral nerve root canal decompression laminectomy. The L4/5 disc was not disturbed at operation. **a** Lateral radiograph, and **b** antero-posterior radiograph of the spine showing features of isolated disc resorption at the L4/5 level, the vertebral end-plates remaining parallel to each other in (b)

Figure 1.3. A lateral radiograph of the lumbar spine of a woman aged 52 years showing a normal L4/5 disc space and isolated disc resorption at the L5/S1 level. The familiar vacuum sign described by Knuttson is seen

Figure 1.5. A photograph of a mid-line sagittal section of the lumbar spine of a man aged 69 years. The pathological features of isolated disc resorption are well shown, with vertebral end-plate remnants in the posterior two-thirds of the disc space visible on either side of an otherwise empty disc space. Note the marked sclerosis of the vertebral bodies on either side of the disc space

In parallel with the natural history of the symptoms, repeated radiological examination will reveal a progressive loss of disc height at the affected level (Figs. 1.2 a–c). In the lower lumbar region in adults, the disc height between adjacent vertebral end-plates ranges from 10–15 mm. In established cases of isolated lumbar disc resorption the height of the intervertebral disc space may be reduced to 3 mm. The vacuum phenomenon of Knuttson is another prominent radiological feature which may become evident if the X-ray is taken with the patient standing with the lumbar spine hyperextended. A black gas shadow will then appear in the disc space. Sclerosis of the adjacent vertebral bodies is found, while marginal osteophyte formation is minimal. Occasionally a ridge of bone covered with a thin layer of annular fibre remnants may be found projecting into the spinal canal (Figs. 1.3–1.5). For example at L5/S1 subluxation of the facet joints with intrusion of the superior facets of S1 into the intervertebral foramina and lumbar nerve root canals will also be seen (Figs. 1.6 a, b).

The disc space narrowing which accompanies sacralization anomalies is not to be confused with that occurring in isolated lumbar disc resorption.



Figures 1.6a and **b.** An oblique view of the lower lumbar spine showing normal relationships of the facets of the L4/5 level, top marker, and subluxation of S1 up against the pedicle of L5 on the bottom marker, with an explanatory line drawing alongside

In established cases where the disc space has become very narrow, with parallel vertebral end-plate settling, the symptoms of buttock and leg pain, if intractable, are usually bilateral.

Earlier in the course of this disease, a small number of patients may present with unilateral sciatica. These patients may exhibit the classic features of neurological defects in either L5 or S1 nerve roots. Usually they will be found to have a sequestrated fragment of vertebral end-plate cartilage impinging on the affected nerve root. This finding is one of the striking features of this disease process. At operation in such cases, the disc space is virtually empty and clearly recognizable necrotic vertebral end-plate cartilage will be found causing the nerve root compression.

b) Anatomy of Nerve Root Canals

i) Normal

The anatomy of the lumbar nerve root canals and intervertebral foramina will be described to assist with the understanding of the genesis of the symptoms and signs which may occur in cases of isolated disc resorption.

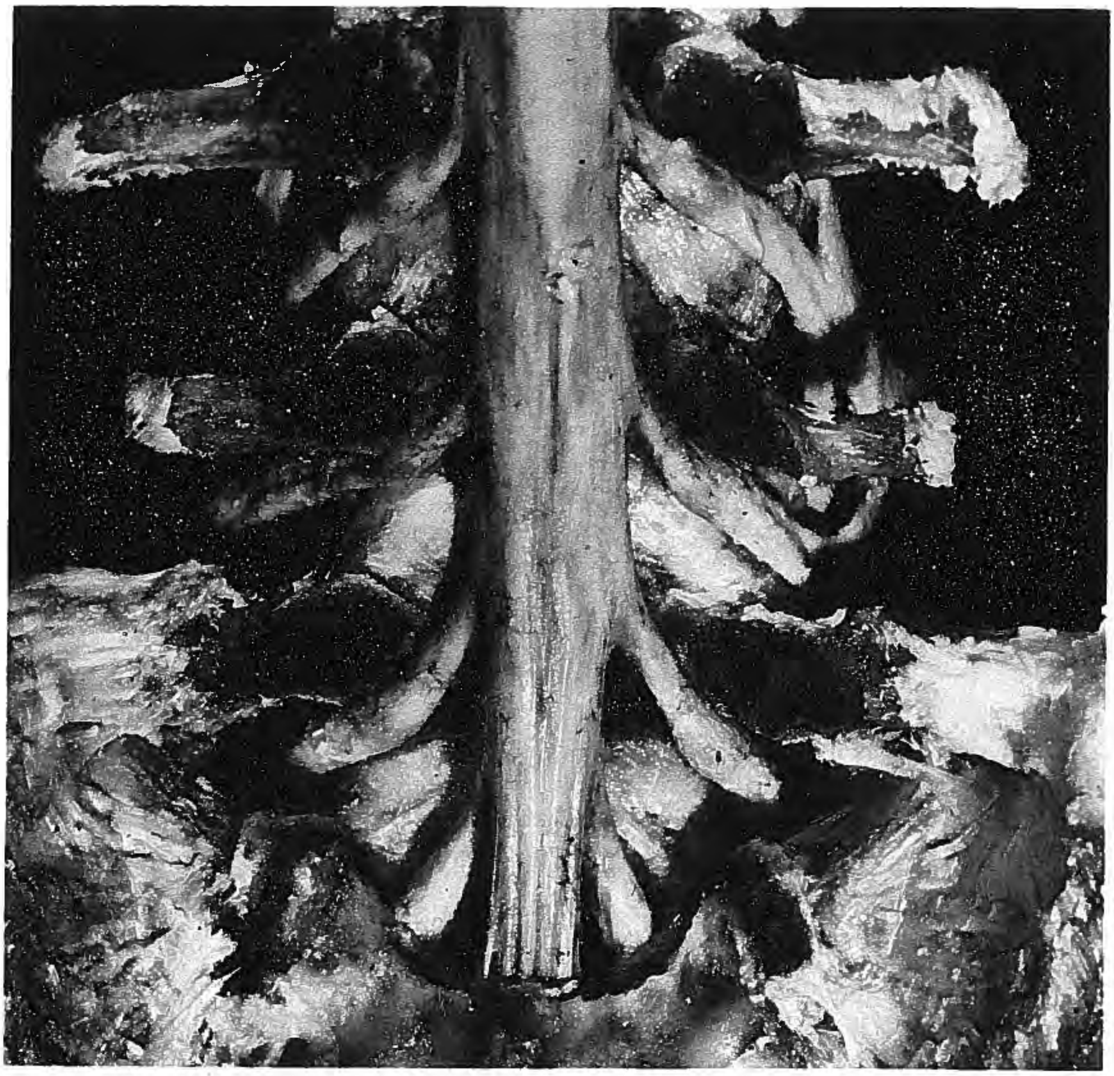
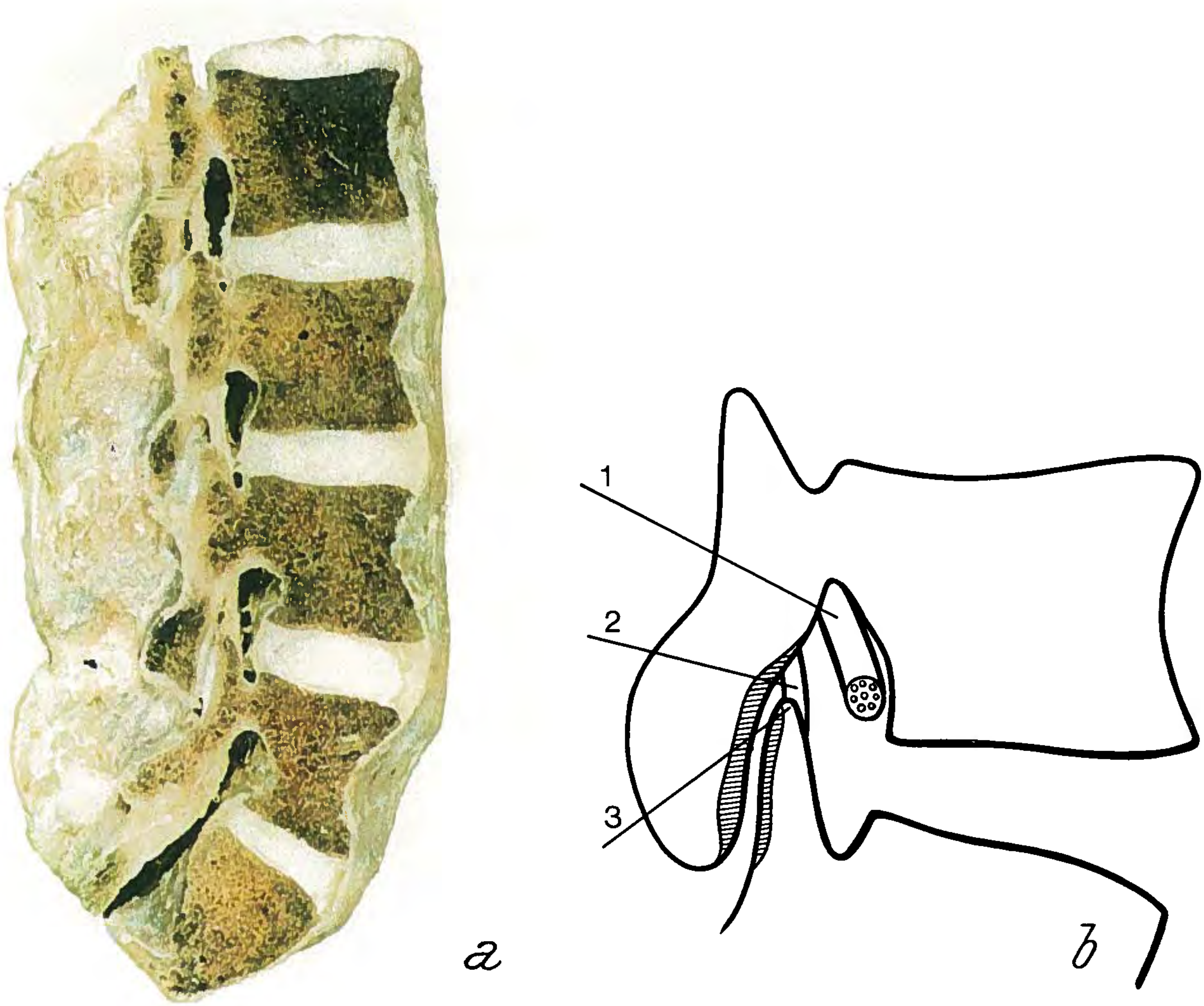


Figure 1.7. A photograph of a dissection of the lower lumbar spine in an adult to show some of the relations of the lumbar nerve roots. Note especially the origins of the nerve root sleeves from the dural sac and the courses of the nerve roots in relation to the pedicles. (Dissected by Dr. M. C. Crock)



Figures 1.8. **a** A sagittal section through the level of the pedicles of a normal lumbar vertebral spine of an 18 year-old male to show the boundaries and major structural relations of the intervertebral foramina. **b** A line drawing taken from a specimen to show the principal relations of the L5 nerve root at the L5/S1 intervertebral foramen. **1** the nerve root; **2** the ligamentum flavum; and **3** the apex of the superior facet of S1

The lumbar nerves run obliquely downwards and laterally from the lateral aspects of the dural sac, emerging at their respective intervertebral foramina and lying inferior to the lumbar pedicle in the upper part of each foramen (Fig. 1.7). Anomalies excluded, each nerve root is intimately related to the medial and inferior aspects of the adjacent vertebral pedicle.

The intervertebral foramen has fixed boundaries, though its dimensions vary depending on the height of the individual disc space and on the size of the related facet joints and thickness of the ligamentum flavum (Figs. 1.8 a, b). Bounded above

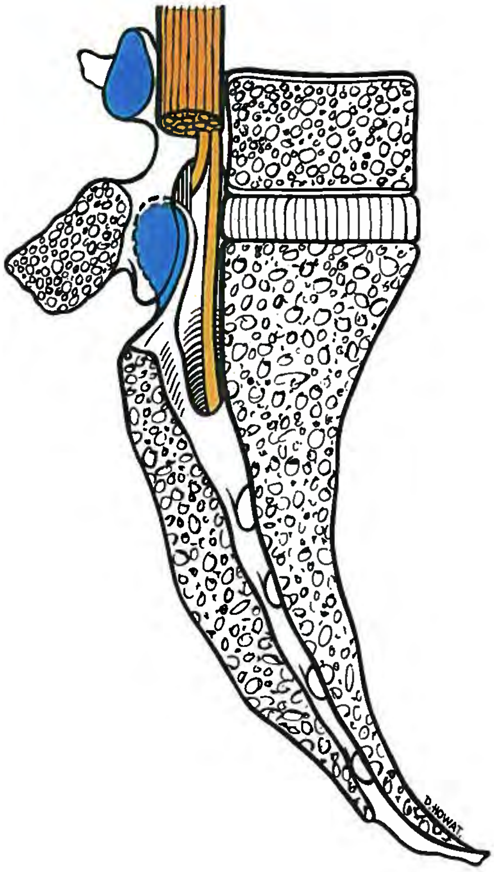


Figure 1.9. A drawing showing the relations of the S1 spinal nerve root canal viewed from within the spinal canal

and below by the vertebral pedicles, the floor from above downwards is formed by the postero-inferior margin of the superior vertebral body, the intervertebral disc and the postero-superior margin of the inferior vertebral body (Fig. 1.9). The roof is formed by the ligamentum flavum, terminating at its outer free edge, and posterior to this structure lies the pars interarticularis and the apophyseal joint formed between the adjacent inferior and superior vertebral facets (Fig. 1.10). The intervertebral foramen is analogous to the doorway at the end of a passage, its vertical height being determined by the vertical height of the corresponding intervertebral disc space.

A nerve root canal, by contrast, is a tubular canal of variable length, arising from the lateral aspect of the dural sac. Viewed from within the sac, the hiatus through which the component motor and sensory nerve roots pass to the spinal nerve has the

Figure 1.10. A transverse section through the lower lumbar spine at the level of the intervertebral foramen, the section passing through the vertebral body. On the left of the specimen note the posterior relations of the nerve root. In the mid-line, the cauda equina can be clearly seen, easily distinguished from the epidural fat

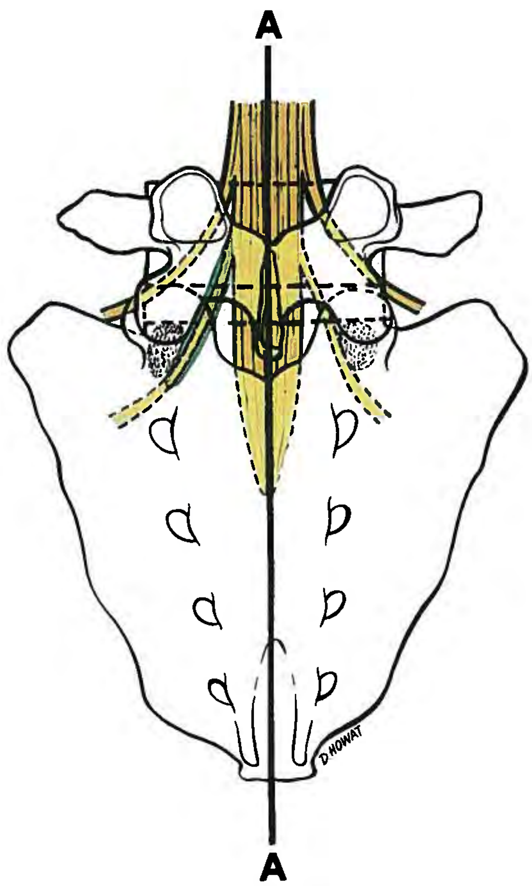


Figure 1.11

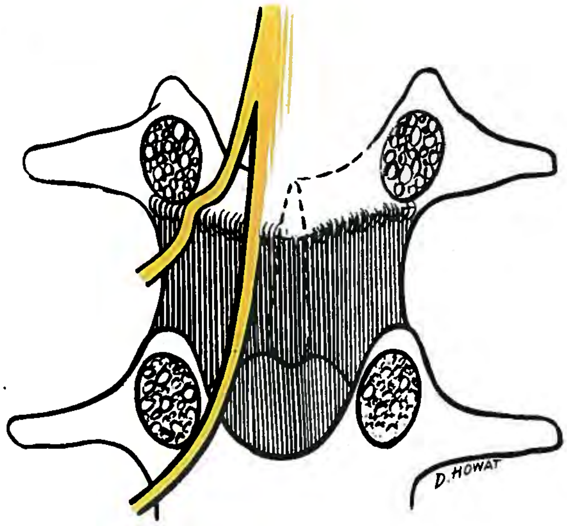


Figure 1.12

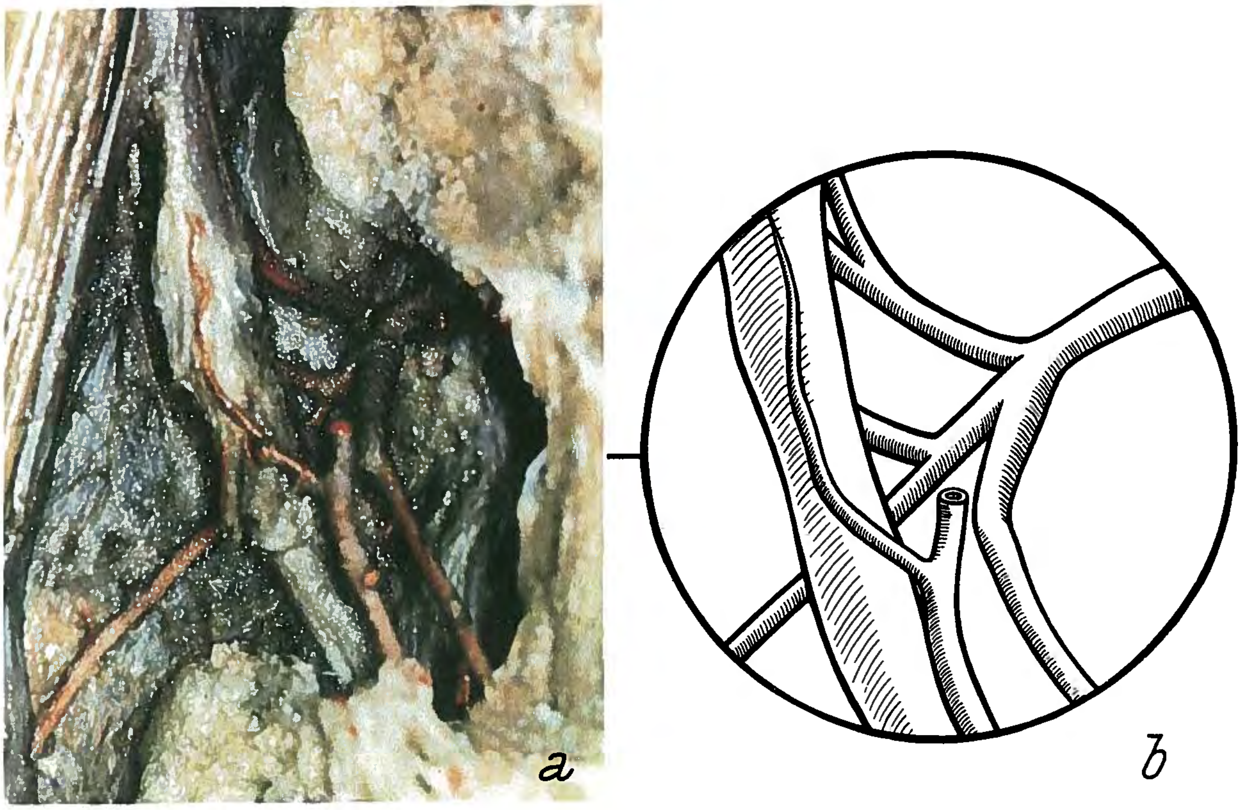
Figure 1.11. A drawing of the normal lumbo-sacral junction. Note the spinal nerve root canal of S1 outlined in green on the left side of the diagram. The line marked AA represents the plane of section for drawings illustrated in Figs. 1.9, 1.16, and 1.20

Figure 1.12. A drawing of two lumbar laminae viewed from within the spinal canal, showing the bony ridge of the upper attachment of the ligamentum flavum to the superior lamina at the intervertebral space. The L5 nerve root on the left side is shown kinked forwards by this ridge at the level of the upper attachment of the ligamentum flavum. The S1 nerve root may be similarly deformed from behind in some cases

shape of a funnel. Viewed from without, the dural sheath clothes the spinal nerve on all sides as it courses obliquely downwards and laterally towards the intervertebral foramen (Fig. 1.11). The upper lumbar nerve roots are often orientated almost at right angles to the dural sac and their intraspinal portions are, therefore, very short. The nerve root canal in such cases becomes, in effect, a useless concept, as the dural sac lies against the medial wall of the upper lumbar pedicle. The emerging lumbar spinal nerve passes at once into the intervertebral foramen at its upper boundary immediately below the pedicle.

The shape of the dural sac changes from a rounded tubular outline, tapering progressively from the level of L3 downwards. Contrasting with the upper two lumbar spinal nerves, the lower lumbar nerves are longer and come off at more acute

Figure 1.13. A coronal section of the mid-lumbar region of an adult, showing the cauda equina and two lumbar nerve roots on the left, each related to a vertebral pedicle. Note the extra-dural fat pads around the upper of the two nerve roots



Figures 1.14 a and **b.** A detailed photograph to show the anterior spinal canal branches of the lumbar artery lying anterior to the emerging lumbar nerve root at the intervertebral foramen, together with the ascending anterior and posterior nerve root branches of the lumbar artery, from a female aged 18 years

angles from the sides of the dural sac. *The concept of a nerve root canal is of greatest significance in relation to the two lower-most lumbar and first sacral nerves.*

In Fig. 1.11, the origin of the S1 nerve from the dural sac is shown just below the level of the inferior margin of the fifth lumbar pedicle. Medially at its origin it is related to the lateral aspect of the dural sac. The nerve courses downwards and obliquely as it passes laterally, lying first medial to the fifth lumbar nerve root and below that, medial to the L5/S1 intervertebral foramen; it then lies adjacent to the medial aspect of the pedicle of S1. At the lower border of this pedicle it enters the first sacral intervertebral foramen (Figs. 1.9, 1.11).

The anterior relations of the S1 nerve root canal from above downwards are: the posterior aspect of the body of L5, the intervertebral disc, the posterior aspect of the body of S1. These constitute the floor of the canal when viewed from behind (Figs. 1.9, 1.11).

The posterior relations vary considerably depending on the length of the individual nerve root and on the orientation of the lamina of L5, which will vary with the lumbo-sacral angle. From above downwards, the uppermost posterior relation of the root canal at its origin is the bony ridge raised on the anterior aspect of the lamina of L5 by the superior attachment of the ligamentum flavum (Fig. 1.12). The nerve root is then covered by the antero-medial aspect of the S1 facet (Fig. 1.11).

Figure 1.15. A photograph of a dissection to show details of the anterior internal vertebral venous plexus from a male aged 71 years. The plexus was injected with latex rubber. Note the large radicular vein joining the plexus

Epidural fat surrounds the spinal nerve root throughout its course to the intervertebral foramen (Fig. 1.13).

The arterial and venous relations of the spinal nerve roots are of great importance.

Knowledge of the anatomy of these veins helps the surgeon to conserve them during spinal exploration, avoiding venous haemorrhage which may lead to faulty technique in root canal decompression, simply because the fine structures cannot be identified in the pool of blood in the depth of the dissection. *Venous obstruction is a cause of symptoms in nerve root canal stenosis* and the task of relieving it is made easy by a knowledge of this local vascular anatomy.

Relations of the nerve root arteries assume practical significance during difficult spinal canal operations. These vessels should be protected when spinal nerves are being manipulated. Diathermy of their branches should be kept to a minimum, thereby minimizing the risk of iatrogenic nerve root injury which may be permanent.

Detailed descriptions of these vessels have been given by Crock and Yoshizawa (1977). The salient features of this anatomy are seen in the accompanying illustrations on pp. 16 and 17 (Figs. 1.14a, b, 1.15).

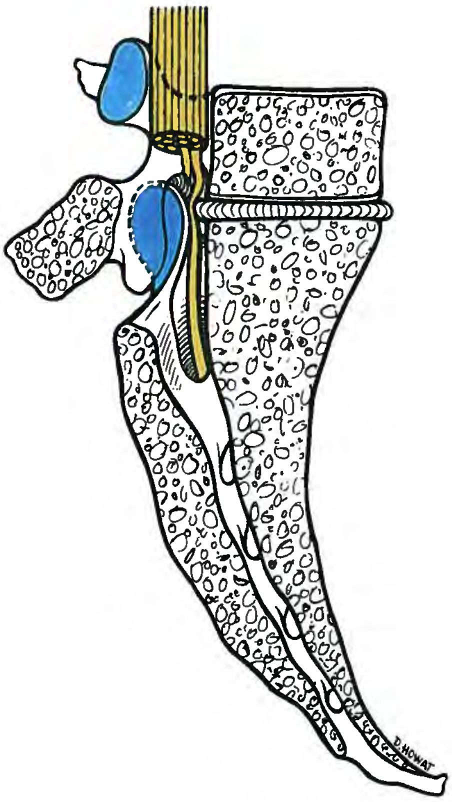


Figure 1.16

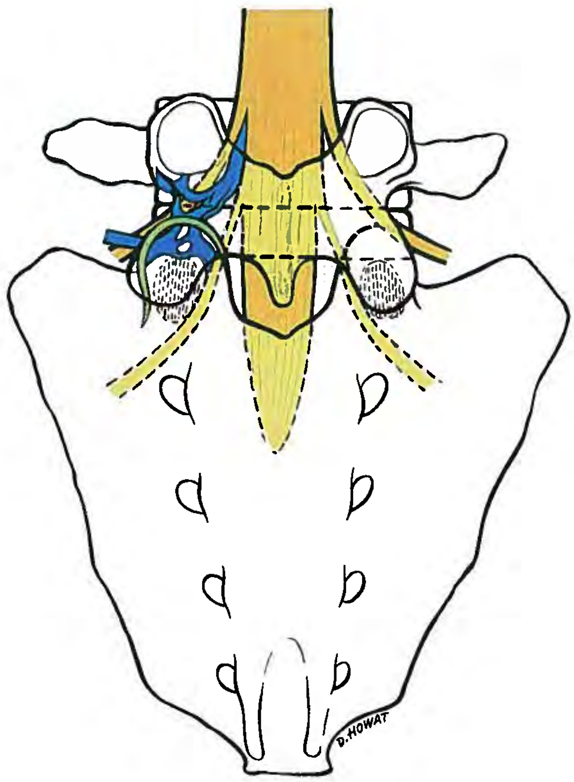


Figure 1.17

Figure 1.16. The distorted root canal viewed from within the spinal canal. Note the buckling of the ligamentum flavum into the intervertebral foramen, compressing the L5 nerve root

Figure 1.17. A drawing showing the normal neural and venous vascular relations at the L5/S1 level. The outline of the upper border of the S1 facet is shown in green

ii) Pathological

When the vertical height of the lumbo-sacral disc space is greatly reduced, changes occur in the floor and roof of the S1 nerve root canal and also in the L5/S1 intervertebral foramen (Fig. 1.5). A narrow transverse bulging ridge formed by posterior fibres of the remaining annulus fibrosus and posterior longitudinal ligament protrudes into the floor of the S1 nerve root canal. Coupled with the movement upwards of the S1 facet towards the pedicle of L5, the anterior and medial edges of the S1 facet come to lie very close to this ridge and occasionally even to the postero-inferior surface of the fifth lumbar vertebral body. In consequence, mechanical obstruction to the S1 nerve root develops (Fig. 1.16).

In some cases, in addition to the infolding of ligamentum flavum, hypertrophy of the bony ridge for its upper attachment may occur, further contributing to stenosis of both the S1 nerve root canal at its origin and, immediately lateral to it, to stenosis of the L5 nerve root canal just medial to the L5 pedicle (Fig. 1.12).

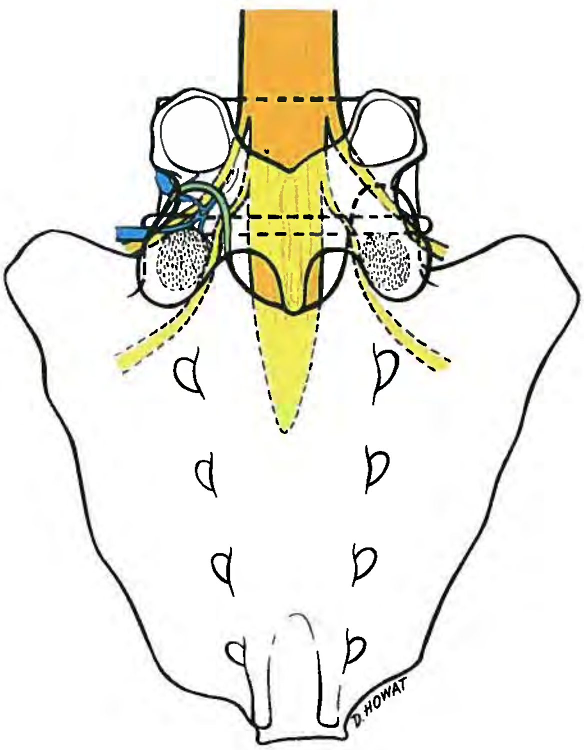


Figure 1.18

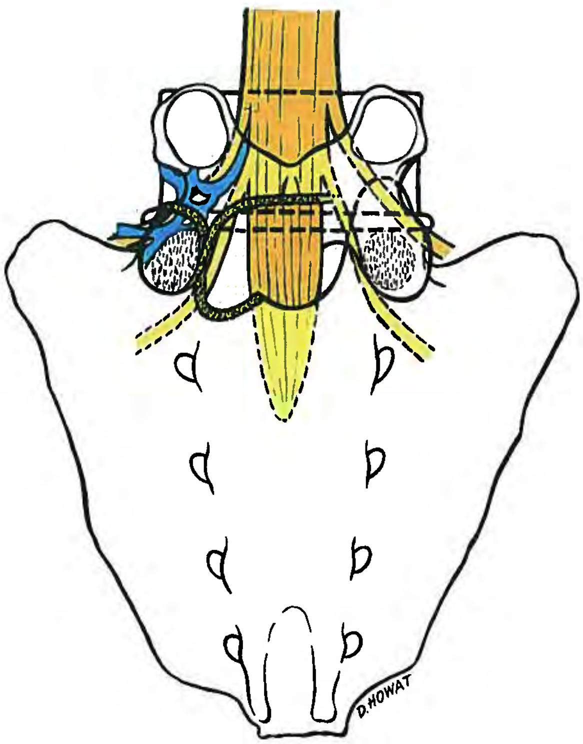


Figure 1.19

Figure 1.18. A drawing showing distortion of the S1 nerve root canal and of the L5/S1 intervertebral foramen due to subluxation upward of the S1 facet in isolated disc resorption of the L5/S1 disc. Note particularly the obstructed veins around the nerve roots. The outline of the medial and apical portions of the S1 facet are shown in green

Figure 1.19. A drawing showing the restoration of normal neuro-vascular relations after decompression of the S1 nerve root canal and L5/S1 intervertebral foramen on the left side at the L5/S1 level. The central portion of the neural arch of L5 has not been removed. The outline of the cut surfaces of bone are shown in stippled green and black

Appreciating these various contributing factors in the stenosis which may affect the S1 nerve root canal and the L5 nerve root at the L5/S1 intervertebral foramen, the planning of an effective surgical decompression can be logically organized (Figs. 1.17–1.20).

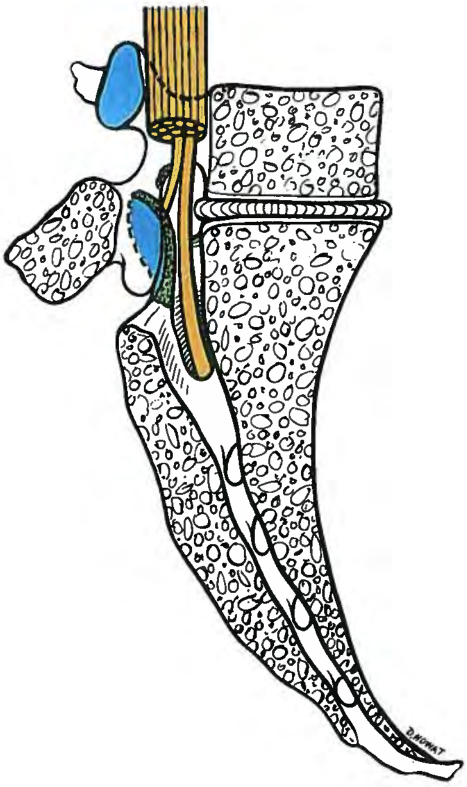


Figure 1.20. A view from within the canal after decompression. The ligamentum flavum has been totally excised. A stippled green and black outline indicates the extent of bony excision of the superior facet of S1 and of the bony ridge on the anterior aspect of the lamina of L5 at the level of the upper attachment of the ligamentum flavum. The L5 spinal nerve is shown emerging unimpeded through the intervertebral foramen

c) Venous Obstruction

While the mechanical obstruction to the S1 nerve root in its canal can be readily appreciated in the condition of isolated disc resorption, the finding of venous obstruction is less widely known. The occlusion of veins that is found in advanced cases of isolated disc resorption is demonstrated in Fig. 1.18. These veins are shown refilled after the operative procedure which is designed to relieve symptoms in this condition (Figs. 1.19, 1.20).

d) Clinical Studies

In recent work published by Venner and Crock in 1981 an analysis was made of the symptoms and signs in a group of 50 patients suffering from isolated disc resorption at the L5/S1 level. 94% of these patients complained of low lumbar pain, and 48%

noted radiation of pain to one or both buttocks: 76% had pain in one or both legs, and 50% complained of paraesthesia. Only 8% reported exacerbation of their pain on coughing, but 18% gave a history of increasing leg pain or paraesthesia on walking distances up to 500 yards (root claudication). Some patients had weakness and occasional dragging of the feet or difficulty in standing, but these symptoms settled on resting, usually by sitting. 94% had lumbar tenderness, but only 8 patients had reduced lumbar movement as defined by Moll and Wright (1976).

Signs of root irritation, evidenced by limited straight leg raising, painful bowstring test or sciatic nerve tenderness were detected in only 6%; and reduced nerve conduction indicated by wasting, motor weakness, sensory abnormality or reflex depression in 16%. One or both ankle jerks were absent in 10%.

In Table 1.1, measurements of the height of the L5/S1 intervertebral disc space in these 50 patients are recorded.

Table 1.1. Height of the L5/S1 intervertebral disc (50 patients)

	Anterior Height			Posterior Height	
	>10 mm*	10–5 mm	<5 mm	>5 mm	<5 mm
Male	7	20	3	5	25
Female	3	14	3	4	16
Totals	10	34	6	9	41

* In only one patient was the height more than 15 millimetres.

e) Investigations

i) Plain X-Rays

Radiological findings are the key to the diagnosis of this condition; plain X-ray examination alone usually suffices to confirm it. Typical findings are: gross disc space narrowing, vertebral body sclerosis especially close to the vertebral end plates, the Knuttson vacuum sign on the lateral extension film, minimal evidence of osteophyte formation and evidence of facet joint subluxation–best seen on oblique views, with intrusion of one facet into the intervertebral foramen seen in the lateral view.

ii) Lumbar Myelography

Disc prolapse is not seen in the established case, so that lumbar myelography is unnecessary except in special circumstances; for example, when the patient has severe unilateral leg pain. Disc prolapse at another level may be found, or vertebral end-plate sequestration at the level of the disc resorption may be confirmed.

The myelogram in a typical case may be normal in appearance and this could influence a surgeon who is not fully aware of the nature of this condition to advise against the surgery that is indicated.

iii) Lumbar Discography

Isolated disc resorption rarely occurs with pathological changes in adjacent intervertebral discs so that lumbar discography is not routinely indicated. An example of a normal discogram at L4–5 above an isolated disc resorption at L5/S1 is shown where the dye injected at L5/S1 has leaked extra-durally into the spinal canal (Fig. 1.21).

Figure 1.21. A radiograph showing a normal discogram at L4/5 with gross extravasation of dye into the extra-dural space at L5/S1 at the level of an isolated disc resorption

iv) Computerized Axial Tomography

Reconstructed C.T. Scanning is useful in confirming the foraminal and nerve root canal stenosis that occurs in this condition. However, transverse scanning at the lumbo-sacral junction is difficult to interpret in relation to the demonstration of root canal stenosis.

v) Epidural Venography

Obstruction of the intervertebral veins can be demonstrated satisfactorily with this special investigation. However, its demonstration is of theoretical interest as the venous obstruction is a concomitant pathological finding in established cases of isolated disc resorption with facet joint subluxation, facet intrusion into the intervertebral foramen and ligamentum flavum buckling.

f) Operations

i) Types

The treatment of choice in cases with bilateral buttock and leg pain is bilateral nerve root canal decompression. The technique of this operation will be outlined below and described in detail on pp. 23–27.

In cases where there is an associated unilateral sciatica, a sequestrum of necrotic vertebral end-plate cartilage will usually be present. The protruding fragment should be removed and the vertebral end-plate cartilage remnants curetted and extracted from the disc space. At the same time bilateral nerve root canal decompression should be performed.

If, at the time of nerve root canal decompression, marked vertebral instability is noted at the site and the patient's symptoms have included the complaint of intractable back pain, then spinal fusion should be carried out. Inter-transverse-alar sacral fusion is recommended. Theoretically, in this circumstance, the ideal procedure is posterior interbody fusion using either the Cloward or Wiltberger techniques, because the grafts fit accurately between the vertebral bodies, producing a strictly localized spinal fusion.

When low back pain is the dominant symptom, primary anterior interbody fusion at the affected level may be indicated.

The cause of the back pain in these cases is not related to nerve root canal and foraminal stenosis, but emanates from either the vertebral bodies, or the arthritic subluxed facet joints.

ii) Technique of Lumbar Nerve Root Canal Decompression at L5/S1 Level

The approach to the L5/S1 interspace is described on pp. 110–117. Details of the technique of nerve root canal decompression are set out below:

The whole of the ligamentum flavum is removed, laterally at the intervertebral foramen and superiorly from its uppermost laminal attachment. The soft tissues are now separated carefully from the anterior surfaces of the lamina and from the superior and inferior facets at the interspace. This is best done with a probe of the Watson-Cheyne type. Forward-angled laminal punches of varying sizes may be used then, under direct vision, minimizing the risks of venous haemorrhage or of dural or nerve root injury (Figs. 1.22–1.24). The upper edge of the inferior lamina is excised together with the overhanging border of its superior articular process, flush with the medial margin of the pedicle. The tip of the superior articular process is then removed and the inner edge of the overhanging inferior articular process of the

Figure 1.22. A photograph of a Watson-Cheyne dissector. The curved tip on the right hand side is sharp and the left-handed end is a blunt probe

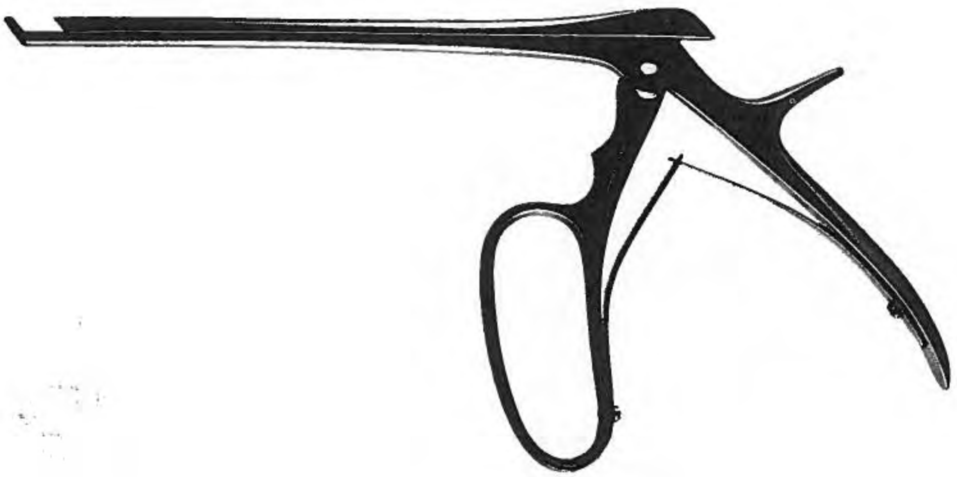


Figure 1.23. A photograph of a 45° forward-angled pituitary punch

superior lamina is trimmed flush with the medial edge of the superior facet, using a right-angled forward cutting laminal rongeur.

In cases where nerve root canal stenosis is severe–as may occur in isolated disc resorption, or facet osteoarthrosis–the anterior surface of the superior facet on the inferior side of a particular vertebral interspace may be closely applied to the posterior surface of the intervertebral disc. Insertion of a forward-angled rongeur between the roof and floor of the nerve root canal may be difficult. The risk of injuring the entrapped nerve root is high in such circumstances so that use of an assortment of different instruments may become necessary to decompress it and to relieve the concomitant venous obstruction in the nerve root canal and intervertebral foramen. Use of a fine sucker, its tip covered with a patty, held as a dural retractor in one hand is recommended. Meanwhile, with a Watson-Cheyne probe in the other hand, the medial edge of the superior facet is defined, soft tissues separated from its anterior surface and the site of maximal obstruction of the nerve root canal determined. Only then, in a bloodless field, can the tactics be planned and the most suitable instruments chosen for the task of nerve root canal decompression. Fine, straight and curved chisels, a variety of forward-cutting laminal rongeurs and fine straight pituitary rongeurs should be available. Some powered tools such as the Quintron oscillating gouge and curette system or air drills may be useful for this delicate work. Powered instruments are potentially dangerous unless they are used with caution (Figs. 1.25, 1.26).

Assuming that one is dealing with a very tight nerve root canal and foraminal stenosis at L5/S1, the site of maximal compression of the S1 nerve root is usually related to the upper, inner and middle thirds of the superior articular facet of S1. The foraminal stenosis is due largely to the apex of the S1 facet together with the ligamentum flavum which has buckled into the foramen. The accompanying diagrams

Figure 1.24. A photograph of a 90° forward-angled punch

Figure 1.25. A photograph showing a sucker and bayonet forceps with patties of different sizes, all vital for use in spinal canal explorations

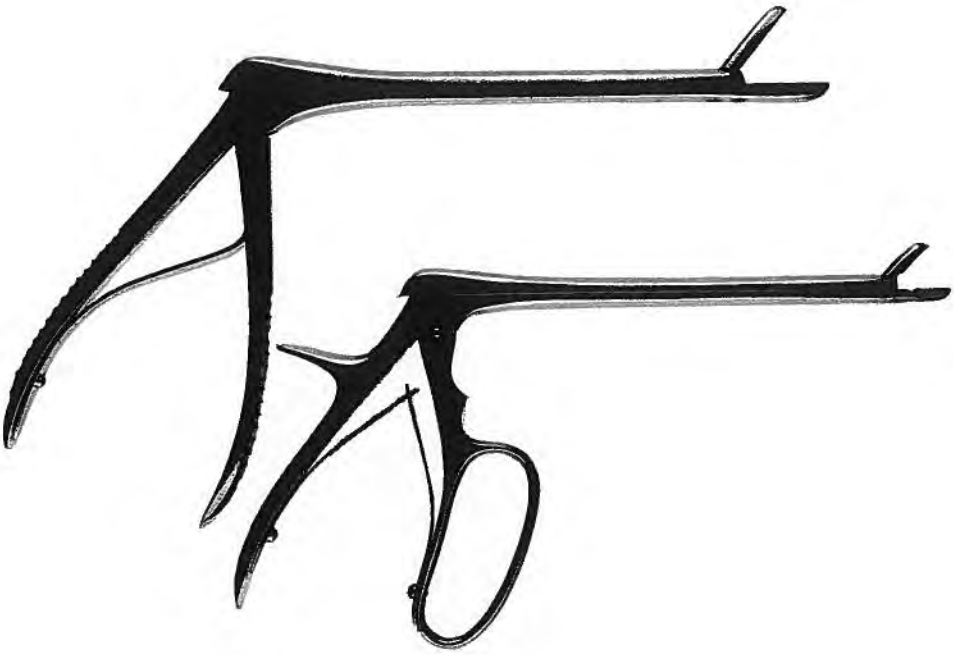


Figure 1.26

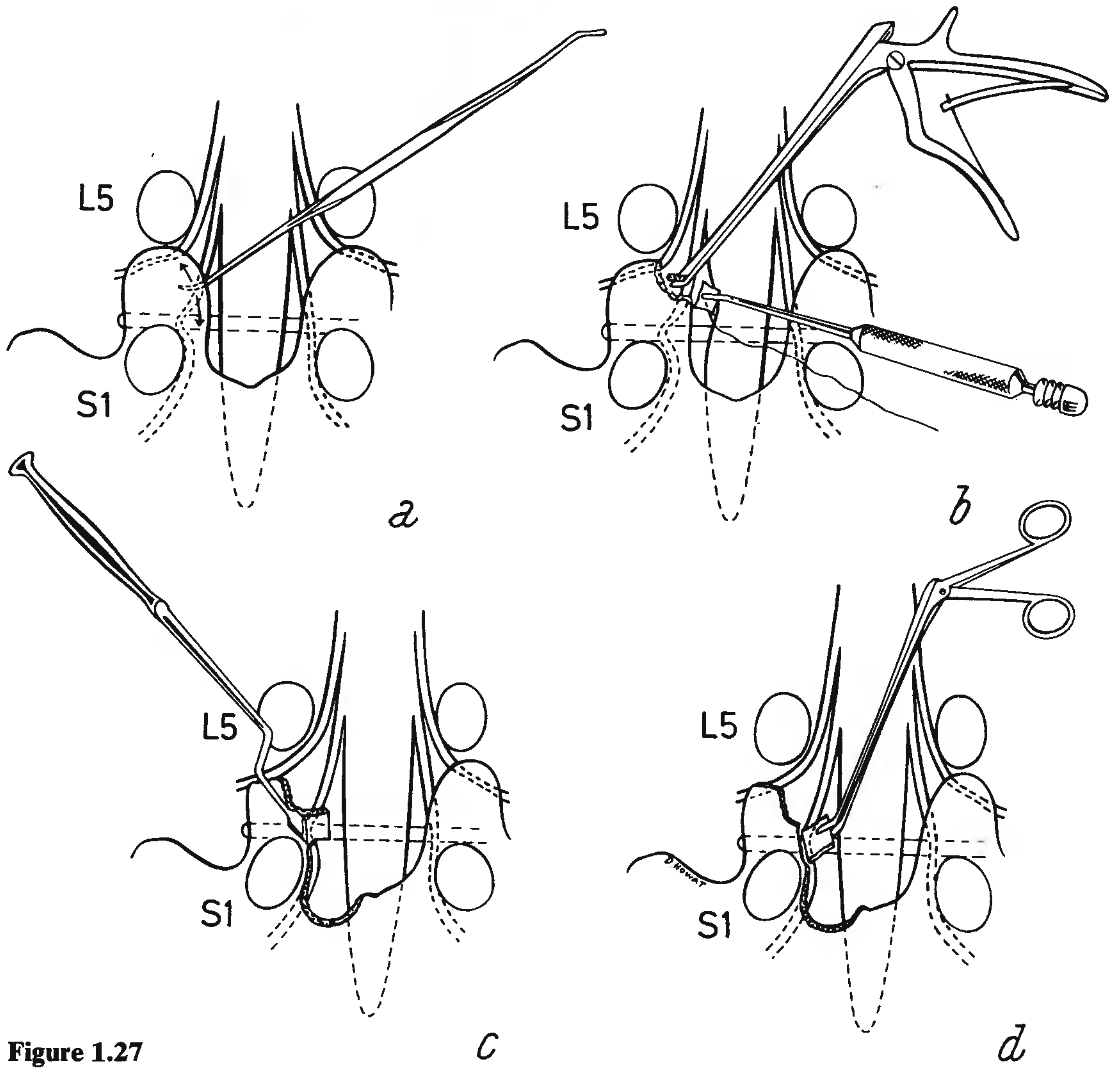
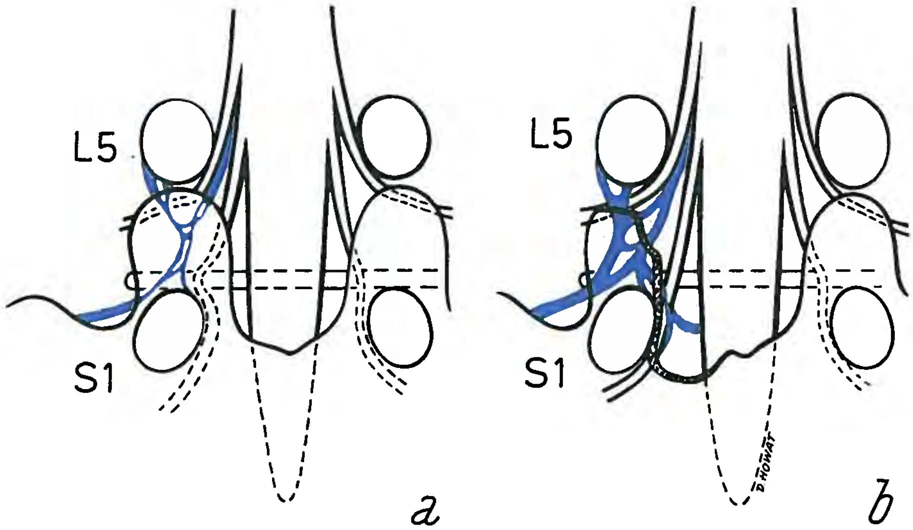


Figure 1.27

depict alternative methods of relieving these stenotic lesions, minimizing risks of nerve root, dural or vascular damage (Figs. 1.27a–d).

During the excision of the medial margin and apex of the S1 facet, obstruction of the intervertebral veins and internal vertebral venous plexus will be noted. When this surgical dissection has been completed the refilling of these veins is dramatic (Figs. 1.28a, b).



Figures 1.28. **a** A drawing to highlight the feature of venous obstruction which is a concomitant of foraminal and nerve root canal stenosis at L5/S1 in a case of isolated disc resorption. **b** On the right, following decompression by excising the apical and medial portions of the S1 facet and the ligamentum flavum, *note that the mechanical obstruction of the nerve roots is relieved and the venous drainage re-established*

In some instances excision of the bony ridge and upper attachment of the ligamentum flavum can be achieved only after excision of the central arch of the lamina of L5. When this becomes necessary, care is taken to preserve the partes interarticulares of this lamina on both sides, leaving the cut bony surfaces smooth and coating them with bone wax; excision of the apex of the S1 facet, together with the lateral edge of the ligamentum flavum is then facilitated.

Rarely is it necessary to interfere with the floor of the S1 spinal nerve root canal in cases of isolated lumbar disc resorption. Occasionally a sub-rhisal vertebral end-plate sequestrum will be found and this obstruction should be removed from beneath the S1 nerve root.

Figure 1.26. A photograph showing straight pituitary rongeurs of varying sizes. A range of these must be available for use during spinal canal decompressions

Figures 1.27. **a** A diagramatic representation of the findings of S1 nerve root canal stenosis at the L5/S1 level in isolated disc resorption. Note the use of the curved pointed end of the Watson-Cheyne dissector being used to free the soft tissues anterior to the medial edge of the S1 facet. **b** Note the disposition of the sucker and patty and the use of a forward-angled 45° fine cup pituitary punch to excise the apical portion of the facet of S1. **c** A drawing depicting the use of a fine chisel to split off the remnants of the medial aspect of the S1 facet where the S1 nerve root canal is most tightly constricted. **d** A drawing depicting the removal of the segment of the S1 facet to complete the decompression of the S1 nerve root canal. A fine-pointed forward-angled pituitary rongeur is used for this purpose

Results

Symptoms arising from isolated lumbar disc resorption have been shown to be severely disabling. The study published by Venner and Crock in 1981 suggests that nerve root canal decompression in isolated disc resorption is a useful addition to the surgical armamentarium for the treatment of pain in the back and leg. In a series of 45 patients with isolated disc resorption independently reviewed on an average of 45 months after surgical decompression of the S1 or lower lumbar nerve roots, complete success was achieved in 62% of the patients and partial success in 24%.

Table 1.2. Success rate of the operation for isolated disc resorption based on six criteria (45 patients)

Criteria	Success rate for each individual criterion (per cent)	Overall success rate of operation (per cent)	
Operation considered by the patient to be "worthwhile"	84	Complete success (6 criteria)	62
Functional disability reduced	71		
Return to work	78	Partial success (3–5 criteria)	24
Relief of backache	84		
Relief of pain in the legs	91	Failure (< 3 criteria)	14
Independent Observer's Assessment: Dr. R. M. Venner	71	Good	71

1.2. Miscellaneous Causes of Nerve Root Canal Stenosis

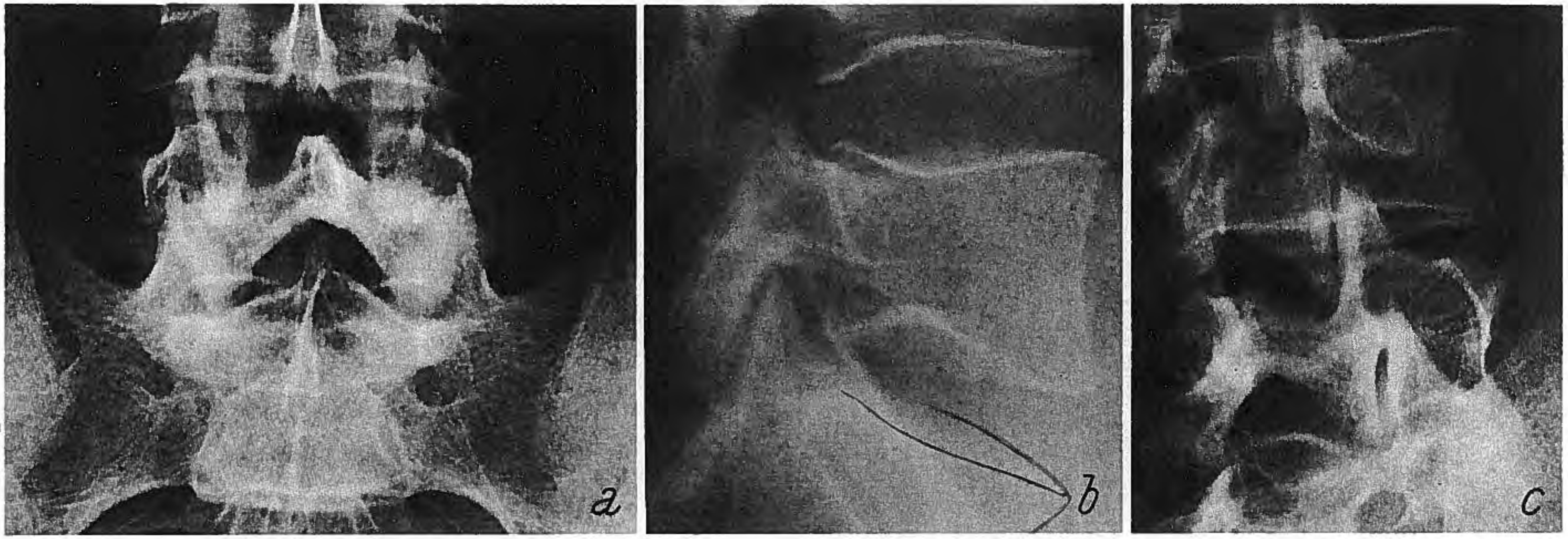
a) Congenital Abnormalities

Some congenital abnormalities of the lumbar spine may easily go unnoticed. Congenital hypertrophy of facets is an important cause of nerve root canal stenosis which may be overlooked, particularly if the intervertebral disc spaces are of normal height (Figs. 1.29a–c).

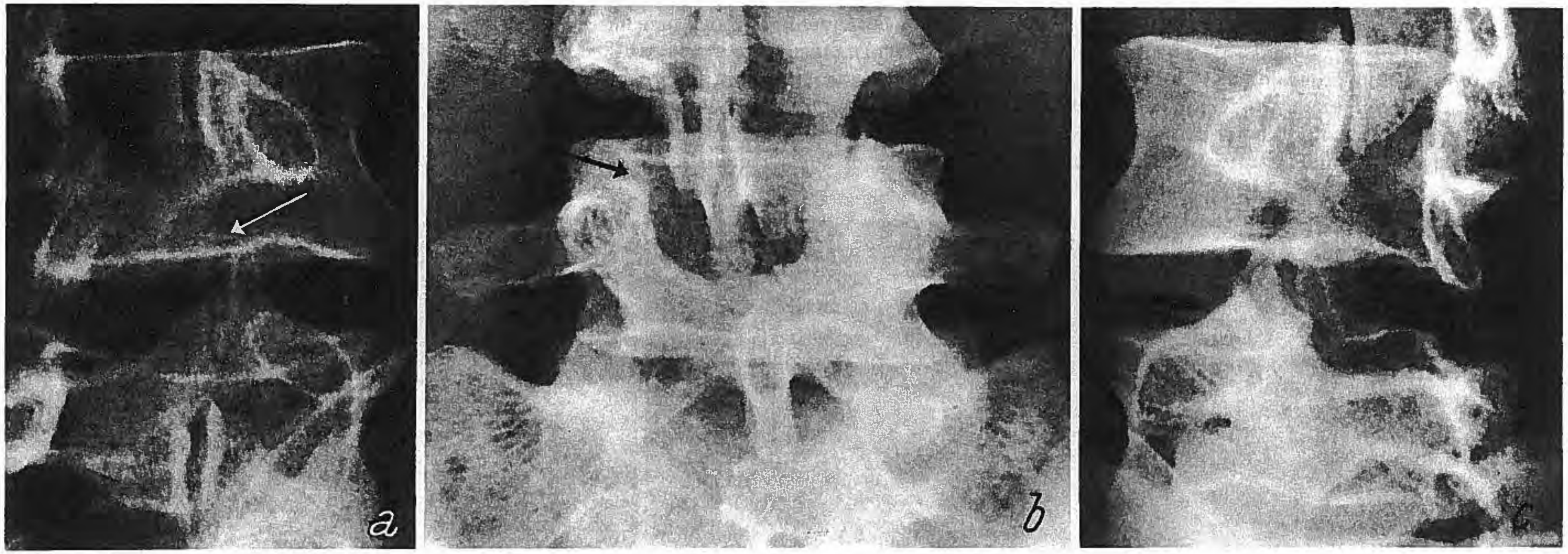
Congenital deficiencies of facets are less common and the defects are sometimes unilateral (Figs. 1.30a–c).

b) Space Occupying Lesions

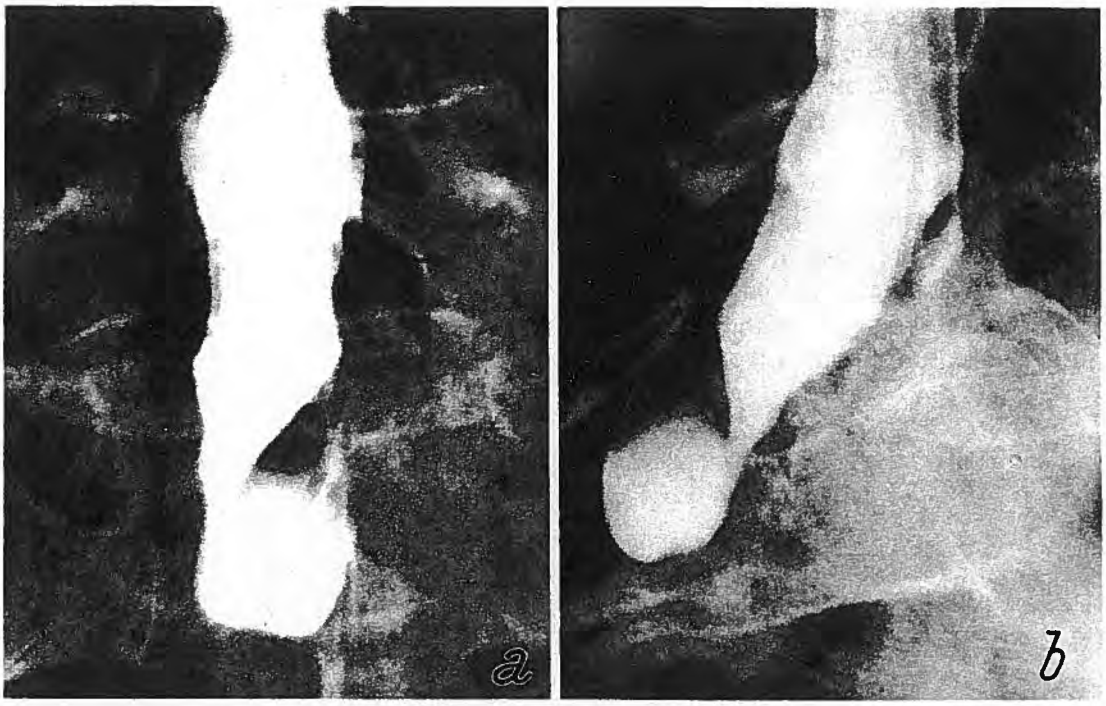
Occasionally, in an otherwise normal spinal canal, space-occupying lesions related to abnormalities in the dura or arachnoid may occur. Extra-dural arachnoid cysts, of the Schreiber type or peri-neurial cysts of the Tarlov type, may produce symptoms of nerve root canal stenosis (Figs. 1.31a, b) (Gimeno, 1978).



Figures 1.29. **a** An antero-posterior radiograph of the lower lumbar spine in a man aged 38 years presenting with symptoms of bilateral buttock and thigh pain extending to the back of the knee, aggravated by standing, sitting or walking. Note the orientation of the facets at L 5/S1 with the apices of the S1 facets visible on the A-P view in close proximity to the inferior borders of the pedicles of L 5. **b** A lateral radiograph of the spine in the same patient showing normal discs at L 4/5 and L 5/S1. Note the *congenital large S1 facets* projecting upwards into the intervertebral foramen at L 5/S1, the apex of the facet being visible close to the inferior surface of the pedicle of L 5. **c** An oblique view of the same spine showing the hypertrophic S1 facet, the apex of which lies close to the inferior border of the pedicle of L 5. The relationships of the apex of the superior facet of L 5 and the pedicle of L 4 provide a marked contrast to the findings at the lower level



Figures 1.30. **a** An oblique view of the lower lumbar spine of a woman aged 34 who presented with unilateral buttock and leg pain aggravated by standing and walking. The arrow points to the congenital abnormality at the pars interarticularis with absence of the inferior facet of L4. **b** An antero-posterior radiograph of the same spine showing the unilateral congenital abnormality with absence of the facet of L4 on one side. In the area indicated at the tip of the arrow, there was a bulky mass of soft tissue found at operation; semicartilagenous in consistency, it was causing root canal stenosis. **c** An oblique view of the opposite side of the spine showing the normal laminal arrangement and intact inferior facet



Figures 1.31. **a** An antero-posterior radiograph of the lower lumbar and upper sacral area showing a myelographic defect produced by an *extra-dural arachnoid cyst of the Tarlov type.* **b** A lateral radiograph of the myelogram in the same spine, showing the deformation of the lower end of the lumbo-sacral dural sac produced by a large extra-dural arachnoid cyst, acting as a space-occupying lesion in the nerve root canal in this area, there being no associated abnormality of the disc or vertebral column

c) Localized Degeneration

More common causes of nerve root canal stenosis are seen in localized degenerative disorders.

i) For example, in isolated disc resorption, retrolisthesis of L5 on S1 may occur, aggravating the tendency for the development of spinal nerve root canal stenosis which occurs commonly in this condition (Fig. 1.32).

ii) Retrolisthesis of one lumbar vertebra on another often occurs in association with disc resorptive changes in the first mobile segment above sacralization anomalies in the lower lumbar spine.

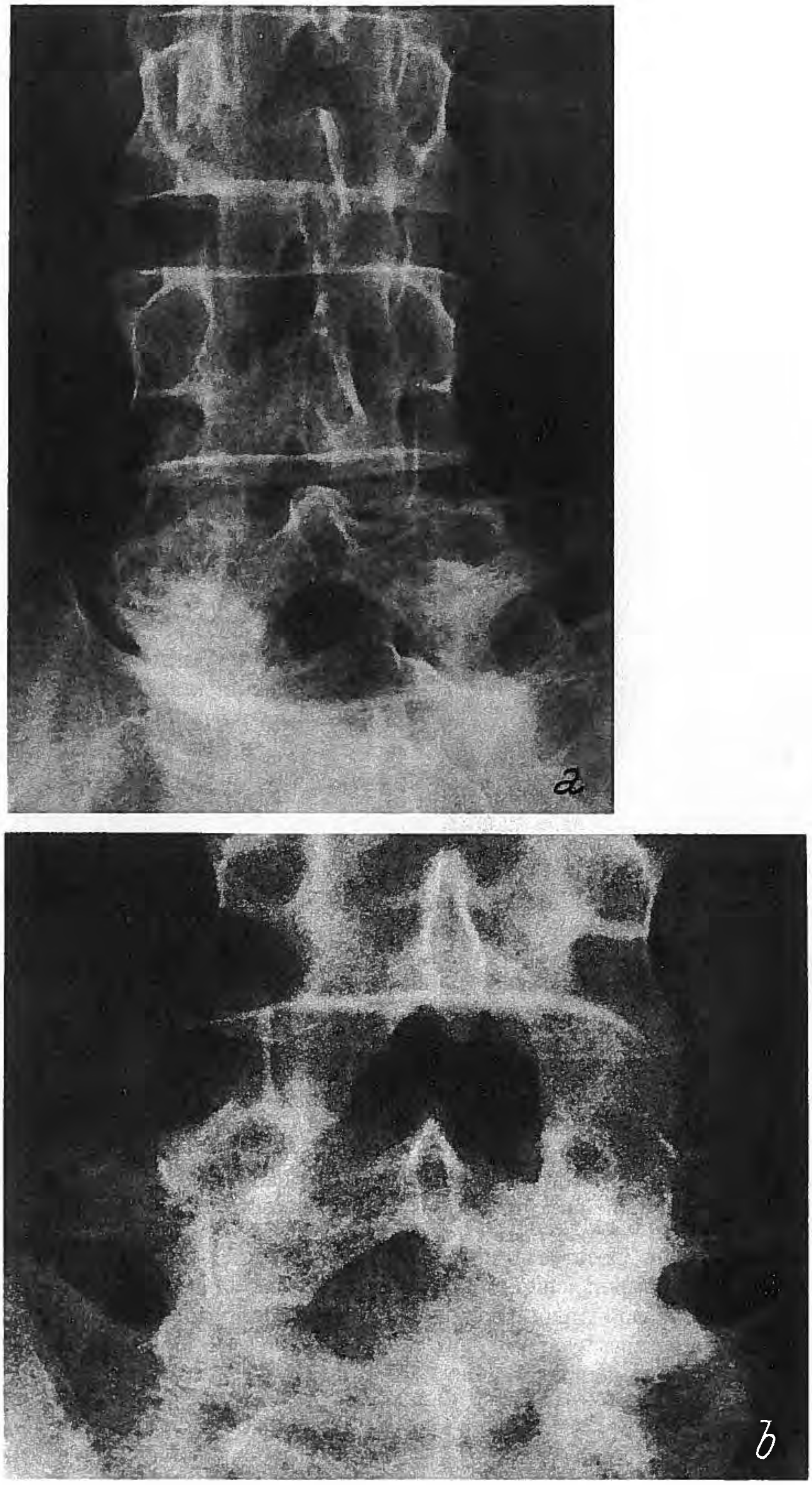
iii) Unilateral facet osteoarthritis may occur at a single level, most commonly at the lumbo-sacral junction, where it can produce unilateral sciatica (Figs. 1.33a, b).

The use of myelography in the diagnosis of these problems is recommended and typical changes, with gross local deformity, can be seen in a number of the miscellaneous causes referred to in this text (Figs. 1.34a, b). However, it is very important to recall that the myelogram may be reported as normal in many of these cases. The surgeon must then fall back on his clinical assessment of the patient, aided by plain X-ray findings, while deciding whether or not to recommend surgical treatment in a particular case.

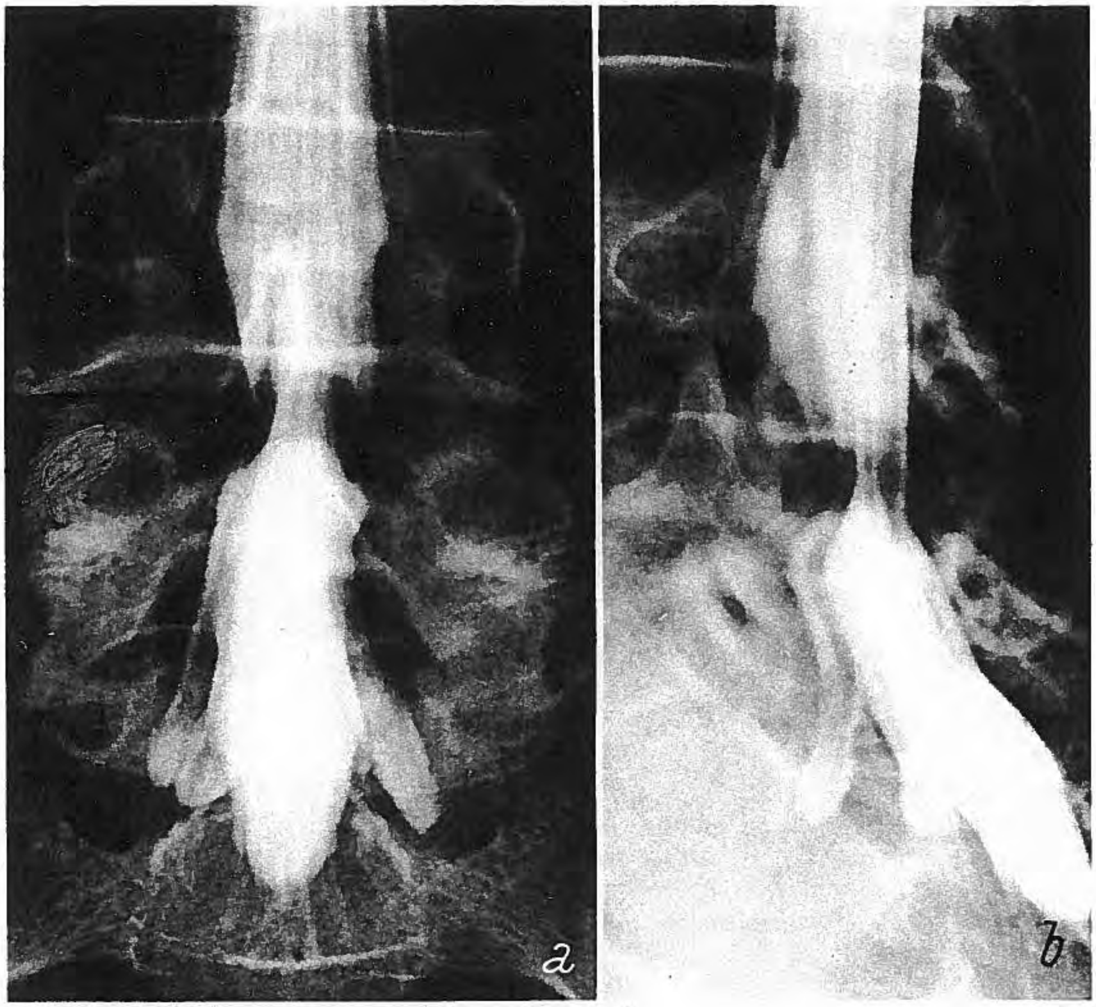
Accuracy of diagnosis has been enhanced since the advent of C.T. scanning, though it must be remembered that these expensive instruments are not yet universally available. In addition, unless the computer facility allows for reconstructions in three planes, its value in the diagnosis of these particular problems is seriously restricted. *Problems in the nerve root canal are not readily appreciated throughout its length by studies of transverse sections alone.* Unless this is appreciated, together with the fact that myelography may not define the anatomy of the nerve root canals completely in particular cases, the surgeon presented with apparently normal myelography and normal C.T. scanning in the transverse plane alone, may be disinclined to believe that the patient is seriously disabled and so deny him or her the surgical treatment which would relieve the symptoms.

Figure 1.32. A lateral radiograph of the lower lumbar spine showing an example of *retro-spondylolisthesis complicating isolated disc resorption at the lumb-sacral junction,* one of the rarer causes of root canal stenosis complicating this localized degenerative disc disease in the lower lumbar spine

Figures 1.33. **a** A radiograph of the lower lumbar spine in a woman aged 49 years showing unilateral facet hypertrophy due to osteoarthritis, leading to unilateral nerve root canal stenosis. **b** An antero-posterior radiograph of the lower lumbar spine of a man aged 30 with unilateral osteoarthritis of a facet at L5/S1 producing root canal stenosis



Figures 1.33



Figures 1.34. **a** An antero-posterior radiograph of the lower lumbar spine to show a myelographic defect (metrizamide) with partial spindling of the main column produced by bilateral facet hypertrophy of the inferior facets of L4. **b** An oblique radiograph of the metrizamide myelogram highlighting the relationship of the deformity in the column of dye to the medial border of the inferior facet of L4. Although there is an element of spinal canal stenosis present in such a case, the principal effect is seen in stenosis of the nerve root canal

2

Internal Disc Disruption

This term was introduced in a paper titled: "A reappraisal of intervertebral disc lesions", published in the Medical Journal of Australia in 1970.

The condition is common and should be readily identified clinically, though discography is essential for its confirmation.

The clinical syndrome which may be associated with this type of disc disorder usually follows severe trauma inflicted on the disc, for example, by sudden unexpected weight lifting, or by forces transmitted through the disc or discs during high speed accidents.

2.1. *Clinical Features*

a) Symptoms

Patients affected by severe grades of internal disc disruption present with an array of symptoms which should arouse the clinician's suspicion early in the course of management, especially if the history of the mechanism of injury is placed in its proper perspective. Back pain is prominent, having the character of a deep-seated dull ache. Their description of referred limb pain differs remarkably from that given by those with disc prolapses. The patient with limb pain due to internal disc disruption always finds difficulty in describing this type of pain. Usually it seems to be widespread in the limb, or deep inside it, having an intolerable aching character. Except for short remissions the symptoms are rarely alleviated by conservative physical therapy and may be aggravated by spinal manipulation or traction.

When these patients first present for treatment, one may be unimpressed with their description of symptoms and struck by the complete absence of abnormal physical signs in many of them. Observation over two or three months will reveal their low tolerance for physical activity. Their symptoms may become widespread with severe occipital headache, intractable spinal pain, nausea and weight loss.

There has been a tendency to label as "functional" or "psychological" many of the symptoms described by patients with lumbar disc disruption including those of headache and temperature dysaesthesia in the legs (Hakelius *et al.,* 1969).

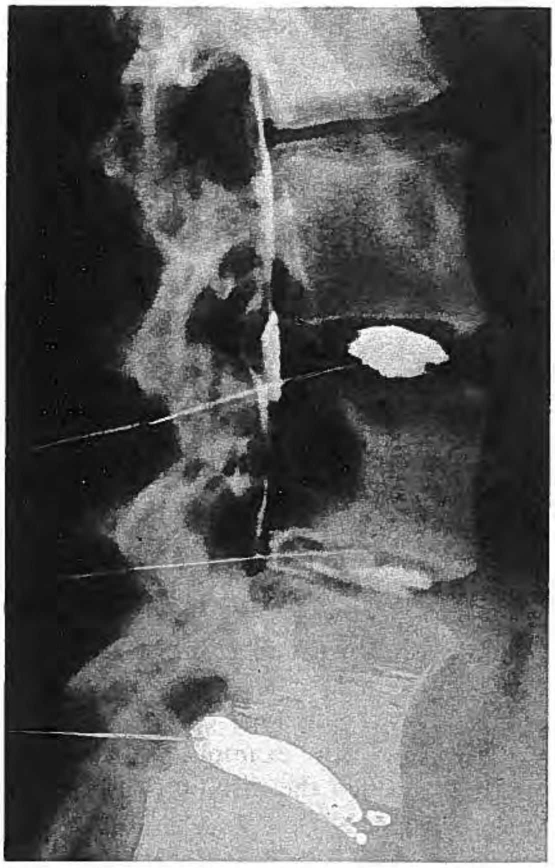


Figure 2.1. A lateral radiograph of the lower lumbar spine from a girl aged 18 showing a normal discogram at L3/4. At L4/5, gross disc disruption is evident with extra-thecal leakage of dye into the spinal canal extending to the level of L2/3. The L5/S1 discogram shows gross disc disruption with dye extending back to the level of the spinal canal but not leaking into it. This is an example of post-traumatic internal disc disruption sustained following a fall from a horse three years previously

b) Spinal Movements

When standing, many have great difficulty in rising from a flexed position. They usually assist themselves by placing the palms of their hands on the anterior aspects of their thighs, literally climbing up from the stooped position using the hands as props. Similarly, when attempting to sit up from a lying position, they may find it impossible without placing both hands flat on the bed behind them and exerting pressure on the upper limbs to raise themselves to a sitting position. At other times they may turn on to one side and get up into a sitting position by rolling their legs over the side of the bed and then levering themselves up slowly and awkwardly, obviously in pain. Spasm of the paraspinal muscles, as seen in cases with disc prolapse, is very uncommon in this condition.

c) Body Weight Loss

In patients who are clearly constitutionally ill as a result of internal disc disruption, weight loss may be profound over the course of a few months, ranging from 6–18 kg.

Conversely, some patients actually gain weight, due to their enforced physical inactivity.

d) Neurological Signs

Abnormal neurological signs in the limbs are uncommon, though complaints of weakness, clumsiness, and sympathetic nervous system disturbances as described above, are often made.

e) Psychiatric Disturbances

The psychological responses to this form of disc injury are partly predictable. These patients are usually incapacitated for many months before the diagnosis is established. They soon realize that their symptoms are a mystery not only to themselves but often to their doctors also. They feel that their problems are being taken too lightly. Financial worries soon begin to plague them and shortly the whole fabric of their lives begins to disintegrate, leading to an acute anxiety state. The view is often expressed that these problems and others, glibly described as litigation neurosis, will not loom as major obstructions to recovery if treatment is undertaken quickly (Macnab, 1969). Iatrogenically induced neurosis is often seen in these patients, especially if they have been under treatment for more than nine months without relief of symptoms.

There is a range of psychiatric disturbances seen in this group which is distinct from the simpler psychological disturbances seen in patients with disc prolapse requiring surgery.

Following total disc excision and interbody fusion for internal disc disruption, a significant, but small percentage of these patients, develop an acute psychiatric illness within a few days. They often become disorientated and violent. This phenomenon is rarely seen following any other orthopaedic operation. One is tempted to relate such disturbances to some biochemical abnormality in the damaged disc tissue, postulating that the psychiatric upset is caused by the sudden release of a sensitizing substance into the general circulation at the time of operation.

In managing patients with this type of disc disorder, it is desirable to work closely with a psychiatrist who has a special interest in these matters. The following comments come from the pen of such a consultant psychiatrist, H.G. Stevenson, writing in 1970:

"Psychiatric problems following disc disease appear to be labelled functional by the surgeon whose treatment has failed to relieve symptoms, and iatrogenic by his colleagues in the profession who have been fortunate not to be involved in the actual surgical onslaught. Neither of these labels appears to be justifiable in the vast majority of cases.

i) Acute Psychotic Reaction

"Two major patterns of disturbance are seen. Firstly, an acute psychotic reaction occurring shortly after operation on either the cervical or lumbar spine varying from a manic type of reaction to one which appears to be schizophrenic in type. The nearest parallel to these are the puerperal psychoses which are accepted as being due to a sudden alteration in biochemical function of the individual following the major physiological alterations of birth, and considered to occur only in patients with a covert psychosis.

"In those who react in this way to spinal surgery, there is probably an underlying covert psychotic make-up which may otherwise never have become apparent without the operation. The acute reaction is usually short-lived, responds to conservative anti-psychotic treatment readily and seldom needs intensive psychiatric or physical treatment.

"Given that patients, suffering from this syndrome, are probably prone individuals of whom there is no dearth in the normal community, it could be fairly said that even with a mild whiplash injury to the neck, a state of depression follows.

ii) Reaction to Prolonged Disease

"With more serious disc disease–particularly of the cervical spine–one finds the second typical syndrome, characterized by irritability, intolerance to noise, periods of severe depression, headaches starting at the back of the head, going over the front of the head and often causing blurring of the vision, a gross degree of introspection which is again probably a factor of a true depressive illness, reduced sexual function, in both male and female and extending particularly in the male to the state of complete impotence, dizziness often postural in type and frequently directly related to the intensity of the headache; pain in the limbs not corresponding to the anatomical areas of sensory supply but notably consistent over a great number of patients, a poor memory and reduced concentration. The overall syndrome responds poorly to anti-depressive medication and the added anxiety of litigation increases the failure of therapy. However, even without litigation this typical syndrome is seen and the 'cure' appears to be more an adjustment to an altered way and principle of living than a return to 'normal'. Whether the cause is biochemical, or due to alteration in the blood supply to the base of the brain, or affection of the sympathetic nervous system is questionable, but this in turn appears to be in parallel with the disc injury rather than a result of the prolonged symptoms or the failure of orthopaedic treatment. Physical strain patterns following damage to the head and neck suggest that the centre of stress is in the region of the hypothalamus, which area has been the focus of attention in most research on depressive states, and this in itself could bring about an alteration in the biochemical balance, particularly in relation to the 5-hydroxytryptamine and plasma cortisol levels.

"Follow-up studies on these patients, suggest that the depressive state persists for a considerable time, that it tends to recur, perhaps in that the patient has learned a depressive form of reaction to stress and this then becomes his normal pattern to stress in the future. The alteration in the personality adjustment in at least some cases, appears to be permanent. The relationship of strain from lower back disease affecting the upper regions of the spine and a typical depressive state occurring in parallel is also seen. Most attention has been centred on the medico-legal aspects, and efforts by Cole (1970), Stevenson (1970) and Parker (1972) have thrown some doubt on Miller's (1961) article on accident neuroses, so that more accurate psychiatric diagnosis in these post-traumatic spinal conditions is gaining acceptance.

"The role of physical psychiatric treatment including electroconvulsive therapy and intravenous amobarbital (Amytal) is doubtful. These methods of treatment are used only when the extent of the psychiatric disability warrants their use, irrespective of the physical condition in the spine."

When internal disc disruption goes unrecognized on the clinical features described above, the patients drift from doctor to doctor, often seeing as many as ten, including family doctors, general surgeons, neurologists, neurosurgeons, orthopaedic surgeons and psychiatrists. Many seek relief in fringe medicine.

2.2. Pathology

a) Macroscopic Changes

The primary defects appear to lie in the field of histochemical pathology and probably also in alterations to the mechanism of disc nutrition.

Macroscopically, disrupted disc tissue is soft, often slightly yellow in colour but otherwise indistinguishable from disc tissue in the early phases of degeneration.

Circumferential tears between adjacent rings of the annulus fibrosus or radial tears in these fibres, short of complete extension to the outer annular layers, can be demonstrated radiographically by discography. After many years of clinical observation, the conclusion is inescapable that in certain individuals these changes in the discs are associated with biological dynamics which lead to a disabling syndrome, precipitated by trauma and further aggravated by repeated minor trauma.

That some dynamic pathological process is active gains support in observations made during vertebral interbody fusion operations for this condition. For example, the lumbar sympathetic trunk may be found matted to such an affected disc and the adjacent paravertebral lymph nodes seen to be enlarged. In addition, the vascularity of the vertebral bodies adjacent to such a disc appears to be increased and their bony densities are reduced.

The significance of these findings relates to observations made during experiments on auto-immunity in the intervertebral discs of rabbits, reported by Bobechko and Hirsch (1965). Credit for first drawing attention to the possible auto-immune basis to the development of biochemical changes in disc prolapse should be given to Naylor (1962). With added knowledge of the anatomy of the circulation in the region of the vertebral end plates, Crock and Yoshizawa (1977), Crock and Goldwasser (1983), and with further evidence on the movement of radio-opaque dyes from disc tissues into the veins of the vertebral bodies (Figs. 2.2.–2.6), it seems likely that *auto-immunity* may play an important role in the development of the severe disabilities that afflict patients with the syndrome of *internal disc disruption.*

Site of Lesions

The lower lumbar discs are most commonly affected (Figs. 2.7 a, b, 2.8).

b) Genesis of Symptoms

In these cases there appear to be three probable causes for the symptoms described: (i) irritation of adjacent nerve roots resulting from abnormal vertebral movements with or without some diffuse disc bulging, (ii) irritation of structures adjacent to the affected disc, the spinal nerves and sympathetic system, due to catabolites diffusing

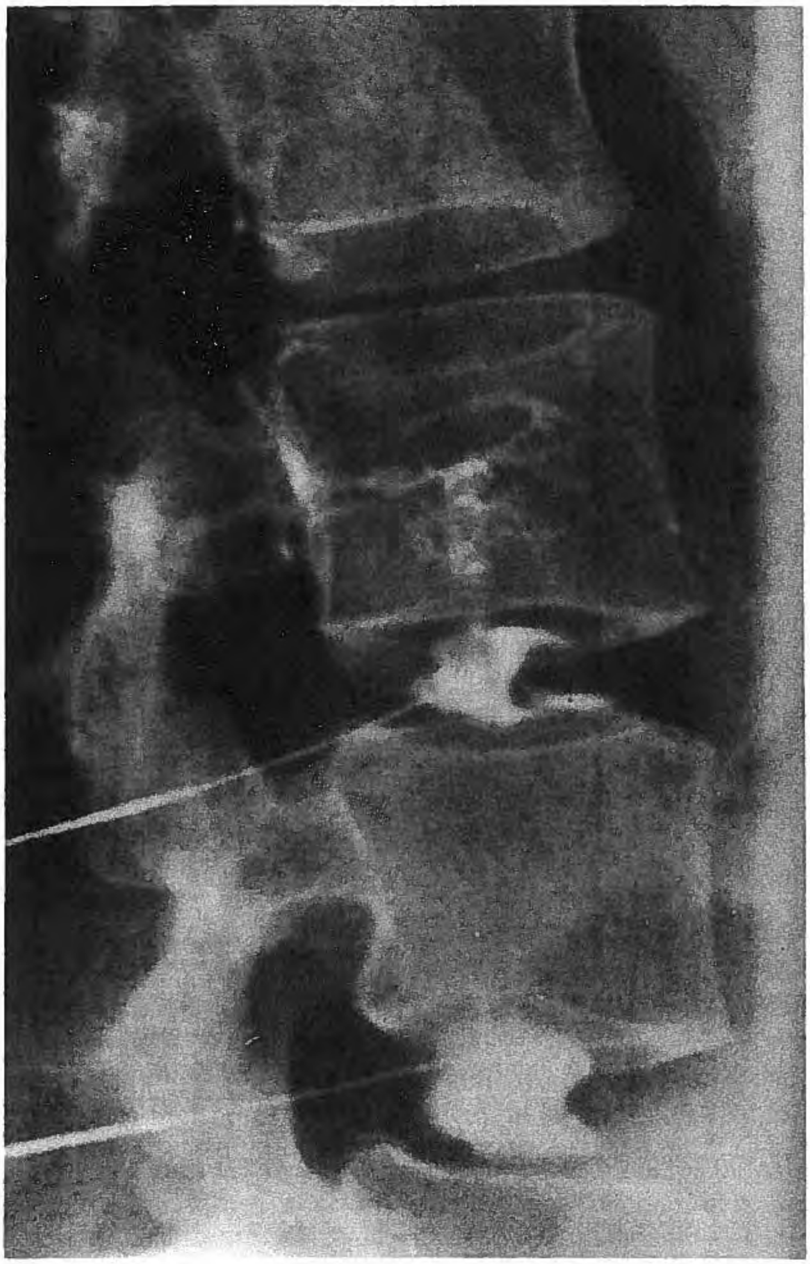
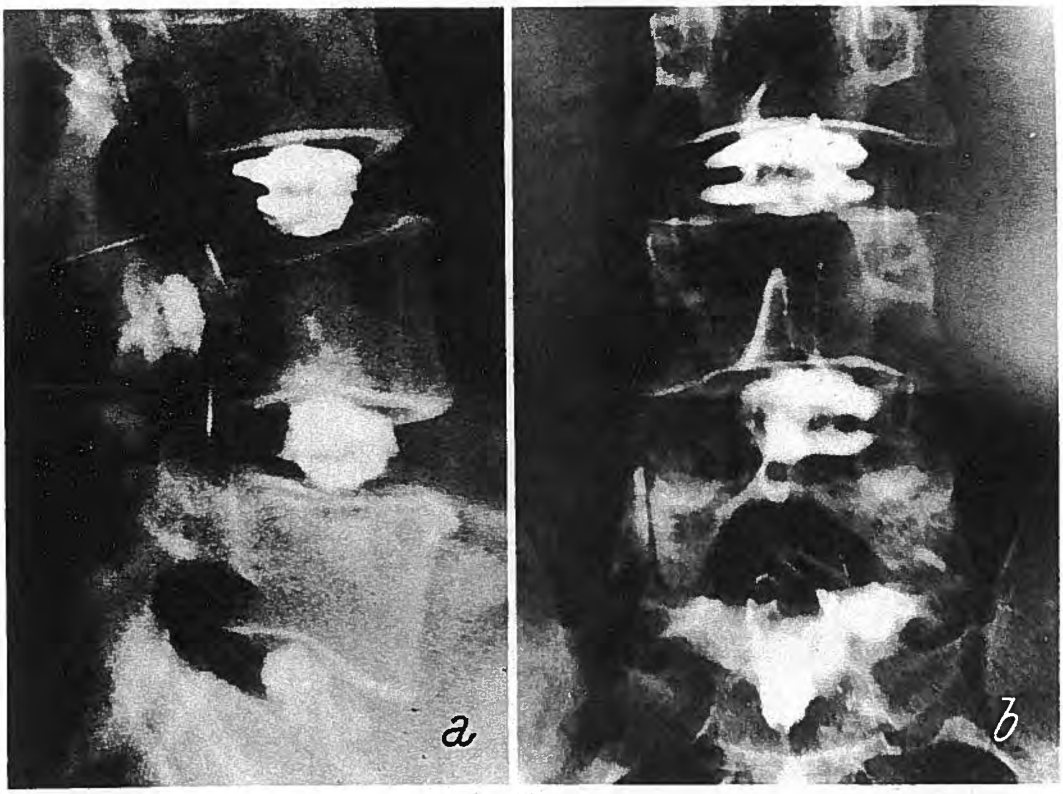


Figure 2.2. A lateral radiograph of the lumbar spine showing discrograms at L3/4 and L4/5. The L4/5 discogram is normal. The L3/4 discogram shows a normal nuclear outline but note the spread of dye into the veins of the vertebral body. Batson's plexus is filled and tributaries of the anterior internal vertebral venous plexus are also filled



Figures 2.3 a and **b.** Radiographs of the lumbar spine of a man aged 37 years showing discograms at the L3/4, L4/5 and L5/S1 levels. Remnants of myodil are noted in the spinal canal from a previous myelogram performed some years earlier. The volume of dye injected at the L3/4 and L5/S1 disc spaces was approximately 1.9 ml at each disc. The volume injected at the L4/5 level was 4.5 ml. Note the flare in the body of the 4th lumbar vertebra, indicating leakage of dye through the vertebral end-plate cartilage. During injection of contrast medium at the L4/5 disc, the patient complained of severe low back pain similar to that for which he had sought treatment. The discograms appear normal in the antero-posterior view

out of the disc, Nachemson (1969); and (iii) leakage of disc protein and catabolites into the general circulation via vertebral end-plate capillaries, producing features suggestive of auto-immune or hypersensitivity reactions. Some of the patients in this group suffer from profound weight loss and they are found to have abnormalities in peripheral blood smears, with rouleaux formation, altered white cell counts and elevated erythrocyte sedimentation rates (E.S.R.) (Crock, 1970). Gurdjian *et al.* (1961) observed elevations of the E.S.R. in patients who progressed satisfactorily following lumbar laminectomy for herniated intervertebral discs. These authors drew no conclusions about the significance of the observation except in those cases where it remained elevated in the range 80 to 120 mm per hour when aseptic necrosis of the vertebral body adjacent to the area of operation, was noted. Grollmus *et al.* (1974) studied the E.S.R. in 49 patients following lumbar laminectomy, contrasting the findings with those in a group of 25 patients with the syndrome of disc space inflammation. Their observations and conclusions in relation to cases with closed disc space infections were similar to those of Gurdjian *et al.* (1961). However, they noted consistent elevation of the E.S.R. after discectomy in patients whose post-operative

Figure 2.4. A micro-photograph (×60 approximately) showing the capillary bed in the vertebral end-plate cartilage in the lower lumbar ragion in an adult dog. Note the drainage of these capillaries directly into the marrow spaces of the vertebral bodies. *This is almost certainly the pathway for the passage of substances from a damaged "avascular" disc into the patient's immune system.* (Prepared by Drs. H. V. Crock and M. Goldwasser)

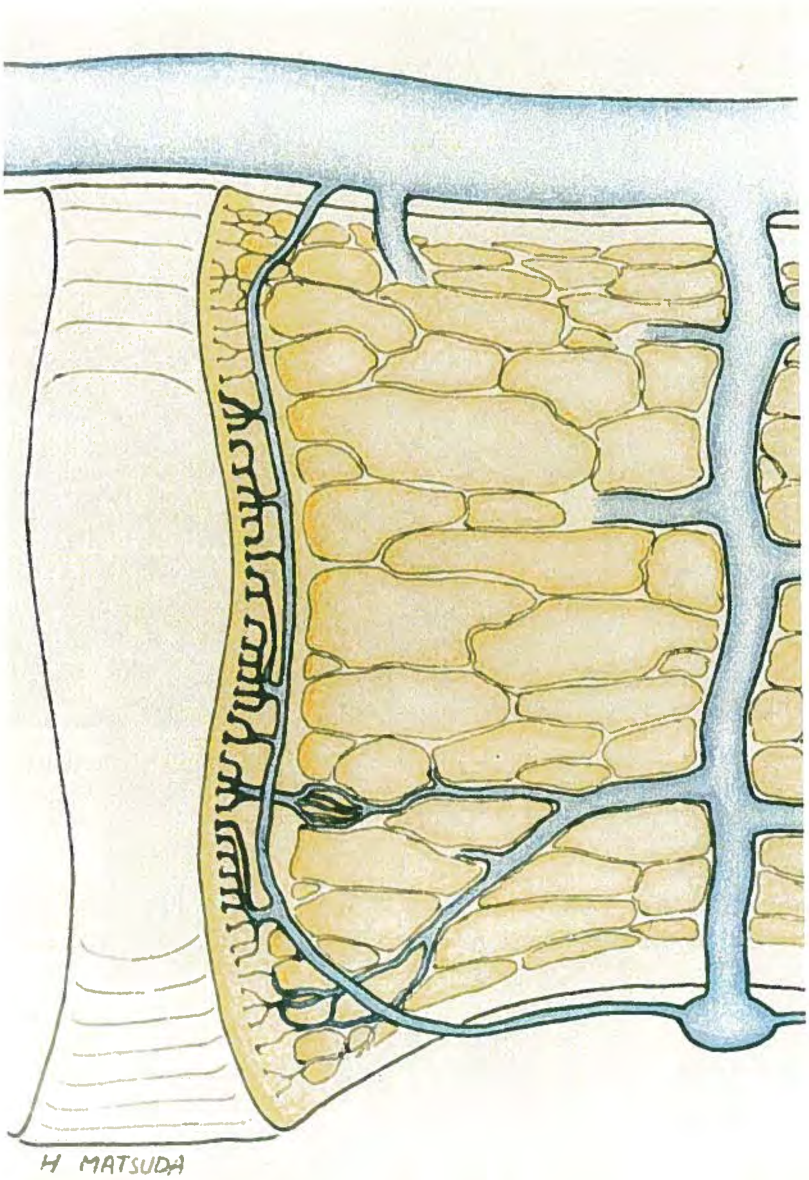


Figure 2.5. A drawing illustrating the methods of drainage of vertebral end-plate capillaries in the dog: (i) either directly into the marrow space veins or, (ii) through a sub-articular collecting vein system into a vertically orientated sub-articular vein system that will drain either backwards into the internal vertebral venous plexus or forward into the external vertebral veins

Figure 2.6. A photo micrograph (×20 approximately) to show the distribution of capillaries in the vertebral end-plate cartilages at the anterior disc margin in the lower lumbar disc of an adult dog. (Prepared by Drs. H. V. Crock and M. Goldwasser)

course was otherwise uncomplicated. They, too, were unable to explain fully this phenomenon, but suggested that the examination should be made routinely following operation.

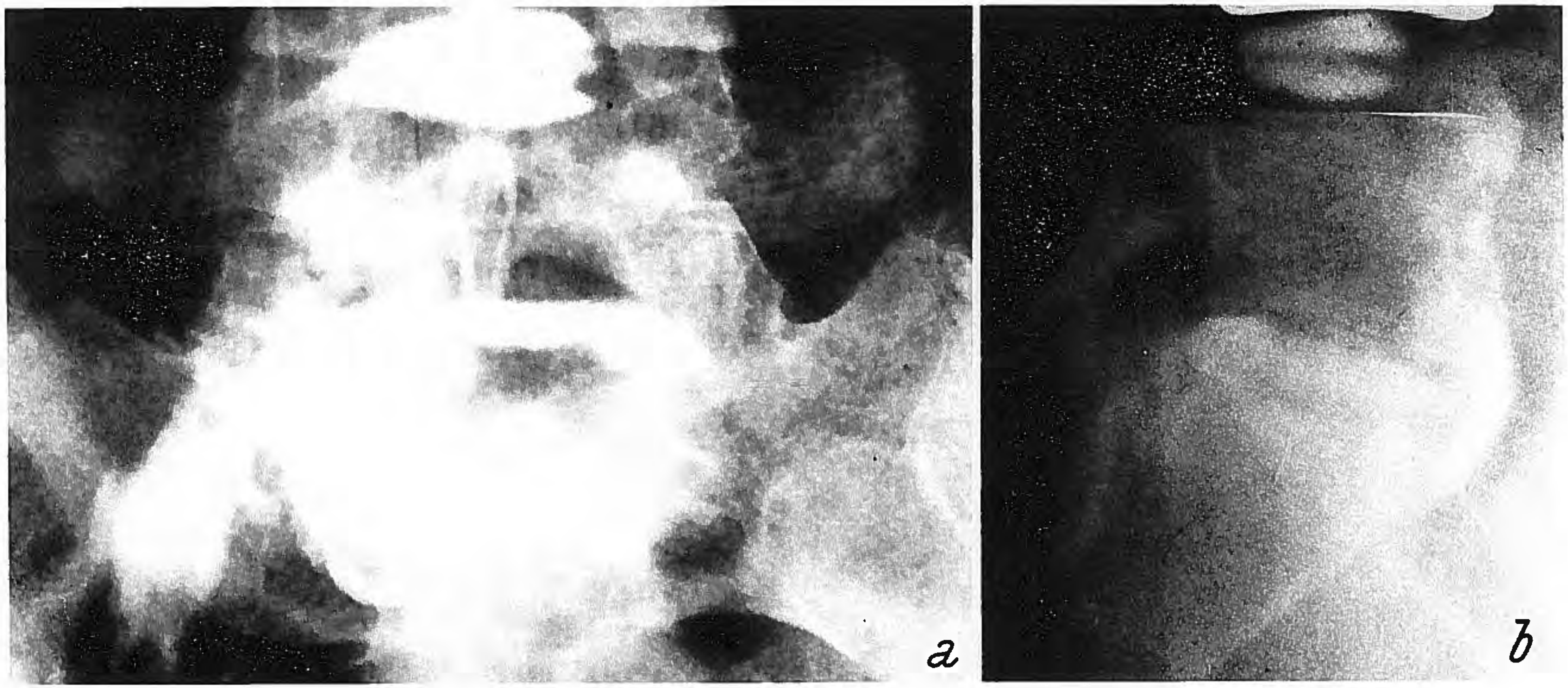
2.3. Investigations

a) Plain X-Ray

Unless clear evidence of vertebral instability can be demonstrated on films taken in flexion and extension, plain X-rays are of no value in establishing this diagnosis (Morgan and King, 1957).

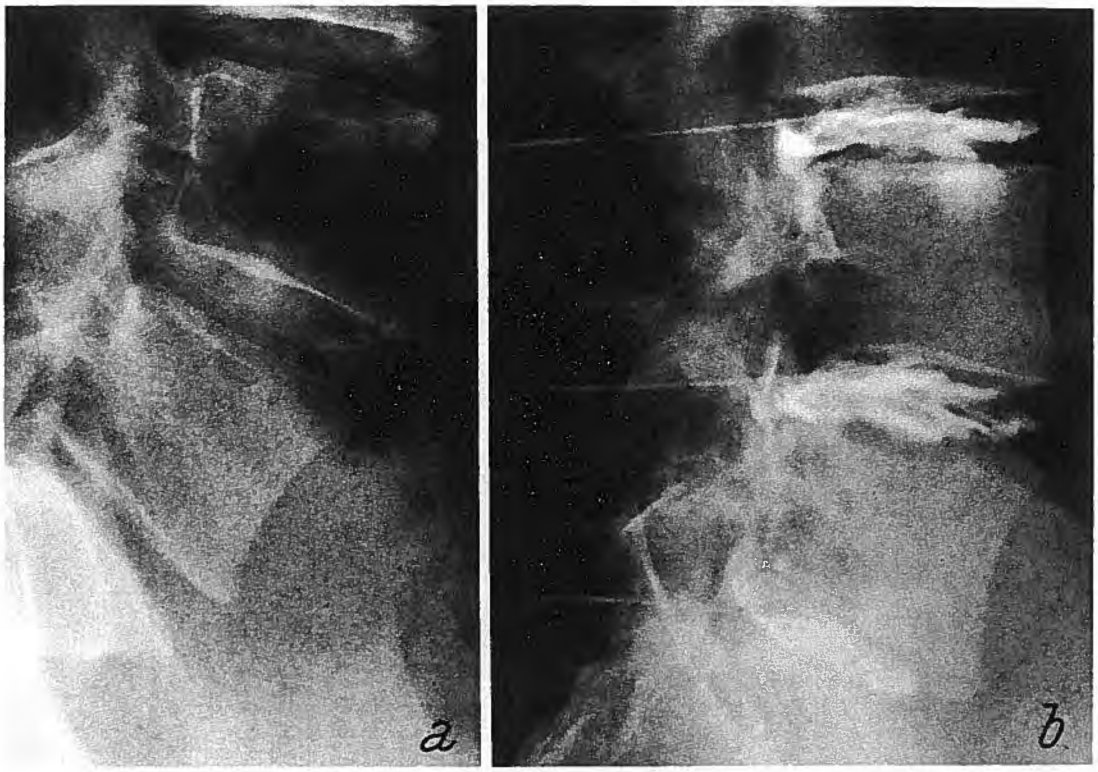
b) Discography

Lumbar Discography was introduced by Lindblom (1948). *This investigation is indispensable in the modern practice of spinal surgery* (Figs. 2.8, 2.9a, b, 2.10a, b). Special needles are required for its performance (Fig. 2.11). Injection of a suitable contrast medium such as Urograffin 60% w/vol should be made through a Luer-lock 1 ml syringe.



Figures 2.7 a and b. Antero-posterior and lateral radiographs of the L 4/5 and L 5/S1 discs in a girl of 17, showing a normal L 4/5 discogram and gross disc disruption at L 5/S1 with antero-lateral leakage of dye. This young lady had been involved in a motor vehicle accident two years earlier and presented with classical features of post-traumatic internal disc disruption, with chronic back pain, referred leg pain, loss of energy, intolerance to physical activity, and profound weight loss

Figure 2.8. A lateral radiograph of the lumbar spine of a man aged 48 years showing normal discograms at L3/4 and L5/S1. 2 ml of dye was injected at each of these disc spaces and no pain was reproduced. At L4/5, 5 ml of dye was injected. Gross disc disruption is shown. The patient's pain was reproduced at the time of injection



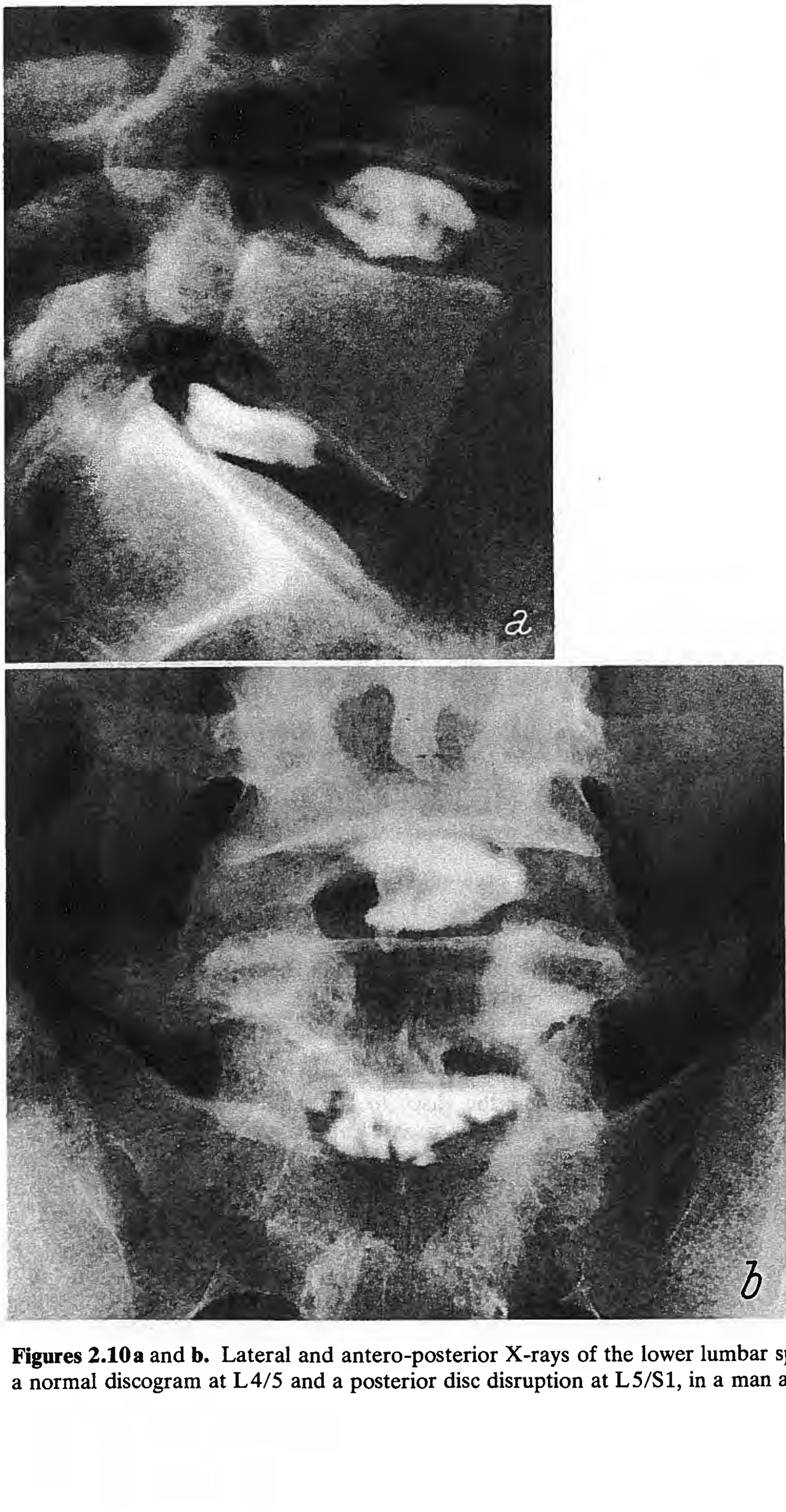
Figures 2.9 a and b. Lateral X-rays of the lumbar spine to show the plain film appearance and the gross disc disruption at three levels demonstrated by discography

Many authorities have tended to play down the importance of discography when their personal experience of it is small (Epstein, 1969; De Palma and Rothman, 1970). Some who have firmly advocated the procedure, place undue emphasis on its use in the investigation of suspected cases of disc prolapse when either myelography or C.T. scanning may be used with greater effect (Collis, 1963).

The indications for discography are: (1) in suspected cases of internal disc disruption assessed on the clinical syndrome; (2) in suspected cases of internal disc disruption in patients who have had failed "laminectomies"; (3) as a supplementary test following negative myelography; (4) in some cases of spondylolisthesis to determine if adjacent discs are disrupted; and (5) to plan the level and extent of spinal fusion in lumbar spondylosis.

Using an image intensifier X-ray machine with video-storage facilities, the needles may be inserted easily into the discs to be examined, the patient being sedated with intravenous diazepam. If this sophisticated equipment is not available, X-rays in two planes should be obtained after the needles have been inserted into the discs. Injections *must never be made* until the needles have been placed accurately in the area of the nuclei pulposi and their positions confirmed by X-rays taken in antero-posterior and lateral views (Figs. 2.12–2.14).

The discogram "guiding needle" should be inserted about four fingers breadth lateral to the spinous process, angled towards the disc space at about 45° to the long axis of the spine. When the discogram needle is passed through the "guiding needle" into the disc, there is a characteristic sensation as though it were being pushed into a



Figures 2.10a and **b.** Lateral and antero-posterior X-rays of the lower lumbar spine showing a normal discogram at L4/5 and a posterior disc disruption at L5/S1, in a man aged 37 years

Figure 2.11

Figure 2.12

Figure 2.11. A photograph of discogram needles showing the shorter guide needle and the longer 22 gauge needle with stilette

Figure 2.12. A lateral X-ray of the lumbar spine showing a control film taken after insertion of discogram needles, to illustrate the importance of obtaining X-rays to determine the position of needles before any injections are made

firm mass of rubber. Occasionally when the Ferguson angle of the lumbo-sacral disc space is higher than normal (38° to the horizontal), difficulty may be experienced in inserting the discogram needle by this method. Re-placing the "guiding needle" in the midline, the lumbo-sacral disc may be punctured by passing the discogram needle through the dural sac.

Injection of contrast medium into a normal disc is painless. When dye enters a disrupted disc, pain is experienced immediately. The pain is mediated via nerve fibres within the disc and its pattern of radiation into the limbs is not radicular (Yoshizawa *et al.*, 1980).

The reproduced pain is usually of the same character as the patient's presenting symptom but more severe; it disappears within seconds of the injection of local anaesthetic into the disc. Pain emanating from a disrupted disc at the time of discography is not provoked by a rise in intra-discal pressure as it may come on after the injection of as little as 0.3 ml of dye, whereas the injection of 1.5 ml of dye into an adjacent normal disc will be painless. Notes should be made on the ease or difficulty experienced in injecting the dye, on the volume and the pattern of the pain response described by the patient. *In internal disc disruption,* dye spreads beyond the

Figure 2.13. A lateral X-ray of a lumbar spine showing control X-rays with needles satisfactorily placed in the lateral view at L3/4 and L4/5 but incorrectly placed at the lumbo-sacral level

normal confines of the nuclear zone, the radiographic patterns of the discogram varying with the anatomy of the disruption of the annular fibres of the disc or with the presence of vertebral end-plate defects (Figs. 2.3a, 2.15a, b, 2.16a–c). *Spread of dye beyond the disc margins and into the spinal canal is a manifestation of abnormal permeability of the annular fibres and should not be interpreted as indicating prolapse of disc material.*

A discogram report should provide the following information:

1. The placing of the needles within individual discs.
2. The type and volume of dye injected.
3. The ease or difficulty of injection.
4. The patient's description of induced pain.

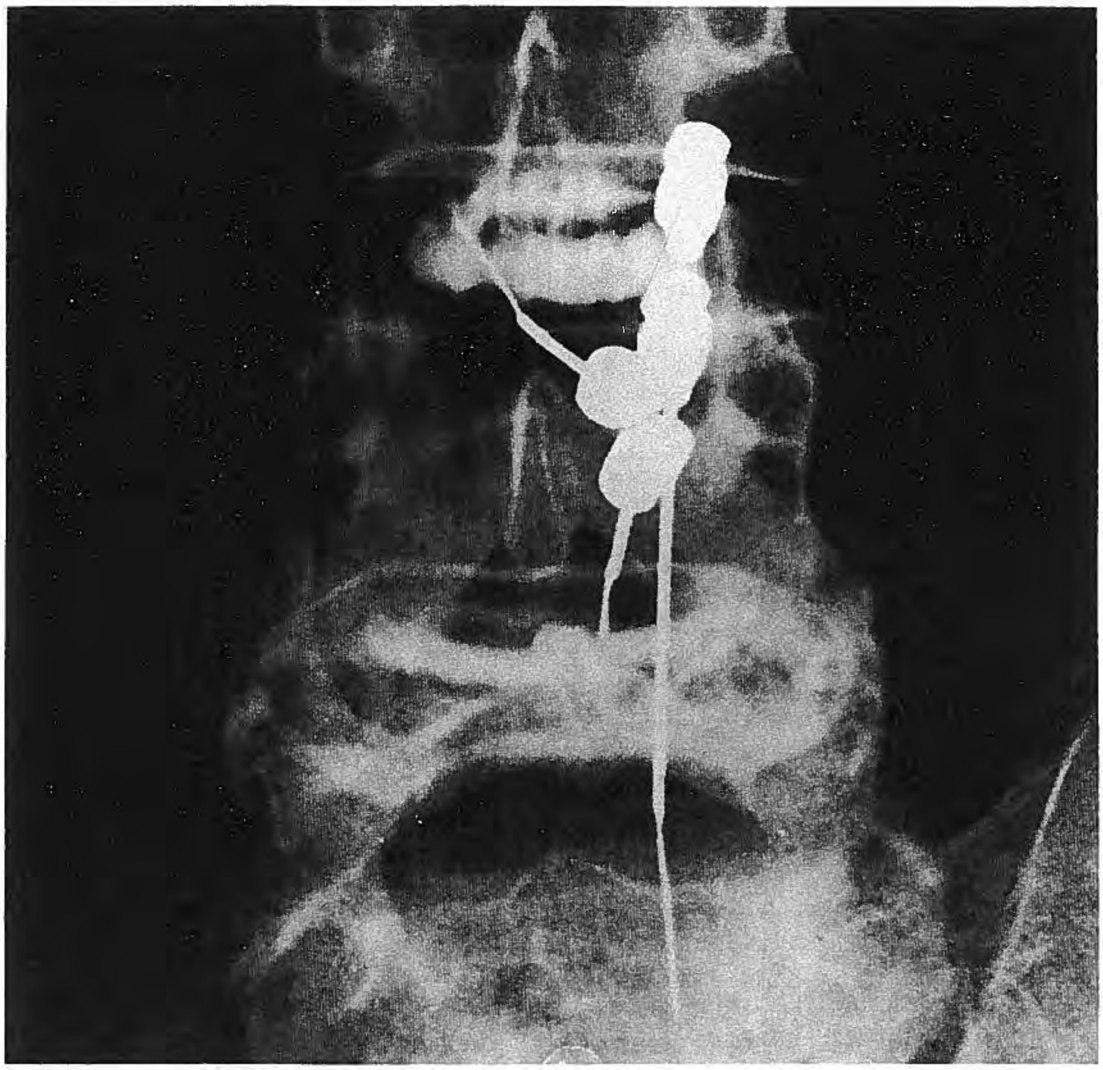
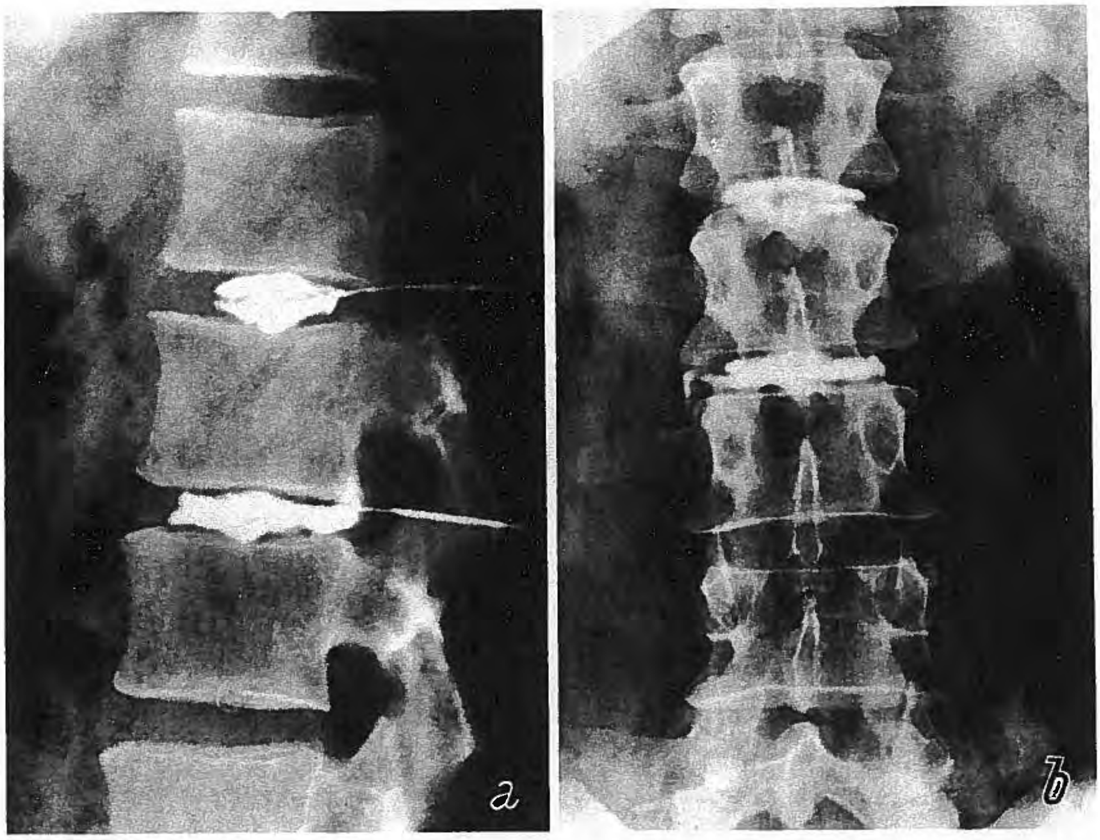


Figure 2.14. An antero-posterior view of the lower lumbar spine showing the disposition of the needles in the intervertebral disc spaces with dye injected at L3/4 and L4/5. If the needles are eccentrically placed in relation to the nuclear zone of the disc, then artefacts will appear when dye is injected

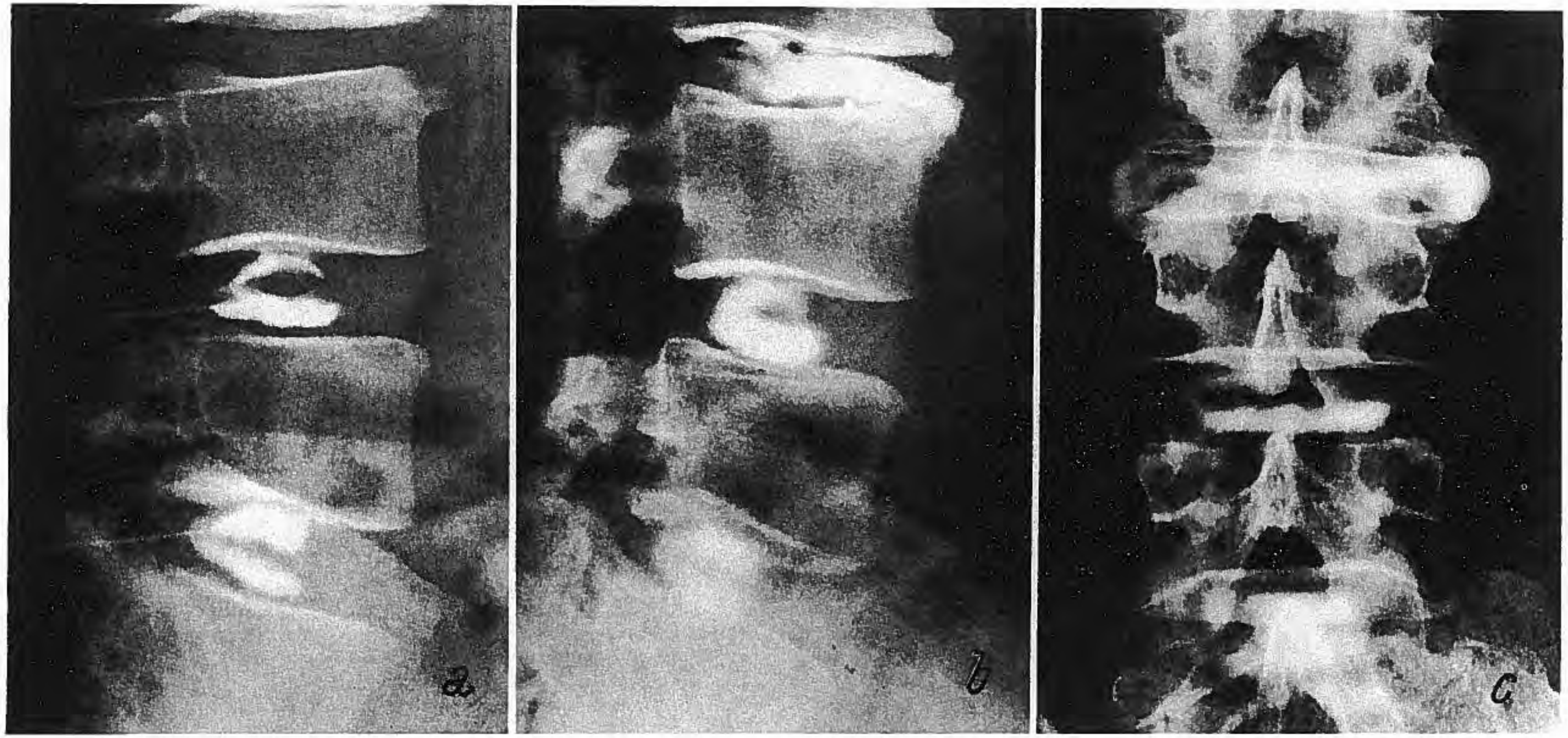


Figures 2.15. **a** A lateral radiograph of the lumbar spine of a man aged 42 years. Discogram needles have been inserted into the discs between L1/2 and L2/3 vertebral bodies, lateral and anterior to the thecal sac. The upper discogram is normal; that at the L2/3 level shows posterior internal disc disruption. **b** Antero-posterior view of the same case

5. The patterns of distribution of the injected dye in antero-posterior and lateral X-rays of the disc space.
6. The volume of corticosteroid injected before the discogram needle was withdrawn.

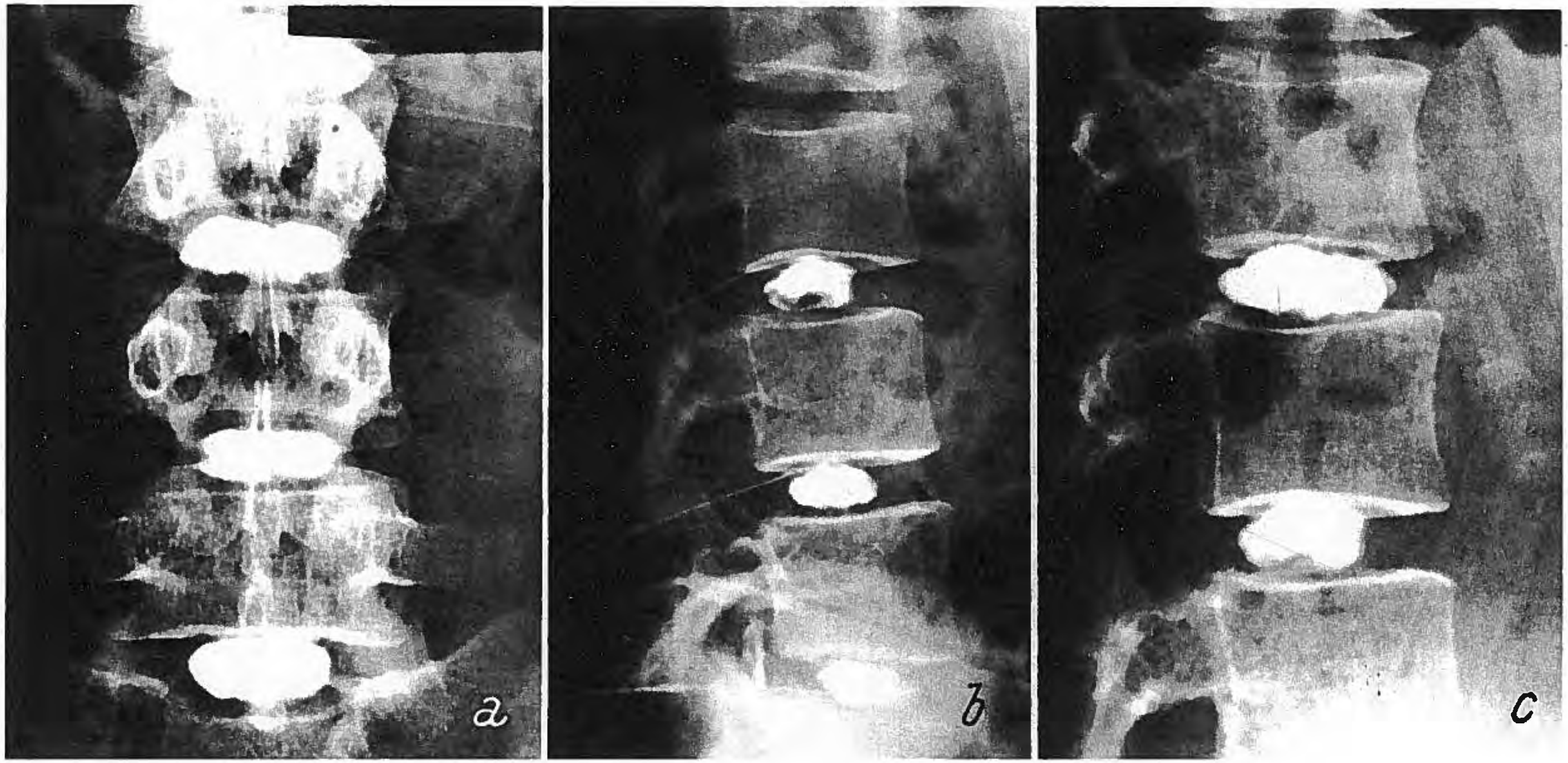
Excluding technical faults in its performance, chemically induced discitis is the major complication which may result from its use. The latent period between the time of discography and the appearance of discitis varies between three to twelve weeks. For this reason, radiologists rarely see the complication. Having performed discograms personally over a period of ten years, I estimate that this complication may occur in about 1.5–2% of patients on whom the investigation has been performed. *This is one of the causes of excruciating spinal pain* and it is often associated with marked spasm of the paraspinal muscles, causing gross lumbar scoliosis.

Post-discogram discitis responds to rest and corticosteroid therapy, either by intradisc injection or orally (Figs. 2.17, 2.18a, b, c, 2.19a, b). Infection due to introduced bacterial contaminants has been reported, though it is rare (Matsubara *et al.,* 1966). Simple puncture of the disc by discogram needles has no proven complication.

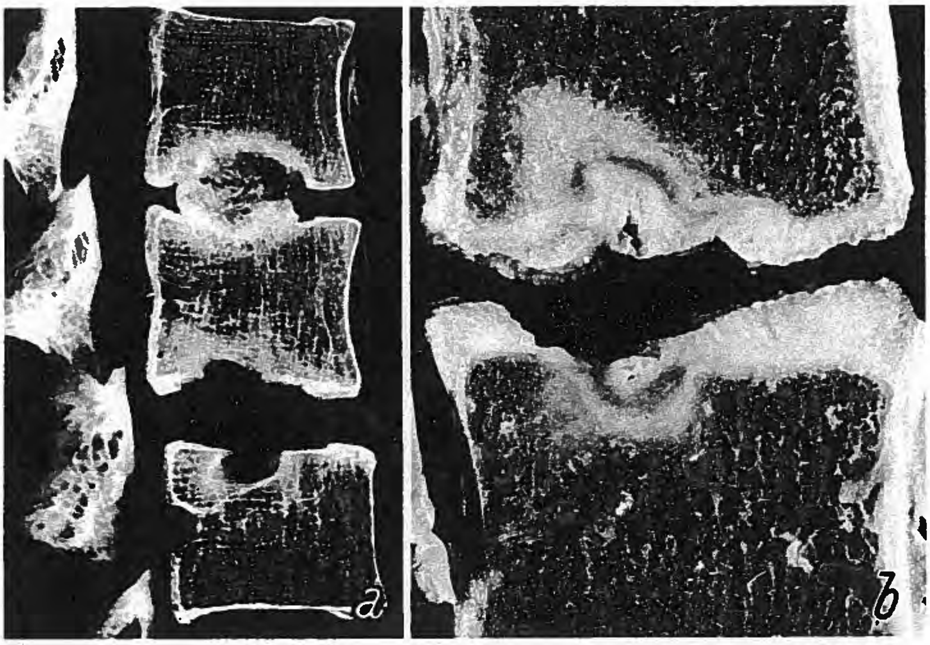


Figures 2.16 a–c. Normal discograms at L 4/5 and L 5/S1, with a needle directed towards the back of the vertebral body of L 3 at the upper part of the picture. In **b** note the gross disc disruption at L 3/4. **c** An antero-posterior view showing normal discograms at L 4/5 and L 5/S1 with marked disc disruption at the L 3/4 level

Figure 2.17. A mid-line tomogram of the lower lumbar spine from a man aged 27 years, taken three months after lumbo-sacral interbody fusion. The L3/4 and L4/5 discograms had been normal. Note the changes of vertebral end-plate erosion and loss of disc height typical of post-discogram discitis



Figures 2.18. **a** An antero-posterior radiograph of the lumbar spine of a woman aged 32 years. The L 2/3, L 3/4, L 4/5 and L 5/S1 discs appear normal. **b** A lateral radiograph showing normal discograms at L 3/4, L 4/5 and L 5/S1. **c** Lateral radiograph showing the L 2/3 and L 3/4 discograms. The L 2/3 disc is disrupted posteriorly, but the L 3/4 discogram is normal



Figures 2.19. **a** X-ray of a thin sagittal section of the lumbar spine taken at necropsy. At L2/3 union of the graft is incomplete. There are erosions of the end-plates of the bodies of the 3rd and 4th lumbar vertebrae with reactive changes in excavated areas of the bodies, resulting from chemical discitis. **b** A detailed photograph of the necropsy specimen at the level of the discitis at L3/4. This patient committed suicide four months after operation for L2/3 interbody fusion

c) Myelography

Myelography has no place in the investigation of internal disc disruption.

2.4. Surgical Treatment

a) Types

Surgical treatment is recommended after the failure of comprehensive conservative treatment. Pain will often subside to tolerable levels after prolonged rest. If re-employment after re-training could be assured–though this is usually not possible in highly competitive industries–then surgery would be indicated less frequently.

Poor results of spinal canal surgery for disc lesions other than for disc prolapse have been reported frequently (Kudelka, 1968). These poor results which are known to follow "negative laminectomies" could be largely prevented by more accurate preoperative assessment including the use of discography. If nothing else, the use of this investigation would restrict the extent of spinal canal exploration, as, often, more than one disc will be inspected in the hope of finding an elusive disc "prolapse". Discography before operation in this case will allow precise definition of the lesion.

Surgical treatment along the following lines should give satisfactory results:

i) Total Disc Excision and Interbody Fusion

Total disc excision and interbody fusion–for single or double level disc disruptions with intractable limb and spinal pain and constitutional symptoms (Fig. 2.1) (Debeyre and Delforges, 1959). In the lumbar region this method may be satisfactory for one or two disc levels, providing:

- the patient is not obese;
- there is no antecedent history of pulmonary embolism or deep vein thrombosis in the legs;
- lumbo-sacral articulation anomalies are not associated with great vein anomalies which may render access to the intervertebral disc space hazardous or impossible; and
- surgical technique is meticulous.

Whereas the operation of lumbar interbody fusion finds a small but undisputed role in the management of failed spinal operations (Sacks, 1965), its real place in the present state of knowledge should be for the primary surgical treatment of non-prolapsing lumbar disc lesions. Cloward (1955) has described a method of inserting grafts between adjacent vertebral bodies via the spinal canal for the treatment of lumbar disc "lesions". The operation which bears his name is not used widely because of the technical difficulties of its execution, although some surgeons still advocate it (Finneson, 1973). Exceptional surgical skill is required for its safe and effective use. For similar reasons, the operation described by Wiltberger (1957, 1958), which involves the insertion of accurately cut dowel grafts between adjacent vertebral bodies via the spinal canal, is rarely used.

When the four prerequisites set out above can be met, anterior lumbar interbody fusion is a satisfactory operation which can be rapidly and safely performed by an extra-peritoneal left-sided abdominal approach, allowing ready access to more than one disc if required. Near-total disc excision can be accomplished by fashioning two parallel dowel cavities into which dowel grafts can be accurately and firmly impacted. The grafts are cut vertically downwards from the anterior third of the left iliac crest. They have tooled cancellous surfaces between the stout cortical tables of the iliac crest and their depth can be determined at will. Inserted parallel to each other with their cancellous faces abutting the prepared cancellous surfaces of the adjacent vertebral bodies, these grafts are ideally situated for rapid vascularization. One cortical surface of each graft on either side of the disc space prevents penetration of any disc remnant which may have escaped removal by curettage before the grafts were inserted, thereby diminishing the risk of non-union.

Anterior lumbar interbody fusion being the operation of choice for the surgical treatment of lumbar internal disc disruptions, the details of technique and assessment of results achieved will be described in detail below.

ii) Bilateral Nerve Root Canal Decompression Laminectomy

Bilateral nerve root canal decompression laminectomy–where single level lumbar disc disruption has been identified by discography in a young patient with predominant referred leg pain without neurological abnormalities or constitutional illness. The aim is to enlarge the nerve root canals, the rationale being to allow the nerve roots to accommodate to the vertebral instability resulting from the disc disruption (Morgan and King, 1957). This operation is described on p. 23.

iii) Posterior Spinal Fusion

Posterior spinal fusion, without spinal canal exploration–for multi-level disc disruption with dominant back pain and insignificant referred leg pain, without constitutional disturbances such as weight loss and psychiatric upsets.

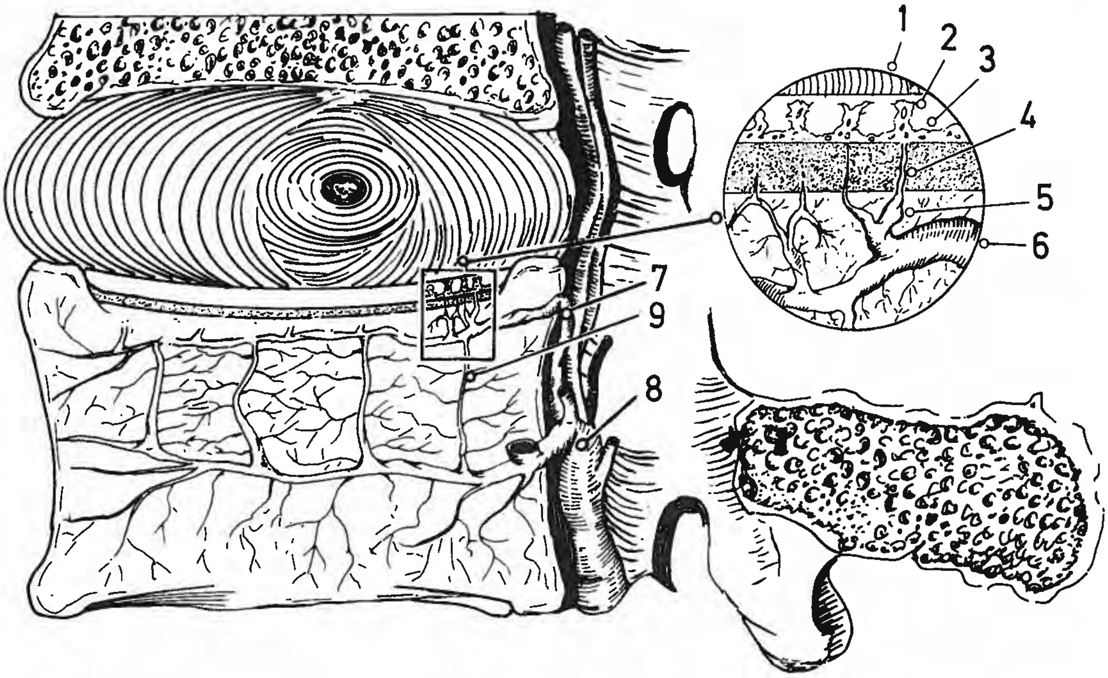


Figure 2.20. A schematic drawing to show the spatial relationships of the veins of a typical vertebral body. **1** intervertebral disc; **2** capillary bed in vertebral end-plate cartilage; **3** sub-chondral post-capillary venous network on the vertebral end-plate; **4** vertebral end-plate perforated by short vertical venous tributaries; **5** vertical tributaries from the sub-chondral post-capillary venous network, draining to the horizontal sub-articular collecting vein; **6** horizontal sub-articular collecting vein; **7** horizontal sub-articular collecting vein joining the anterior internal vertebral venous plexus; **8** basi-vertebral vein joining the anterior internal venous plexus; **9** vertical tributary of the basi-vertebral system of veins

Armstrong (1965) makes sound comments on the selection of posterior spinal fusion operations in his chapter on the operative treatment of lumbar disc lesions. The procedure is most likely to succeed where a single level fusion is required. If fusion is attempted concomitant with spinal canal exploration, methods using other than postero-lateral or inter-transverse-alar grafting are likely to fail. The probability of failure is even higher if posterior fusion is attempted following earlier spinal canal surgery (Adkins, 1955).

The diagnosis of internal disc disruption is most often established by a process of exclusion after months of careful clinical observation. Attention has been drawn to the importance of assessing correctly the role of precipitating trauma. Attention has also been focused on the description of pain and especially on the difficulty which these patients find in describing their limb pain. When first seen their problems are indistinguishable from many of the common short-lived episodes of spinal and limb

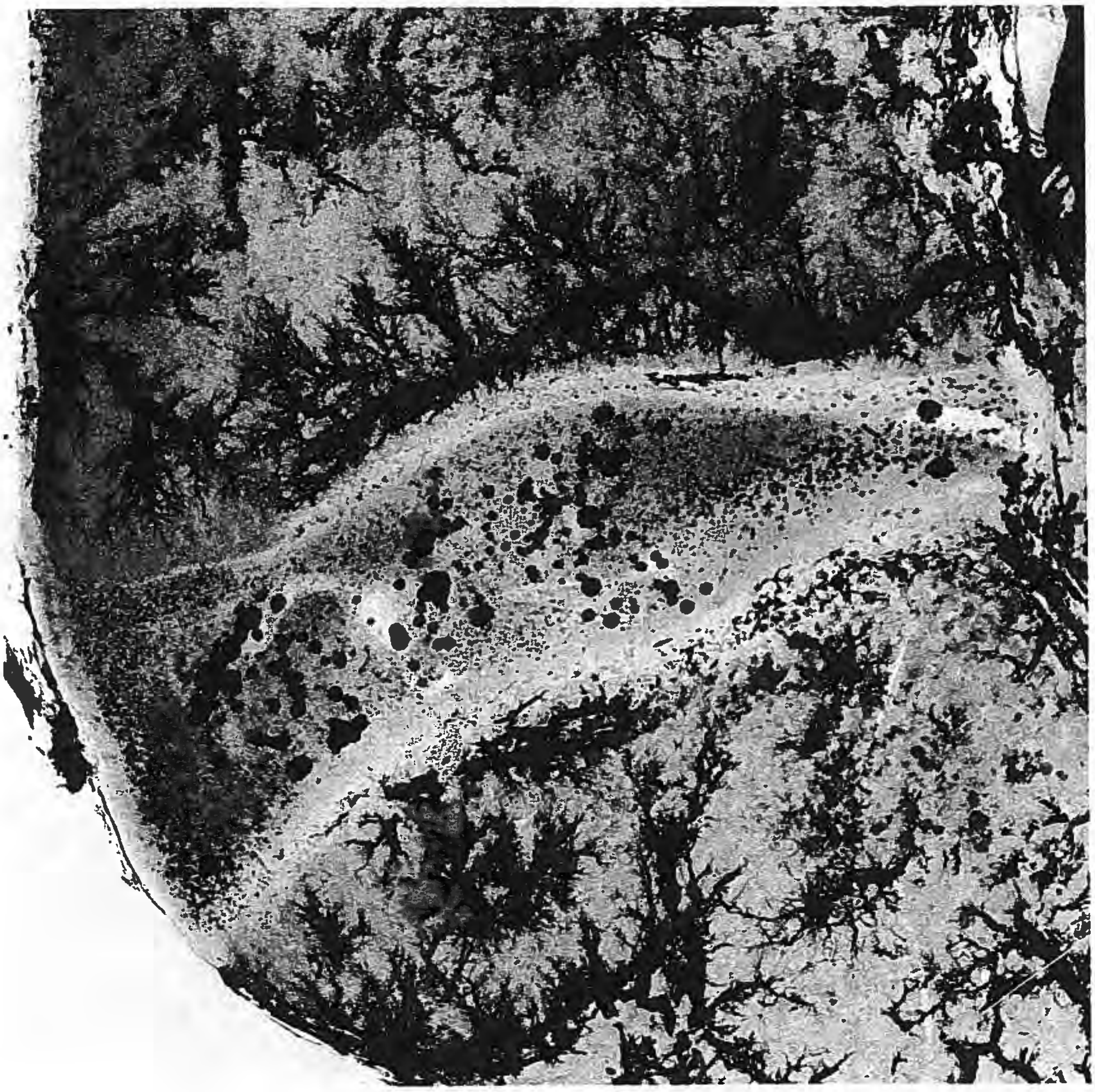


Figure 2.21. A radiograph of a thin sagittal section cut laterally near the vertebral pedicle from the lumbo-sacral junction of a woman aged 67 years. Some fragments of barium sulphate debris have adhered to the cut surface of the disc. The horizontal sub-articular collecting vein system of the vertebral body can be seen running parallel to the vertebral end-plate area on the lower surface of the 5th lumbar vertebra. Nearer the disc, of smaller calibre, running parallel to the vertebral end-plate cartilage, the sub-chondral post-capillary venous network can be seen. It is only partly filled. This system drains by vertical stems through perforations in the vertebral end-plate into the larger horizontal sub-articular collecting vein system. In this specimen only one such stem can be seen joining these two venous channels. [Reproduced by courtesy of the Editor, J. Bone Joint Surg. *55b* (1973), and J. B. Lippincott & Company from: Clinical Orthopaedics and Related Research, No. 115 (1976)]

Figure 2.22

Figure 2.23

Figure 2.24. A photograph of a dissection to show the aorta and the vena cava in the abdomen. Note the bifurcation of the aorta at the lower border of the 4th lumbar vertebra. The relationship of the common iliac arteries to the common iliac veins is clearly shown. The ascending lumbar vein can be seen in the depths of the dissection, just below the disc between L4 and L5, on the right hand side of the photograph. Note that the left psoas muscle has been removed, so that the lumbar arteries and veins can be seen on the right side of the photograph. See also Fig. 2.36, p. 72

Figure 2.22. A detailed photograph taken from the central area of the disc and vertebral body (500 μm thick) from a woman of 30 years. Spalteholz-cleared specimen (approximately $\times 20$). The demarcation line between the intervertebral disc and vertebral end-plate cartilage is clearly visible. The vertebral end-plate cartilage capillary bed is shown, with vertical tributaries draining to the sub-chondral post-capillary venous network orientated parallel to the vertebral end-plate

Figure 2.23. A detailed photograph of a dissection of the lumbo-sacral junction in an adult, showing the relations of the 3rd and 4th lumbar arteries to the sympathetic trunk and the pattern of branching of the median sacral artery related to the 5th lumbar vertebral body. (Dissected by Dr. S. Sihombing, of Indonesia)

Figure 2.25. A photograph of a dissection of the lumbar vertebral column in an adult viewed from the left side, showing the origins and distribution of the lumbar arteries from the aorta. The median sacral artery is also clearly shown. The psoas muscle has been removed in its entirety

pain for which, in about 80% of cases, no cause is evident (Dillane *et al.*, 1966). However, these patients consistently fail to respond to conservative treatment and often are made worse by standard methods of physical therapy involving exercises or spinal manipulations. Likewise, their symptoms are aggravated by travelling in modern vehicles. It is important to distinguish these cases from disc prolapses in order to reduce significantly the "negative laminectomy" rate which accounts for many of the poor results of spinal surgery for disc lesions.

Certain anatomical factors are pertinent to the interpretation of the causes of symptoms in internal disc disruption. These and others relevant to the performance of interbody fusion operations and to their ultimate success are shown in Figs. 2.20–2.28.

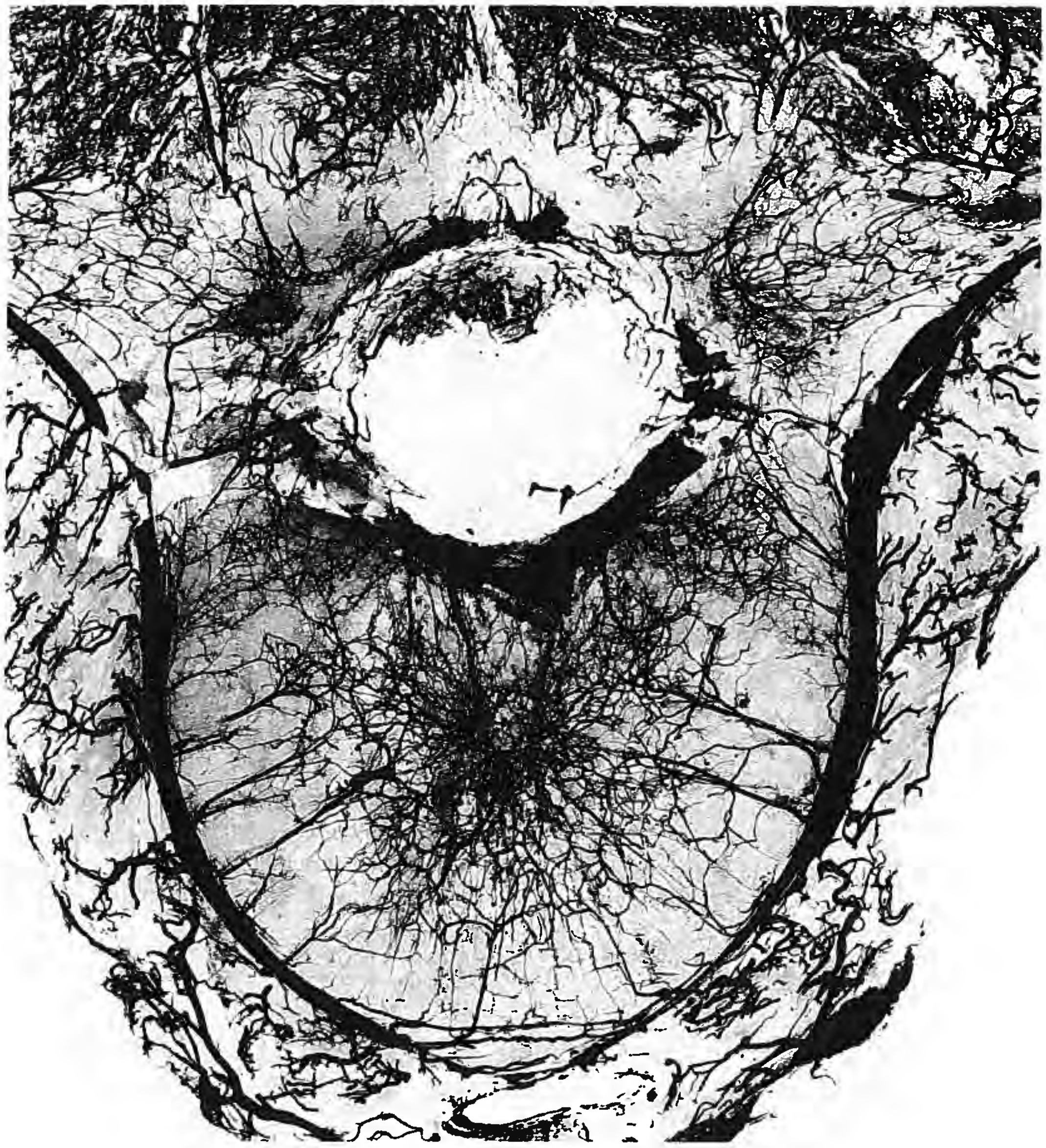


Figure 2.26. A transverse section through the lumbar vertebral body of a child aged 13 years. The radiate distribution of the centrum branches arising from the inner surface of the lumbar arteries on each side has been shown. Note the muscular branches passing directly into the muscles from the outer side of the main trunk of each lumbar artery. [Reproduced by courtesy of J. B. Lippincott & Company from: Clinical Orthopaedics and Related Research, No. 115 (1976)]

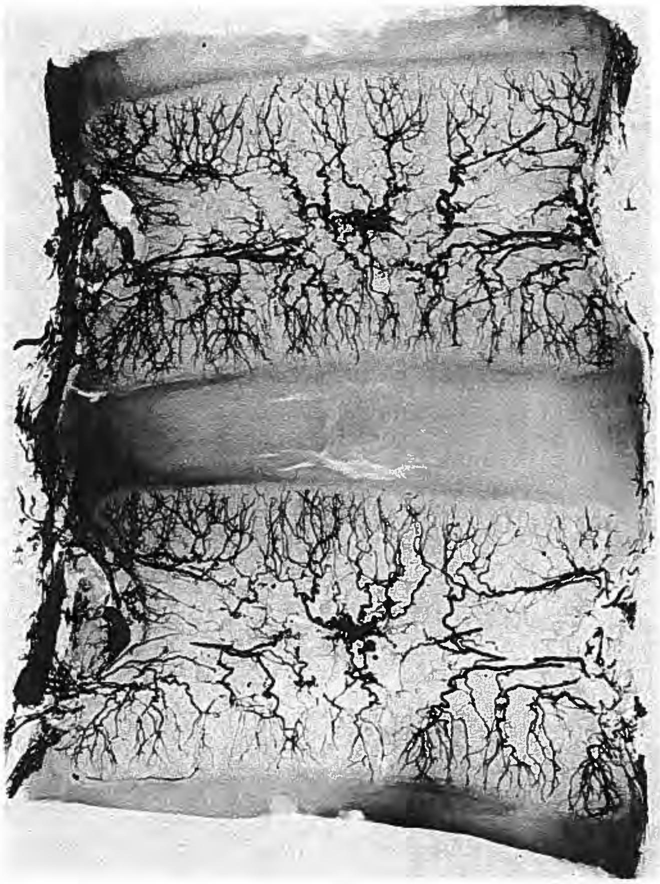


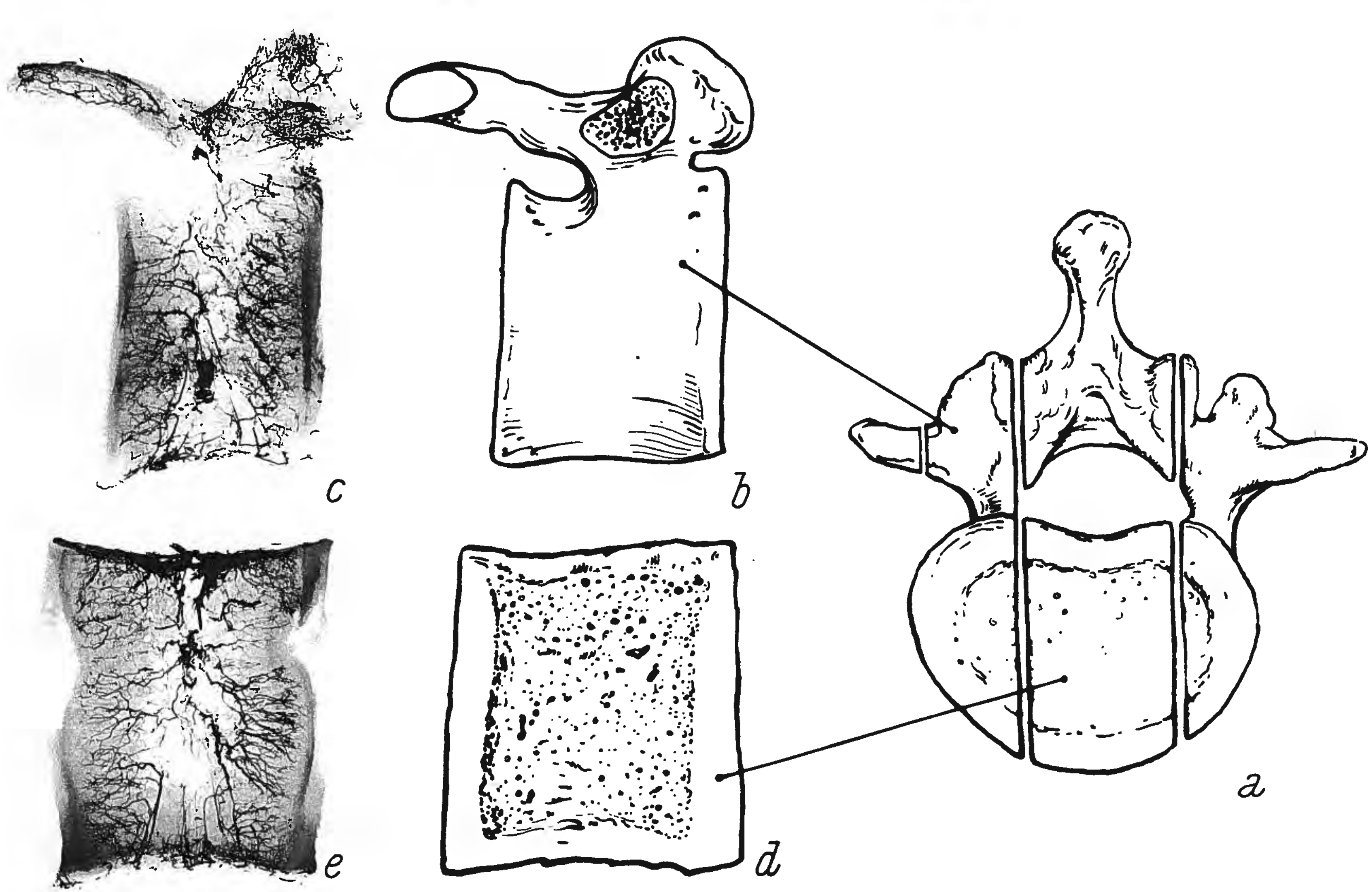
Figure 2.27. A thin coronal section through the centre of two adjacent lumbar vertebral bodies from a male aged 65 years, showing details of the intra-osseous distribution of arteries. [Reproduced by courtesy of J. B. Lippincott & Company from: Clinical Orthopaedics and Related Research, No. 115 (1976)]

b) Technique of Anterior Lumbar Interbody Fusion

i) Indications

The operation of spinal fusion was introduced first by Albee (1911) for the treatment of spinal tuberculosis. Its use was then extended by the application of anterior interbody fusion methods, popularized in Hong Kong by Hodgson and Stock (1956). In selected cases with spinal tuberculosis, anterior interbody fusion still enjoys an undisputed and favoured place in treatment (see p. 233).

The role of spinal fusion in the treatment of disorders of the lumbar spine has remained vexed and confused. Apart from a general agreement on the possible application of spinal fusion in the treatment of spondylolisthesis, there are no clear-cut published statements on indications for the use of spinal fusion techniques. With the decline in the use of fusion operations for major joints in the limbs, there has been a corresponding fall in the number of these procedures applied to spinal problems. In particular, a number of the degenerative disorders of the lumbar spine



Figures 2.28 a – e. Line drawings **a, b, d** indicating the division of a lumbar vertebra into sagittal sections. Sections **c** and **e** of the specimen alongside show the distribution of arteries within the vertebral body from a male aged 30 years. The feeding branches to the centrum grid can be seen in both sections. [Reproduced by courtesy of J. B. Lippincott & Company from: Clinical Orthopaedics and Related Research, No. 115 (1976).]

now can be more effectively treated by some form of spinal canal or spinal nerve root canal decompression.

In the author's opinion, the present indications for the use of anterior lumbar interbody fusion operations are as follows:

1. For the treatment of other failed spinal operations;
2. for the treatment of certain disc lesions:
   a) internal disc disruption (frequently),
   b) isolated disc resorption (occasionally),
   c) nucleus pulposus calcification (rarely),
   d) disc herniation (rarely);
3. in the management of selected cases of spondylolisthesis;
4. for the treatment of certain spinal infections;
5. for the correction of selected spinal deformities;
6. for the treatment of rare miscellaneous cases, e.g. vertebral body tumours.

The operation of lumbar interbody fusion should be performed ideally with the aid of two competent assistants. Until the orthopaedic surgeon is thoroughly familiar with every aspect of the procedure, he would be wise to work with a general surgeon who has special competence in vascular surgery.

When Sir John Charnley first introduced his operation of total hip joint replacement in the early 1960s, he provoked an angry response from many surgeons by refusing to allow them to obtain the recommended instruments until they had been specially instructed in their use. The wisdom of his early caution doubtlessly served a good purpose in as much as total hip joint replacement operations, performed by otherwise untrained surgeons, can maim. But when anterior lumbar interbody fusion is attempted by surgeons who are not specially trained, the results can be devastating and the patient may lose his life.

ii) General Pre-Operative Preparation

Patients arrive at the operating room with an intravenous infusion inserted. Two or three litres of compatible blood should be available for use during the operation; blood loss at the time of surgery is usually about 300–500 ml, varying with single or double level fusions.

The patient's X-rays, including lumbar discograms when appropriate, should be clearly displayed. Facilities should be available for taking control X-rays on the theatre table when fusions above the lumbo-sacral junction are to be performed. The quality of such films is often poor. Good quality films of the patient's spine must be available in the theatre for comparison with those taken at the time of surgery.

iii) Positioning

For approaches to the lower three lumbar intervertebral discs, patients are placed supine on the operating table. For rarer upper lumbar fusions, they are placed in the lateral position with the left loin uppermost. The surgeon should pay particular attention to the placing of restraining devices and arm supports, ensuring that the patient's trunk is held in a stable position and that undue pressure is not exerted on the peripheral nerves or veins in the legs. Electric calf stimulators are applied.

iv) Abdominal Incision

In the lower lumbar region, oblique, left-sided incisions are made, commencing at the mid-line between the umbilicus and symphysis pubis and extending upwards and laterally, parallel to the level of the iliac crest. The anterior rectus sheath is divided in the line of the skin incision, extending out into the fibres of the external oblique muscle and over the length of the skin incision. At the lateral border of the rectus abdominis muscle, the internal oblique muscle and transversalis fascia are split to identify the extra-peritoneal space. The peritoneum is separated from the inner aspect of the abdominal wall, and these two muscles are further split laterally in the line of the main incision. In obese patients, it is wise to retract the lateral border of the left rectus abdominis muscle, to identify the inferior epigastric vessels. These should be divided between ligatures and the rectus abdominis muscle then divided across transversely to the level of the mid-line; such an incision will allow wide extra-peritoneal approach to the lower lumbar spine. The accompanying illustrations show the steps in the muscle splitting approach devised by Fraser (1982) which allows wide extra-peritoneal approach to the lumbar spine, *without division of the rectus abdominis muscle.* The posterior rectus sheath is also split vertically downwards after retraction of the outer edge of the rectus abdominis muscle (Figs. 2.29–2.32).

The skin incision should be placed nearer the umbilicus if the L3/4 disc is to be approached. Mid-line trans-peritoneal approaches may be indicated for operations at the L5/S1 level in some cases of spondylolisthesis or in very obese patients with high Ferguson angle measurements at the lumbo-sacral junction (Ferguson, 1949).

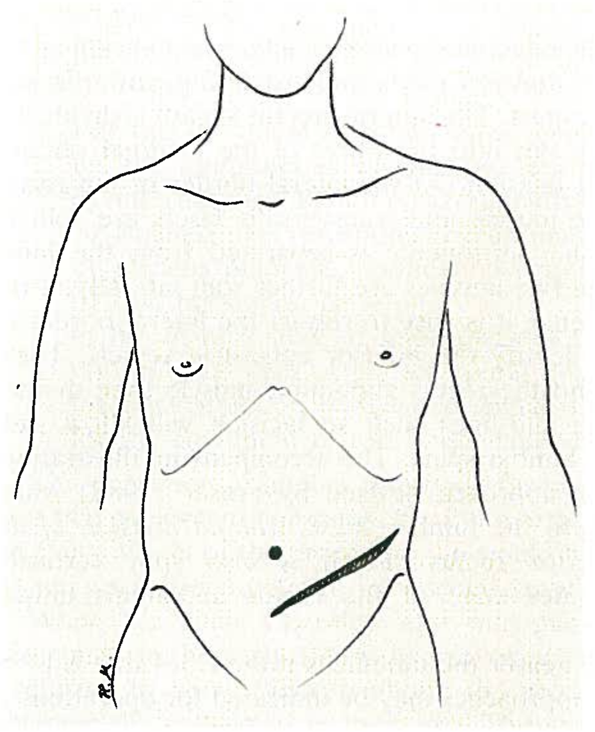
When the abdominal wall incision has been completed, the peritoneum is separated from the posterior abdominal wall and the psoas major muscle. A small Raytec pack is inserted into the paracolic gutter and pushed upwards for some distance. The ureter can be seen lying adherent to the peritoneum. It is carried forward when a large modified Deever-type retractor is inserted, resting on the anterior surface of the lumbo-sacral disc or on the antero-lateral edge of the L4/5 or L3/4 discs at the anterior edge of the left psoas major muscle, depending on the level to be fused (Fig. 2.33).

v) Haemostasis

The techniques of vessel ligation are vital to the success of exposing the disc spaces at various levels in the lumbar spine and essential for the safe performance of these operations.

Vascular sutures, including 5/0 suture material on atraumatic needles, are required. In addition, long-handled instruments and right-angled artery forceps must be available for use.

When the median sacral vessels have been ligated and divided, small gall bladder dissecting swabs mounted on long-handled forceps are used to clear the loose tissues from the front of the disc space between the limbs of the aortic bifurcation and the right and left common iliac veins, thus clearly exposing the anterior longitudinal ligament (Fig. 2.34). In retro-peritoneal approaches to the L5/S1 disc space, the filaments of the presacral sympathetic plexus are rarely seen; the danger of damaging these nerves in the male has been exaggerated by opponents of this method of spinal fusion (Flynn and Hoque, 1979). The thin anterior longitudinal ligament is then



Figures 2.29–2.33. The Fraser Incision

Figure 2.29. A drawing to show the line of the skin incision for a left-sided extra-peritoneal approach to the lower lumbar vertebral column

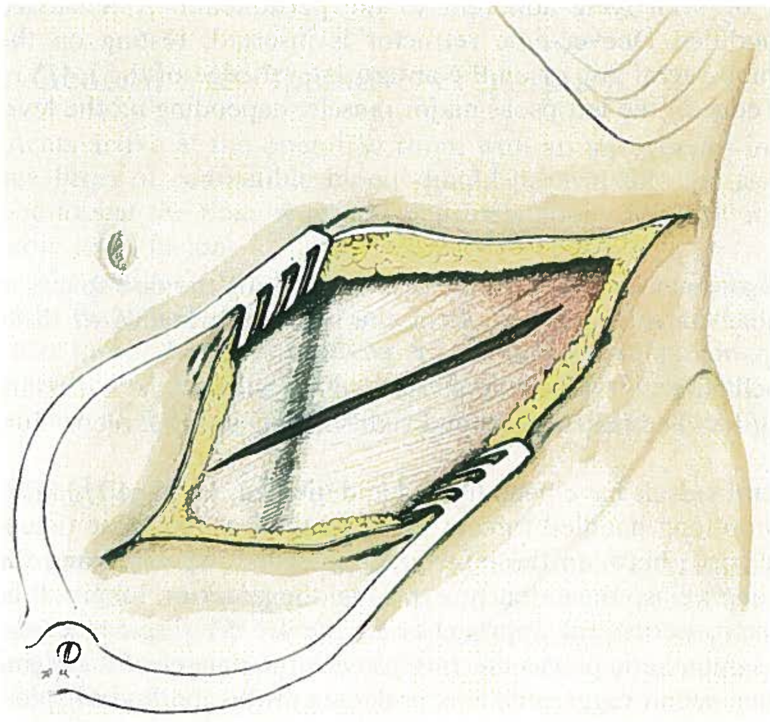


Figure 2.30. A drawing to show the line of division of fibres of the external oblique muscle

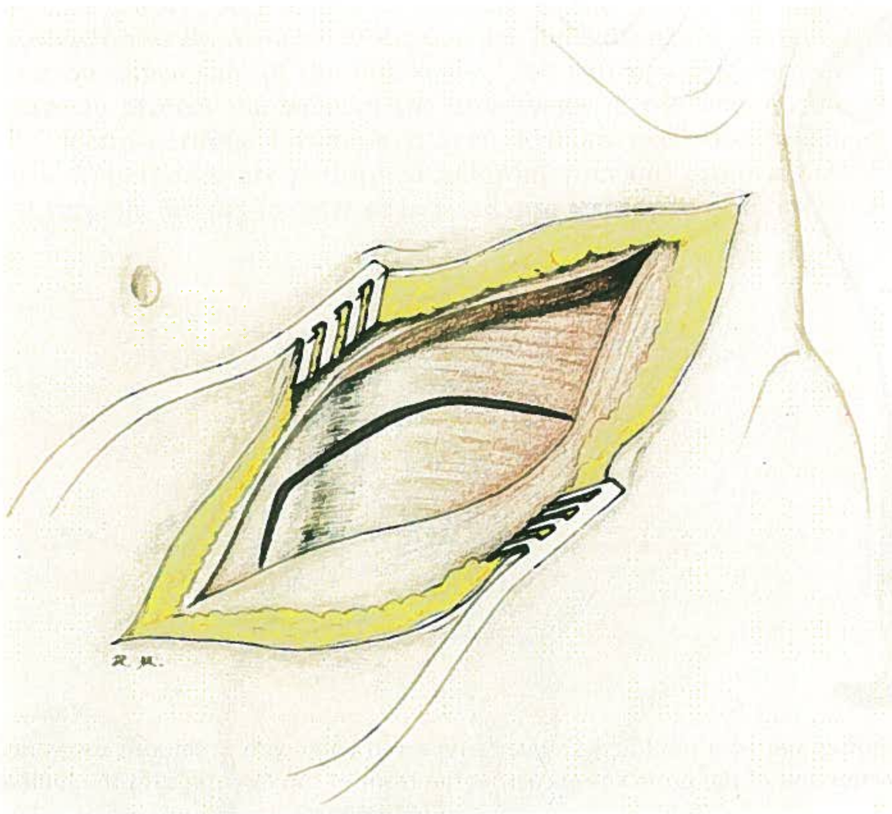


Figure 2.31. A drawing depicting the division of the rectus sheath vertically downwards at its lateral edge

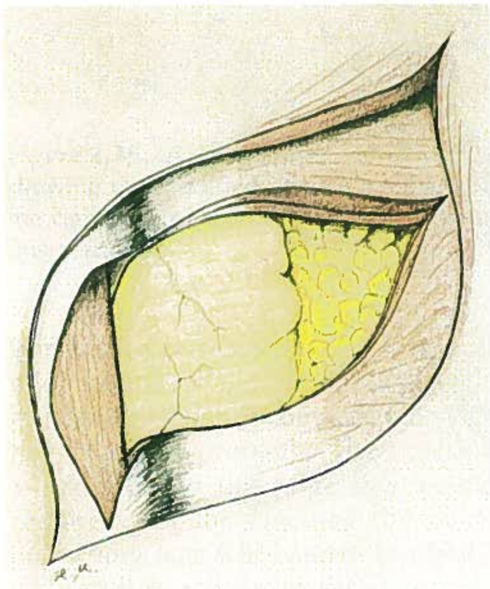


Figure 2.32. A drawing illustrating the splitting of the fibres of the internal oblique and transversalis muscles to expose the extra-peritoneal space on the left side of the abdomen. Division of the anterior layer of the rectus sheath vertically downwards permits wide exposure of the extra-peritoneal space without requiring division of the rectus abdominis muscle mass

Figure 2.33. A photograph of a modified Deever's type retractor with a smooth excavated end, suitable for retraction of the great vessels across the front of the disc space in the lumbar region

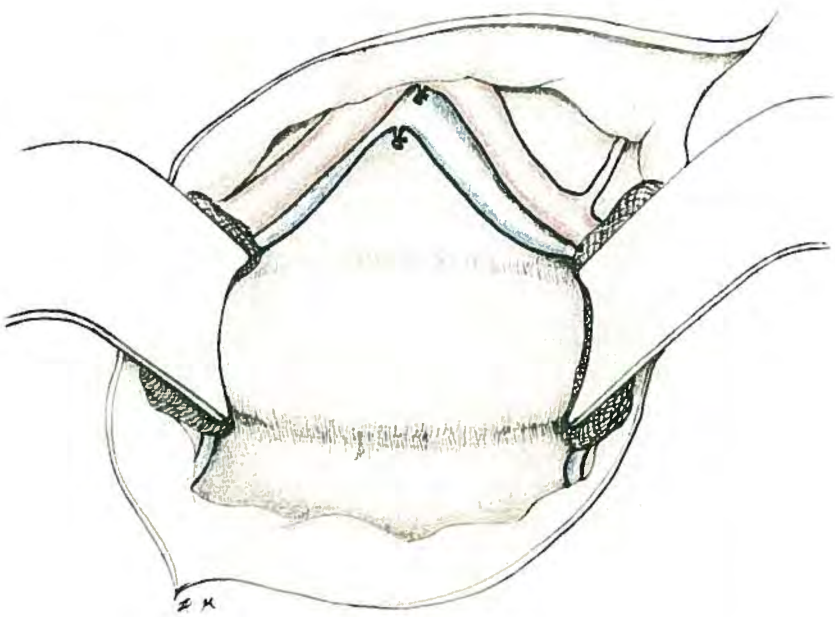


Figure 2.34. A diagram illustrating the use of the retractors at the lumbo-sacral space, with loose Raytec swabs beneath them protecting the walls of the great vessels

divided transversely across the middle of the disc space and the ends are swept upwards and downwards to expose the junction of the vertebral end plate and the disc on either side of the disc space. The cuff of tissue formed by its rolled edges helps to protect the walls of the great veins at the sides of the disc space.

Retro-peritoneal fibrosis is seen without exception when anterior interbody fusion operations are performed following previous explorations of the spinal canal. Of variable density in cases of isolated disc resorption or internal disc disruption, this

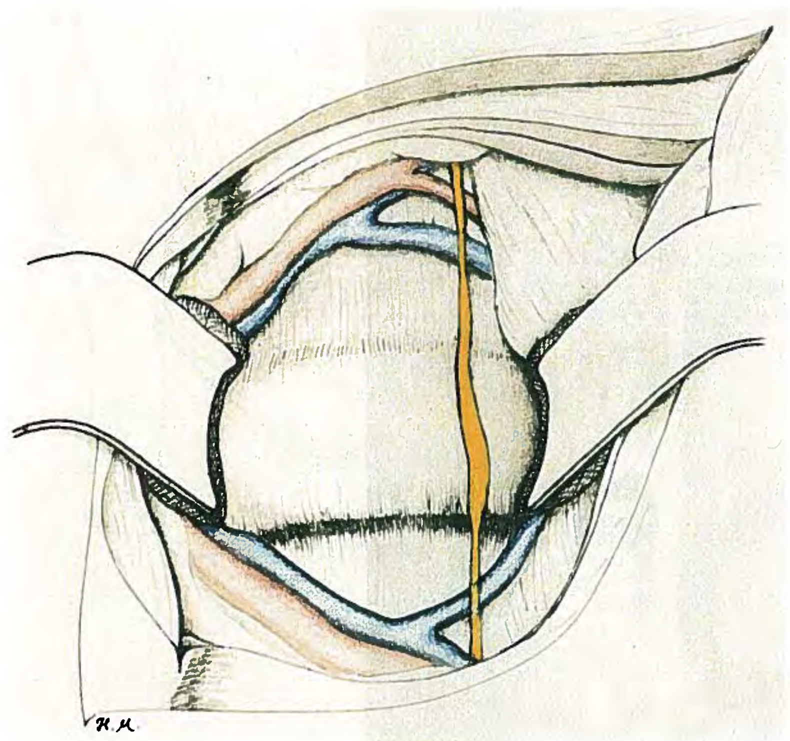


Figure 2.35. A drawing to illustrate the principal anatomical features at the L4/5 level, showing the modified Deever's retractors in place. Note the retraction of the psoas muscle on the right side of the drawing, with the outline of the sympathetic trunk (in yellow) anterior to this retractor

fibrotic tissue may make it very difficult to separate the common iliac veins in the midline, even rendering access to the disc impossible. In such cases damage to the thin wall of the left common iliac vein is likely to occur unless the surgeon is aware of this potential problem. The application of artery forceps or vascular clips–such as Weck clips–to this large thin-walled vein should be avoided. Repair of this vessel requires that the bleeding site be adequately exposed. Digital pressure above and below any tear will control the blood flow to allow identification of the defect in its wall until it can be repaired with a fine atraumatic vascular suture.

The left common iliac vein is sometimes very large–measuring 3 or 4 cm from lateral to medial edge, rendering access to the lumbo-sacral disc between the medial edges of the right and left common iliac vessels impossible. In such circumstances, the medial border of the left psoas muscle should be retracted carefully. Un-named

Figure 2.36. A photograph of the left side of the specimen illustrated in Fig. 2.24 to show the arrangement of the left ascending lumbar vein in relation to the left common iliac vein

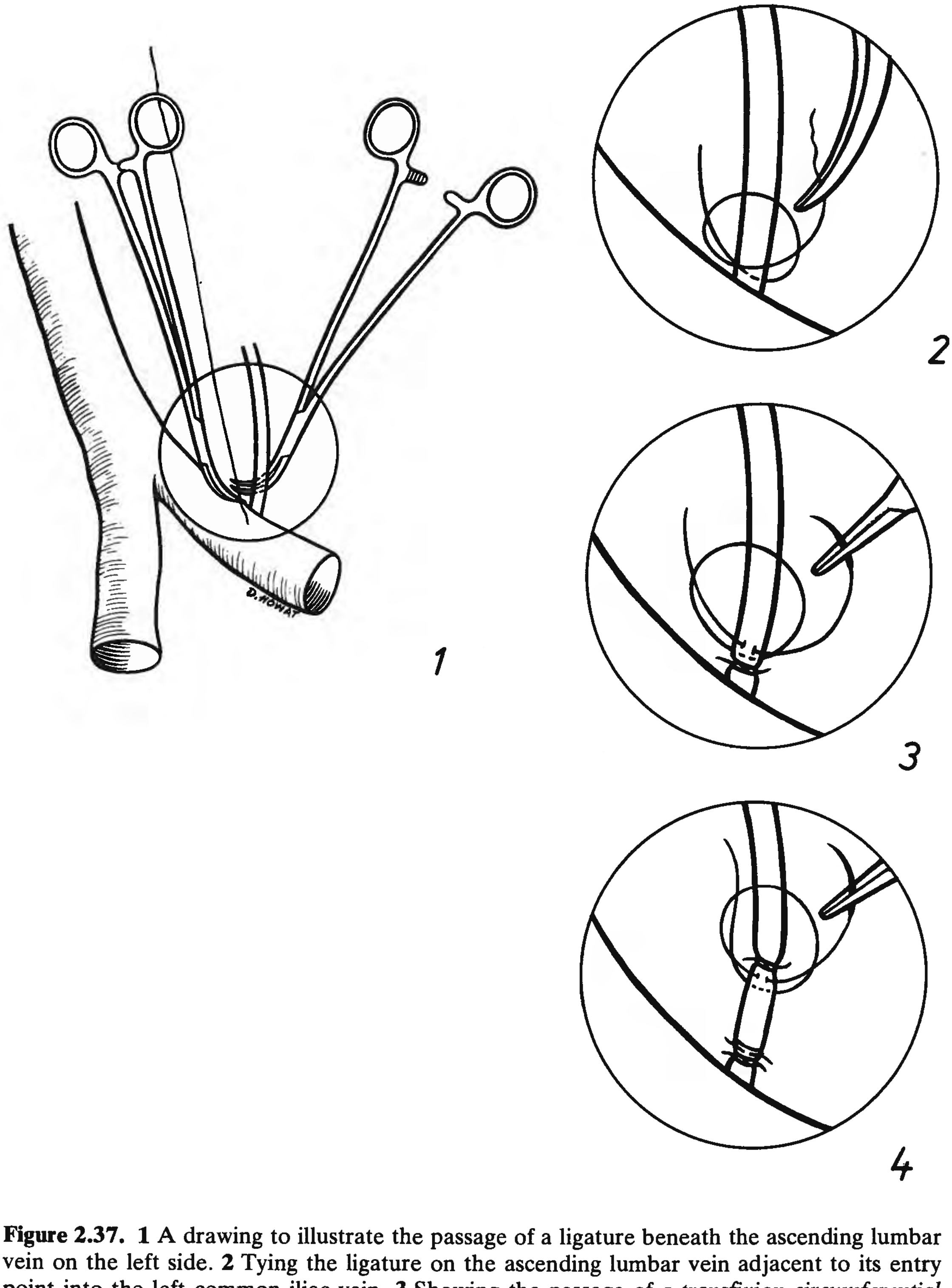


Figure 2.37. **1** A drawing to illustrate the passage of a ligature beneath the ascending lumbar vein on the left side. **2** Tying the ligature on the ascending lumbar vein adjacent to its entry point into the left common iliac vein. **3** Showing the passage of *a transfixion circumferential locking suture* beyond the first tie placed on the ascending lumbar vein near its junction with the left common iliac vein. **4** Showing the insertion of *a transfixion circumferential locking suture* further along the course of the ascending lumbar vein. The vessel is divided then between these four ligatures, without risk of slipping of the ties after the vessel has been cut

arteries and veins often pass into the muscle directly from the lateral walls of the adjacent left common iliac artery and vein. These small vessels can cause troublesome haemorrhage. They should be carefully isolated and coagulated with diathermy well clear of their origins from the great vessels, before being divided.

The lateral wall of the left common iliac vein should then be exposed by careful blunt dissection aided with the use of a sucker to remove surrounding loose fat. The left sympathetic nerve trunk should be identified and regional lymphatic channels coagulated before the edge of the left common iliac vein can be clearly seen. The ascending lumbar vein will be seen at this stage and the decision taken to ligate and divide it, depending on its length. If it becomes tightly stretched, preventing retraction of the common iliac vein across the front of the L5/S1 disc space, it must be divided. Details of this manoeuvre are outlined below.

To expose the disc between the L4 and L5 vertebral bodies, it may be necessary to ligate and divide the left ascending lumbar vein. The sympathetic trunk is first identified where it lies along the anterior margin of the psoas major muscle, on the side of the vertebral body (Fig. 2.35). The fibres of the fibrous arcade, which attach the psoas muscle to the superior and inferior vertebral margins at the disc space, are divided and the psoas muscle is retracted laterally.

The ascending lumbar vein is often quite large, with a diameter at its entry point into the lateral wall of the left common iliac vein of between 3 and 5 mm (Fig. 2.36). The techniques for the safe handling, dissection and ligation of this vessel are among the most critical manoeuvres to be performed in the whole of this operation. Whether or not ligation is required depends on the length of the vessel and its site of entry into the left common iliac vein. This vein is usually surrounded by fatty tissues from which it must be dissected free. This can be done by using a blunt probe and a smooth-ended fine sucker.

The vessel is ligated with sutures of 3/0 black silk, just beyond its entry point into the left common iliac vein and again, further along its course, deep to the psoas muscle. It is essential to lock these black silk sutures on to the wall of the ascending lumbar vein with 5/0 sutures, transfixing its wall and encircling the vessel adjacent to each suture. The vessel is then divided between these locking sutures with a fine scalpel blade, mounted on a long handle. With these precise manoeuvres safely completed, the great vessels may then be retracted towards the mid-line from the antero-lateral surface of the L4/5 disc space (Figs. 2.35, 2.37).

Exposure of the L3/4 disc space can be achieved often without division of any significant vessels; although, on occasions, the lumbar vessels lying on the side of the body of L4 may need to be separately ligated near the anterior margin of the psoas major muscle before the great vessels can be safely retracted from the antero-lateral surface of this disc.

Exposure of upper lumbar discs is best done with the patient in the lateral position on the operating table and with the incision running through the bed of the twelfth rib to allow extra-peritoneal exposure of the upper lumbar vertebral column.

vi) Preparation of the Interspace for Graft Insertion

The preparation of dowel cavities in the intervertebral space is carried out with the use of special cutters supplied in six sizes for use at any vertebral level. Each cutting cylinder has circumferential markings clearly visible on its external surface. These rings are separated from each other by 5 mm (Figs. 2.38, 2.39).

Figure 2.38. A photograph showing a modified Hudson brace and three dowel cutting instruments, with starter centre pieces and one graft ejector. On the right side, note the special gouges which are used with the cutters. At the bottom of the picture, an extension piece is shown for use during lumbar interbody fusion operations. These instruments are manufactured exclusively by the Thomson and Shelton Instrumentation Company, 6119 Danbury Lane, Dallas, TX 75214, U.S.A.

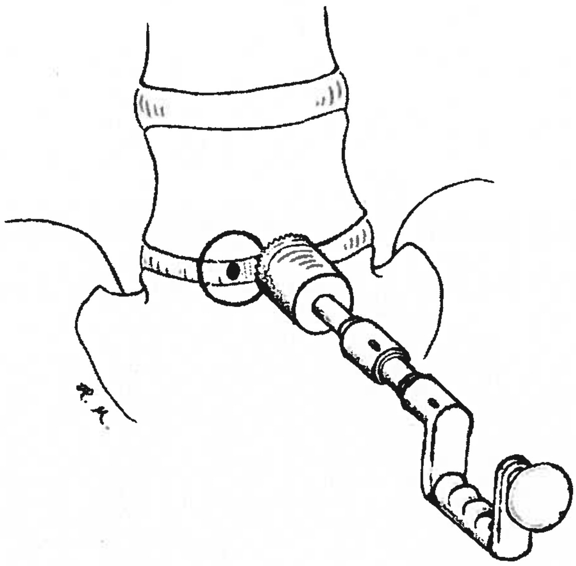


Figure 2.39. A drawing to illustrate the use of the Hudson brace, with the extension piece and the cutter, to prepare a dowel cavity at the lumbo-sacral junction

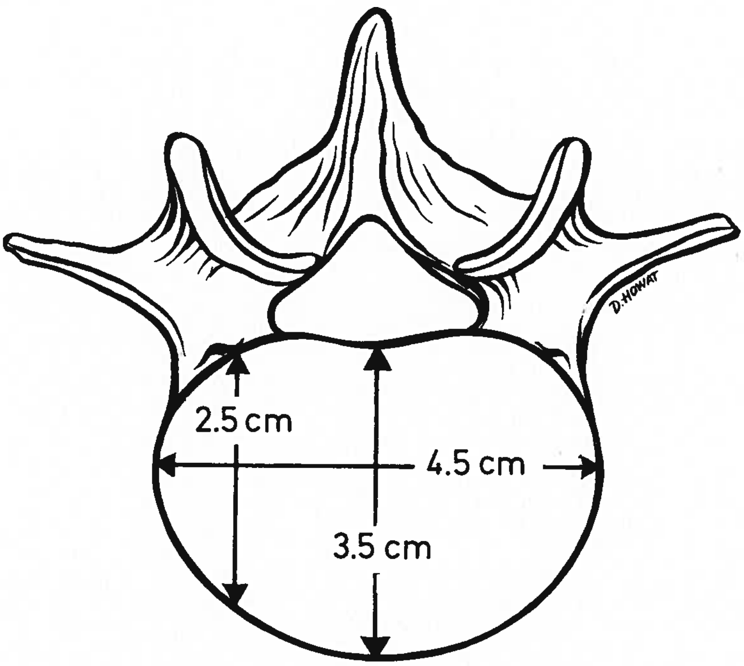


Figure 2.40. A drawing to illustrate the measurements of the L5 vertebral body in an adult of average size

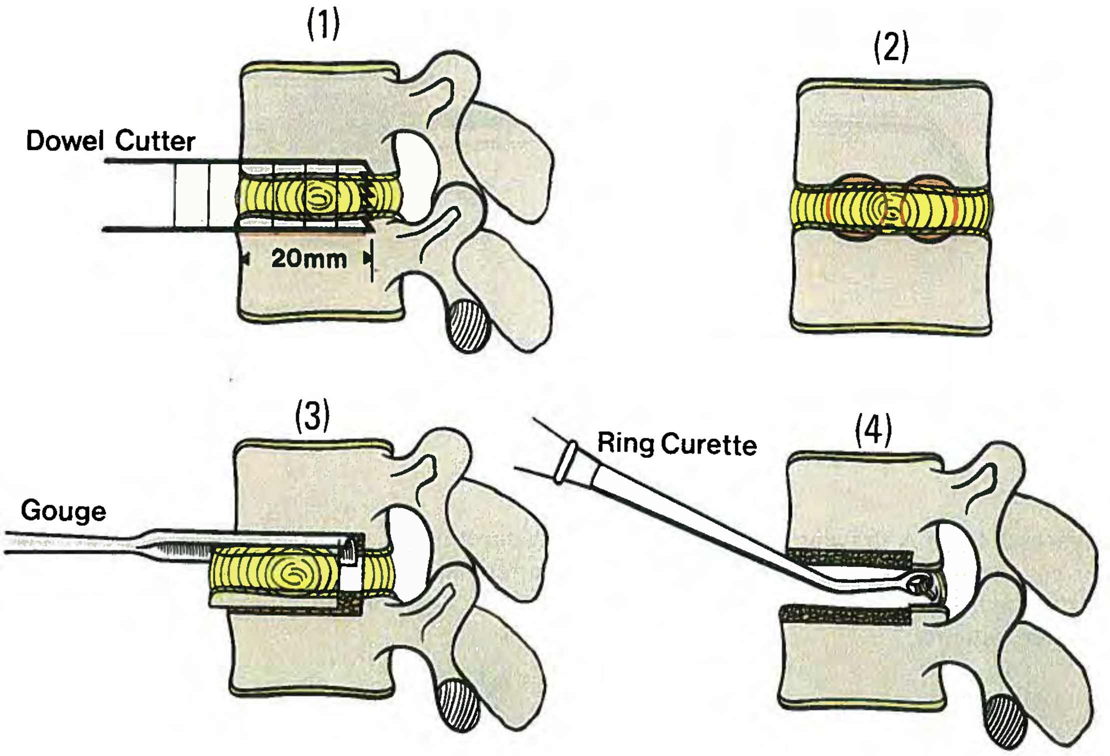
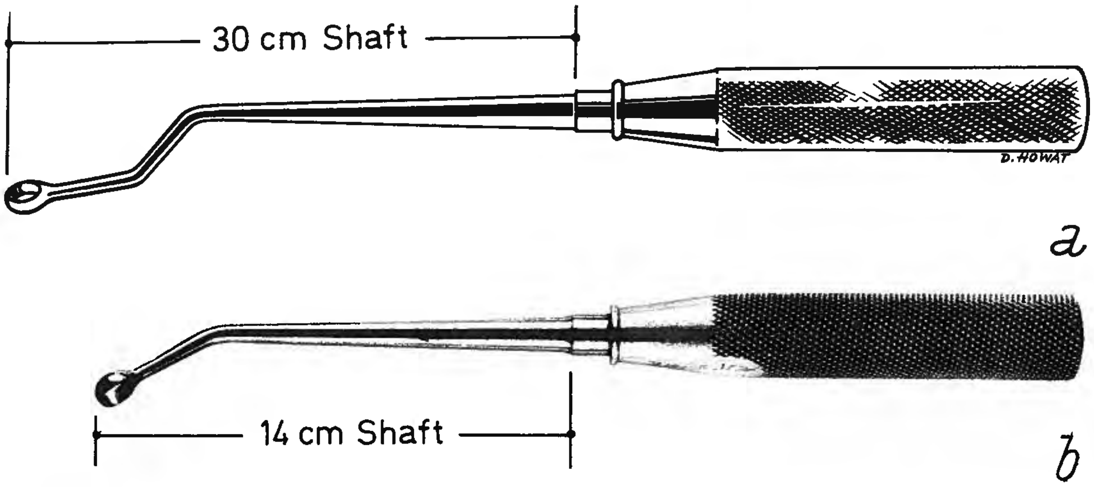


Figure 2.41. Lower lumbar dowel cavities. **1** The use of a dowel cutting instrument in the lumbar spine. **2** The antero-posterior orientation of two dowel cavities in the lower lumbar area. **3** The use of the special gouge to displace the disc and adjacent fragments of the vertebral bodies. **4** The use of the ring curette for the removal of vertebral end-plate and disc tissue remnants from the interbody space

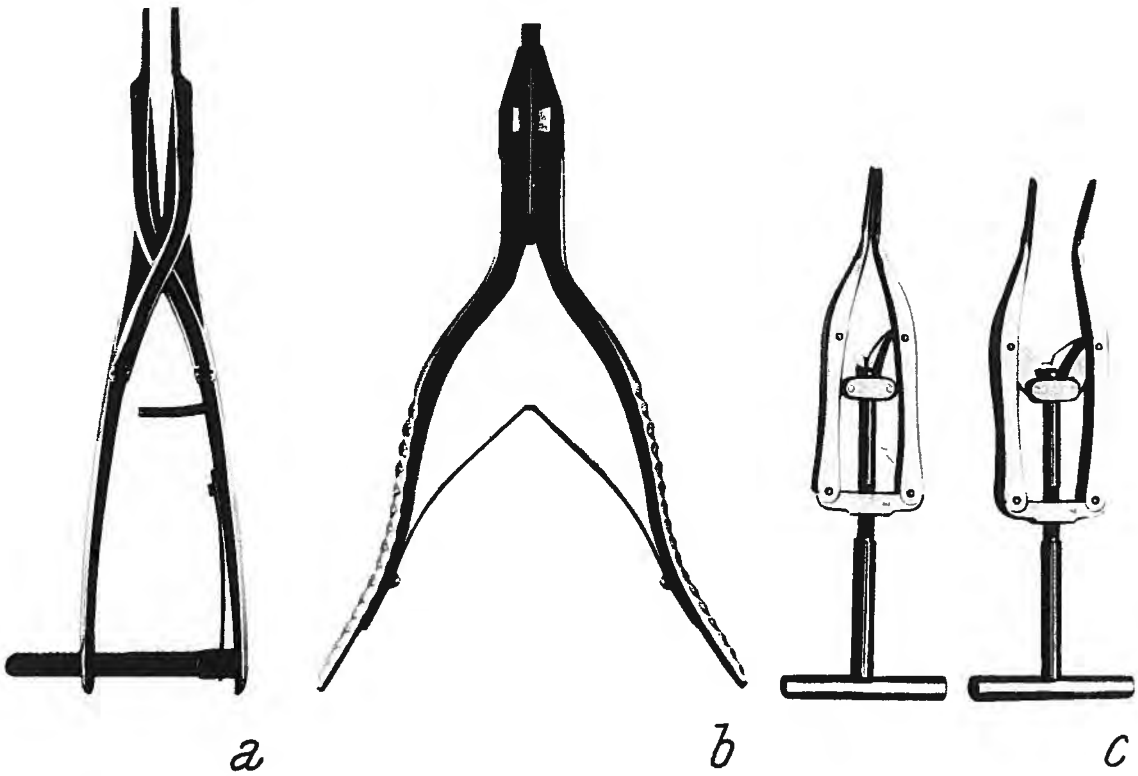
In due course, *grafts are cut using the cutting cylinder that is one size larger than that used to cut the intervertebral dowel cavities.* When the cutting instruments are in use in the disc spaces, the surgeon must at all times have the undivided attention of his two assistants, to ensure that the great vessels are protected from injury. Specially modified Deever's retractors, which have smooth excavated ends, are held in place with loose Raytec swabs positioned to prevent the edges of the great vessels or adjacent soft tissues from herniating beneath them.

The surgeon must be thoroughly familiar with the measurements of the intervertebral space in each patient when preparing the dowel cavities. Measurements of the vertical height of the disc space and the antero-posterior depth should be available from preoperative roentgenograms. In addition, it is to be noted that the antero-posterior measurements vary, being greatest in the mid-line and smallest laterally because the shape of the disc bearing surface of the vertebral body is oval, not rectangular (Fig. 2.40).

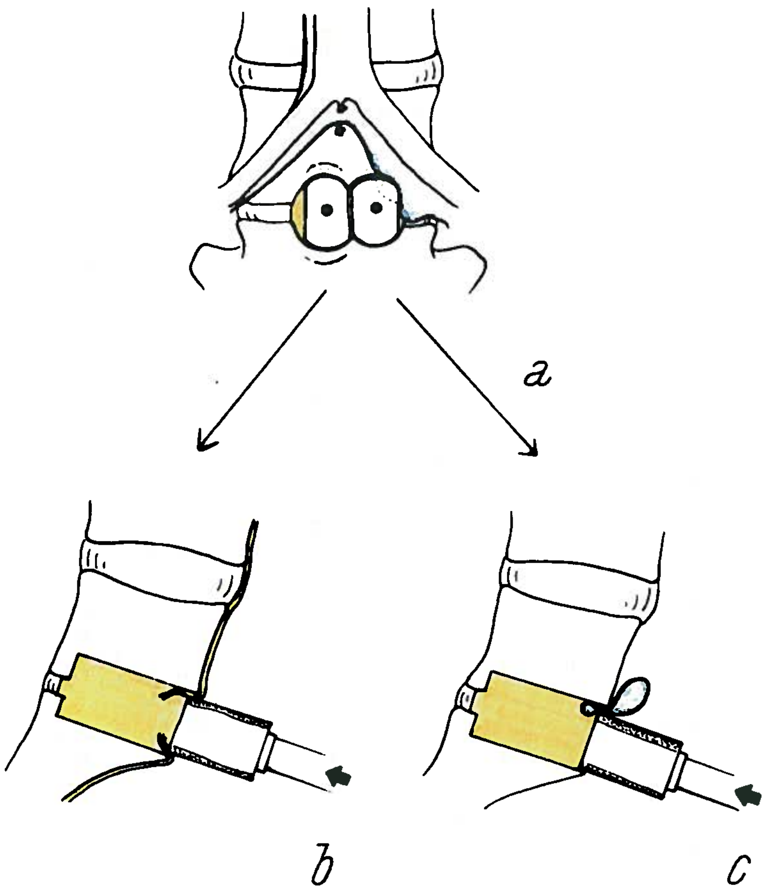
When the parallel plugs of the adjacent vertebral body fragments and the intervening intervertebral disc have been displaced from the interspace using a gouge specially tooled to match the size of the cutter (Figs. 2.41, 1–4), the disc remnants are then removed from the interspace with rongeurs. In addition, vertebral end-plate remnants should be removed with ring curettes (Figs. 2.42a, b). Aided by the use of a vertebral spreader, it is possible to remove the bulk of the disc tissue and vertebral



Figures 2.42. **a** A drawing of a long handled ring curette with a double-angled shaft, suitable for curettage of the vertebral end plate and disc remnants in lumbar interbody fusions. **b** A photograph of a Cloward-type ring curette with single angle on the shaft, suitable for use in smaller patients



Figures 2.43 a–c. Photographs of different types of vertebral spreaders. The central instrument is of Cloward design and is not self-retaining. It is suitable for use in interbody fusions, though it was not designed for that purpose. The instruments in **a** and **c** are of Japanese design



Figures 2.44. **a** Drawing illustrating the entrapment of part of the medial wall of the left common iliac vein after graft impaction. **b** A lateral view of the lumbo-sacral space depicting the rolling inwards of the free margins of the anterior longitudinal ligament during graft impaction. This should be avoided by proper retraction of all soft tissues adjacent to the dowel cavity before grafts are impacted. **c** A lateral view of the lumbo-sacral space demonstrating the hazard of trapping the medial edge of the left common iliac vein during graft impaction. This problem should be avoided at all times by careful retraction of the vessels at the time of graft impaction

end-plate cartilages from the interspaces (Figs. 2.43a–c). However, during these manoeuvres the surgeon must avoid penetrating the spinal canal or damaging the great vessels, which may have slipped out from beneath the retractors (Figs. 2.44a–c).

The graft beds prepared by this method are well-vascularized. Indeed, one of the great advantages of this operation is that the blood supply of the vertebral bodies is not disturbed; thus, vascularization of appropriately placed grafts is assured (Crock and Yoshizawa, 1977).

Graft Preparation

The use of autogenous bone grafts is strongly recommended. The left iliac crest is exposed by retracting the infero-lateral edge of the abdominal incision. A

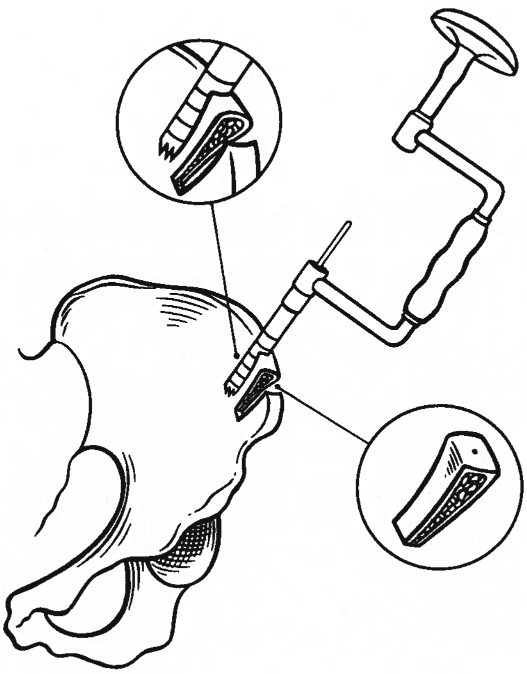
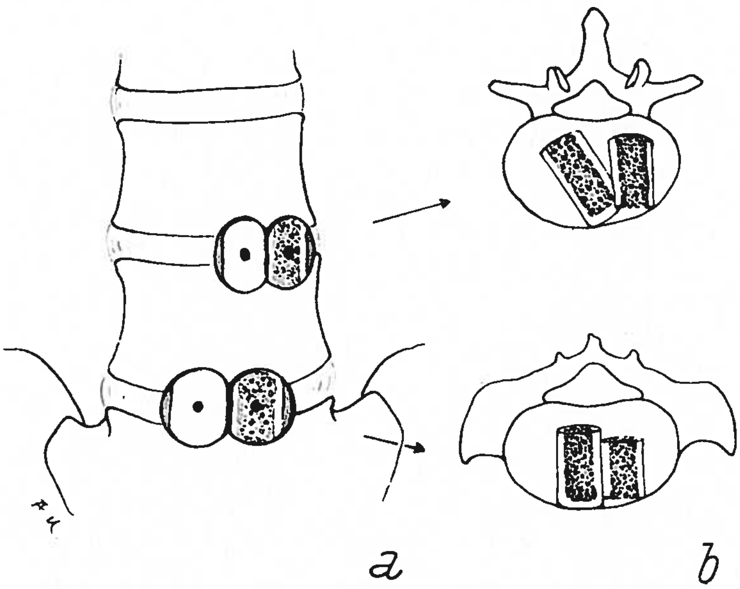
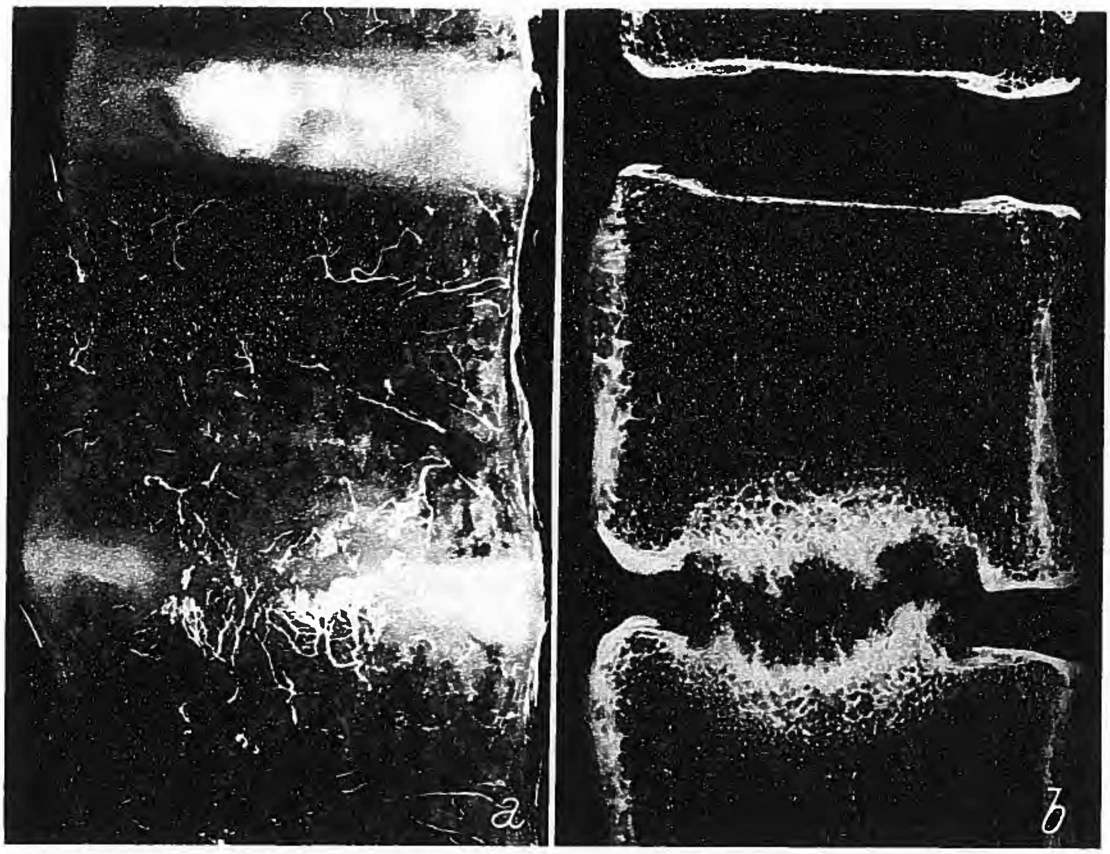


Figure 2.45. Drawing to illustrate the method of cutting grafts from the anterior third of the iliac crest. Each graft has two tooled cancellous surfaces and stout cortical faces on three sides



Figures 2.46 a and **b.** Drawings illustrating the orientation of grafts in the intervertebral spaces at L5/S1 and L4/5



Figures 2.47. **a** Photograph of a thin sagittal section of the lumbar spine taken at necropsy. The L1/2 disc is shown at the top of the specimen. At L2/3, vessels in the interbody graft can be seen. On the right, tufted vessels abut against invading disc tissue. Centrally, the graft is vascularized. **b** At the L2/3 level, union of the graft is incomplete, and the cancellous bone of the graft has been infiltrated by disc tissue remnants

supplementary incision is then made running along its upper border. *Dowel cutting instruments one size larger than those used to prepare the dowel cavities in the intervertebral space, are then used to cut grafts from the iliac crest,* passing vertically downwards to the required depth. Grafts of 2.5–2.8 cm in depth are of satisfactory size in most patients. On occasion, cancellous chips may be cut from the bony fragments of vertebral bodies obtained from the dowel cavities. (These fragments may be used to supplement the iliac crest grafts in larger patients.) The iliac crest grafts have three cortical faces and two "tooled" cancellous faces (Fig. 2.45). They are designed to be impacted adjacent to each other with the cortical faces orientated laterally in the disc space and the cancellous surfaces facing the vertebral bodies (Figs. 2.46a, b). Purely cancellous grafts inserted into the intervertebral disc space have been shown by Crock (1976) to be liable to invasion by disc remnants, thus predisposing to non-union (Figs. 2.47a, b). This complication has been largely obviated by the use of grafts cut from the anterior iliac crest in the manner just described.

vii) Graft Impaction

In the last phase of this operation, the intervertebral disc space is again carefully exposed by the assistants. A vertebral spreader is inserted into one of the dowel cavities and opened to allow a final inspection of the interspace. *The depth of the dowel cavity is checked with a depth gauge and ruler* and the first graft then impacted. This is a potentially dangerous manoeuvre as the edge of a great vessel may become trapped between the graft and the wall of the dowel cavity. Successful retraction at this critical stage of the operation calls for strict attention to detail.

Following impaction of the first graft, the vertebral spreader is removed from the second dowel cavity and the second graft is then impacted. Some haemorrhage will occur from the site; but this is never severe and usually ceases in two or three minutes.

Attention is finally focussed on the donor site. If two grafts have been cut from the iliac crest then *the bony defect is filled with orthopaedic bone cement* before the wounds are closed in layers with suction drainage. Small cavities are curetted out between the cortical faces of the iliac crest at the anterior and posterior limits of the pelvic defect left after removal of the dowel grafts. Bone cement pushed into these cavities helps to maintain the stability of the newly moulded "pelvic crest" and diminish pain in the post-operative period.

The method of operation described here has been used by the author at St. Vincent's Hospital, Melbourne, since 1961. Of approximately 1,000 operations performed in 20 years, three patients have died. Two of these died in the post-operative period of acute coronary occlusion; the third committed suicide four months after operation.

No significant urologic complications have been encountered with this method of spinal fusion. Retention of urine occurs in some patients, but its management only rarely involves the use of a catheter for one or two days. In most cases bladder function is restored after the use of one or two doses of Urecholine (Merck, Sharp & Dohme).

In exposing the lumbo-sacral intervertebral disc space in the male, the use of diathermy in the presacral area has been avoided. The author is aware of complaints of sterility in only two patients, both of whom were psychiatrically disturbed and both of whom had complained of impotence before operation.

viii) Post-Operative Care

Patients are nursed supine with one or two pillows, and rolled from side to side several times a day with a pillow placed between their legs. We recommend the use of beds which can be tilted vertically to allow patients to stand and to get out of bed with little assistance from the nursing staff. Intravenous therapy is continued until bowel sounds are heard or flatus has been passed.

Prophylactic anticoagulant therapy with subcutaneous calciparine (Heparin, Difrex Australian Laboratories Pty. Ltd., Glebe Street, Glebe, N.S.W.) is administered until patients have become fully mobile.

Spinal supports are fitted within a few days of operation and worn for three or four months afterwards.

ix) Complications

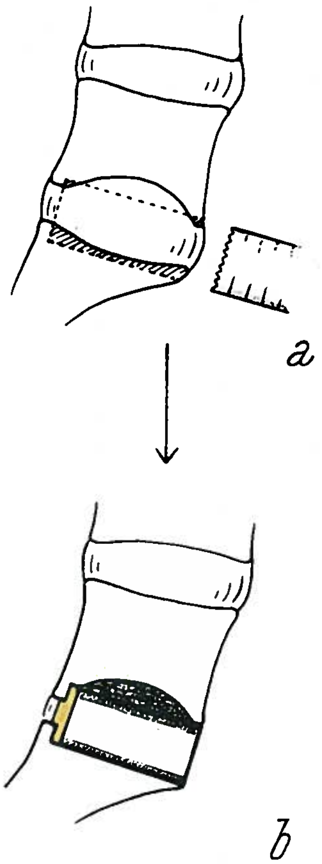
1. Deep vein thrombosis

This is a major problem. An important step in its prevention is to avoid entrapping the edge of a great vein during graft impaction (Figs. 2.44a–c).

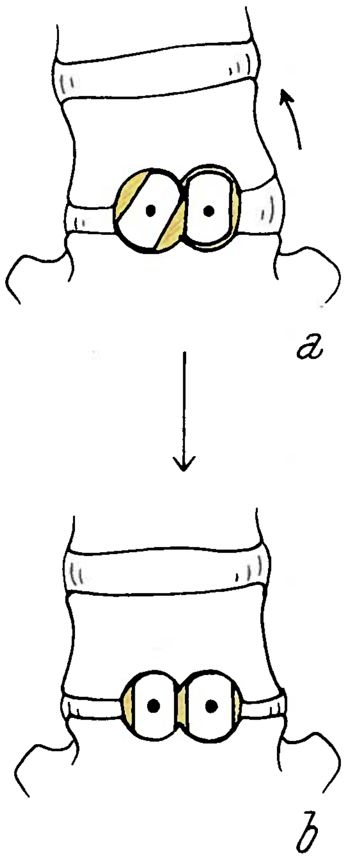
2. Non-union of grafts

a) The use of purely cancellous grafts may lead to non-union following infiltration of the grafted bone by reactive disc tissues which also prevent vascular penetration of the graft (Figs. 2.47a, b).

b) Special surgical techniques will be required to prevent non-union in the following circumstances:



Figures 2.48



Figures 2.49

Figures 2.48. **a** A drawing of a lateral view of the lumbo-sacral space to illustrate the problem created when the vertebral end-plate of L5 is "ballooned". A cutter then fails to remove the "ballooned segment" when it is inserted in the course of preparing the dowel cavity. **b** A drawing to show that the area needs to be separately prepared with a curette and grafted with cancellous chips before the dowel graft is impacted

Figures 2.49. **a** A drawing to illustrate the point that the graft which has been inserted eccentrically–as on the left-hand side–distorts the outline of the other cavity so that the second graft will not fit firmly into it. **b** A drawing to demonstrate the correct placing of grafts parallel to each other, so that each fits snugly in the intervertebral space

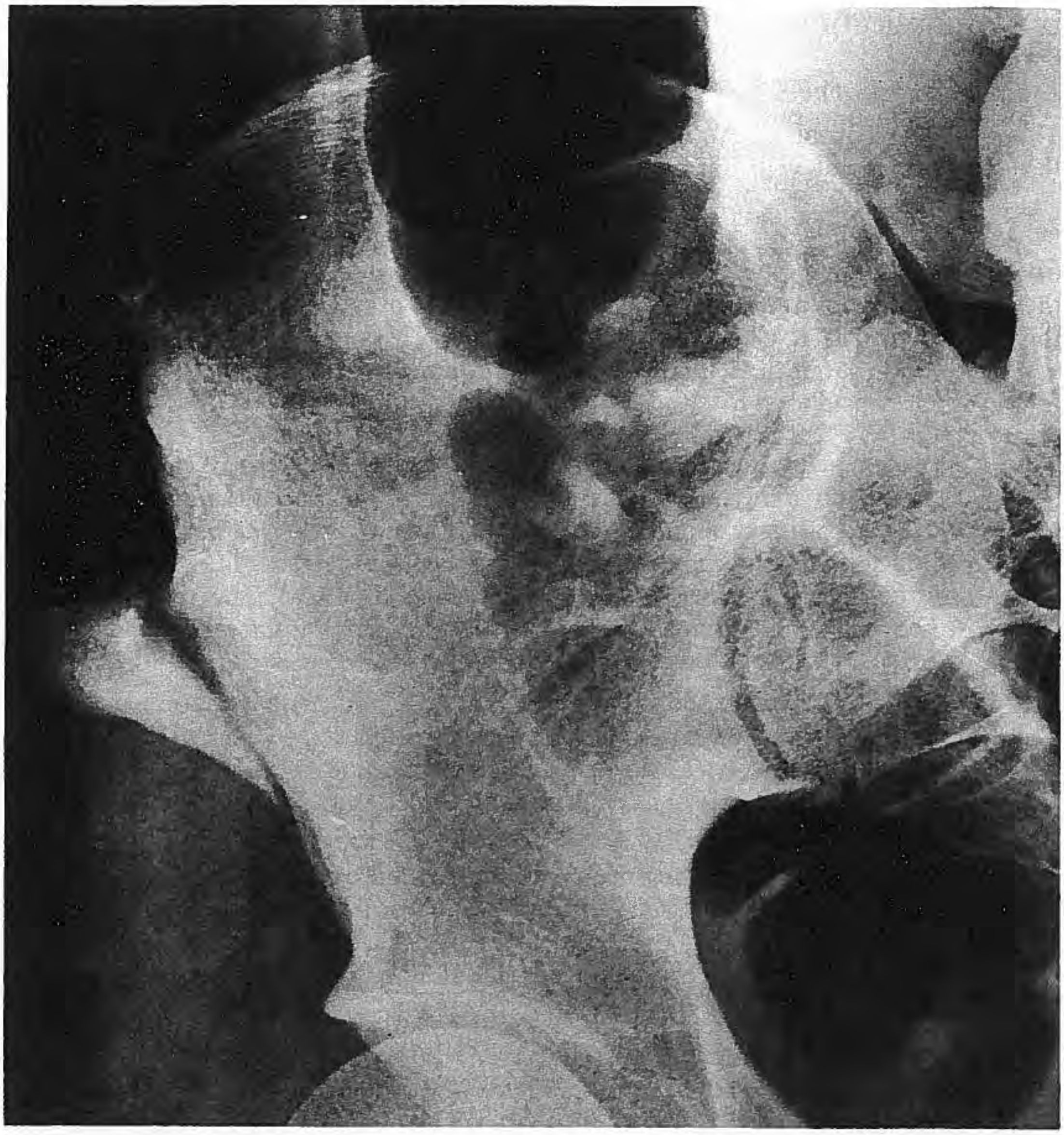


Figure 2.50. A radiograph of the ilium to show a fracture in the region of the anterior-superior iliac spine which occurred following removal of grafts for interbody fusion

i) When the vertebral end-plates are widely separated. The disc tissues should be excised with a scalpel and the vertebral end-plate cartilages curetted. The disc space is thereby narrowed. A dowel cutter of appropriate size should then be selected. The starter centre piece should be removed and the cutter, affixed to the extension piece alone should be placed across the disc space and tapped into place with a hammer. The Hudson brace is then fitted and the cutter oscillated, at first counter-clockwise, then clockwise, until an accurate circular dowel cavity is cut between the vertebral bodies.

ii) When the vertebral end plates are of irregular shape, the cutters may fail to remove a segment of vertebral end-plate cartilage. This area should be identified, by using a *dental mirror.* After curettage of the "uncut" vertebral end-plate remnants, cancellous chips should be placed in the cavity, preliminary to graft impaction (Figs. 2.48a, b).

c) During impaction, care should be taken to avoid rotation of the graft. If this occurs, the dimensions of the second dowel cavity will be larger than required and the second graft will fit loosely (Figs. 2.49a, b).

3. Infection at the graft site

This is a rare complication after interbody fusion operations. If it occurs it may be very serious. Management of this problem is discussed on p. 262.

4. Iliac crest fracture (Fig. 2.50)

5. Post-operative entrapment of the lateral cutaneous nerve of the thigh

Meralgia paraesthetica due to fibrosis around the iliac crest donor site occurs occasionally. Symptoms may be relieved by local steroid injections, though sometimes surgical release of the entrapped nerve may be necessary.

c) Results of Anterior Interbody Fusion

With the use of a technique that allows repeated, reproducible accuracy, lumbar interbody fusions can be achieved in a high percentage of cases in a wide range of disorders of the lumbar spine.

Figure 2.51. A tomogram of the lumbo-sacral junction to show the appearance of an interbody graft inserted three months previously

The results of 150 anterior lumbar interbody fusion operations performed by two surgeons in Australia (H.V. Crock and G.M. Bedbrook) were published by Fujimaki *et al.* (1982).

The data on these patients was gathered, analyzed and classified into three groups: Group I (84 cases): those patients in whom their first and only spinal operation had been an interbody fusion; Group II (38 cases): those patients in whom interbody fusion had followed some other spinal operation; and Group III (28 cases): those patients in whom supplementary operations had been performed following lumbar interbody fusion operation.

The results, including information on occupation, time lost from work and on ultimate re-employment are listed for each group in Table 2.1.

The radiological assessment in these cases is set out in Table 2.2 (Figs. 2.51–2.58).

Table 2.1. Summary of findings

Group	Occupation		Time off (months)	Resumed same occupation	Commenced other occupation	Did not return to work
	Non-sedentary	49	11.8	39	7	3
1	Home duties	18	3.3	16	1	1
	Sedentary	17	7.4	17	0	0
		84				
	Non-sedentary	23	24.0	14	6	3
2	Home duties	7	5.6	6	0	1
	Sedentary	8	6.5	7	0	1
		38				
	Non-sedentary	19	16.5	10	3	6
3	Home duties	5	11.5	3	1	1
	Sedentary	4	12.5	2	0	2
		28				

Table 2.2. Radiological assessment

	Group	G.M.B.	H.V.C.
1.	84 Cases	26 cases	58 cases
	Union	24	56
	Non-union	2	2
2.	38 Cases	16 cases	22 cases
	Union	16	21
	Non-union	0	1
3.	28 Cases	8 cases	20 cases
	Union	8	19
	Non-union	0	1
Total Union		48 (96%)	96 (96%)

Figure 2.52. A lateral tomogram to show an L5/S1 anterior interbody fusion in a male aged 30 years, taken nine years after anterior fusion

Figure 2.53. A lateral radiograph of the lower lumbar region showing sound L5/S1 interbody fusion ten years after surgery, with a normal L4/5 space above the fused level

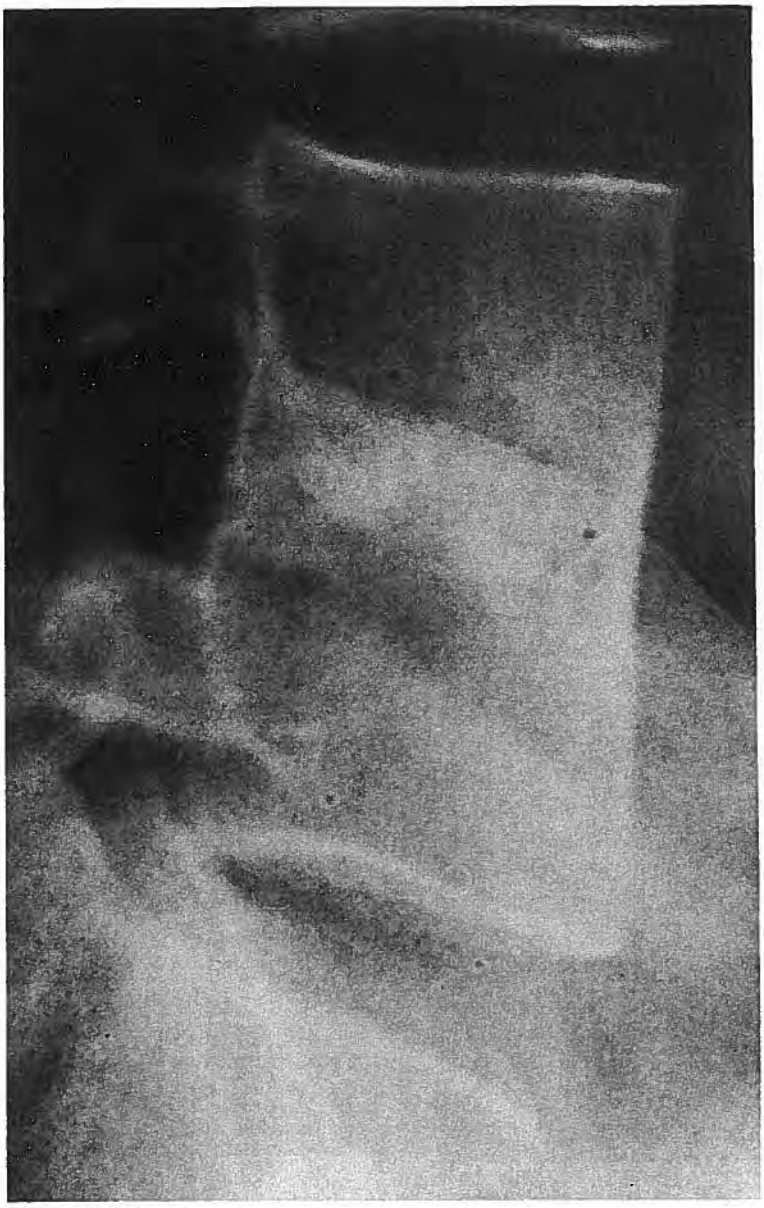


Figure 2.54. A lateral view radiograph showing an L4/5 interbody fusion in a 46 year old woman ten years after operation

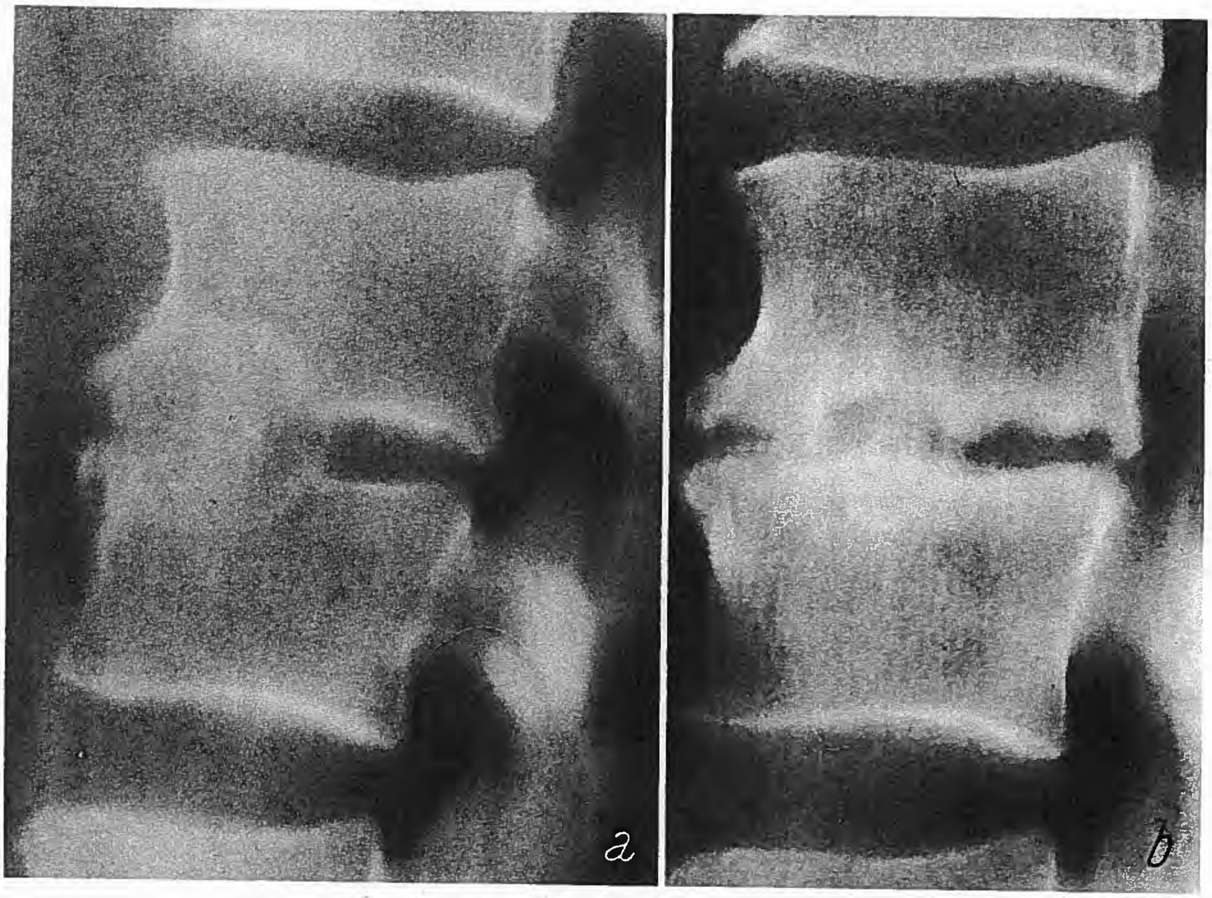
Figure 2.55. A lateral radiograph showing an L4/5 interbody fusion five years after operation

Figure 2.56

Figure 2.57

Figure 2.56. A lateral radiograph showing L4/5 and L5/S1 interbody fusions in a 48 year old man five years after operation

Figure 2.57. A lateral radiograph of the lower lumbar spine showing a sound L4/5 interbody fusion and an un-united L5/S1 interbody fusion, with sclerosis anteriorly in the intervertebral disc space



Figures 2.58. Lateral tomographs of the upper lumbar spine of a man aged 46 years. **a** Three months after operation. A circular cancellous graft has been inserted transversely at the L3/4 level. **b** One year later. There is collapse of the graft and established non-union

3

Lumbar Disc Prolapses

3.1. Introduction

Despite the fact that Mixter and Barr published their description of rupture of the intervertebral disc with involvement of the spinal canal in 1934, confusion still exists about the diagnosis of this lesion and there is often uncertainty about which cases should be treated surgically. Even from the vast literature on this subject a synthesis of practical guidelines to diagnosis and surgical management can be made only with difficulty.

Careful neurological examination is the corner-stone of clinical diagnosis, though it may not be possible to distinguish between disc prolapses at the L5/S1 or L4/5 levels on neurological grounds.

Lumbar disc prolapses requiring surgery are not common. For example, in my own clinic, among 150 cases requiring spinal operations in a six month period during 1981–1982, only four cases were found to have frank disc prolapses.

In operations for suspected disc prolapse where none is found, and following which the patients' symptoms are worse, further investigation will often reveal an unrecognized lesion within the spinal canal, such as some other intervertebral disc disorder–post-traumatic internal disc disruption, or spinal canal or nerve root canal stenosis.

When a surgeon operates on a patient for suspected disc prolapse, but does not find one, he may consider that the exposed disc is unduly soft on palpation or merely bulging. Should he proceed to incise the annulus fibrosus and to remove some portion of disc tissue, the patient's symptoms will usually be worse after the operation (see pp. 47, 56, 245).

Against this background, what then constitutes a useful guide to the management of lumbar disc prolapses?

These lesions are characterized by the escape of disc tissues beyond the normal confines imposed by the intact outer annulus fibrosus and vertebral end-plate cartilages. Synonyms for disc prolapse in common usage include slipped disc, herniated intervertebral disc, protruded intervertebral disc and ruptured disc.

In the lumbar region, disc prolapses are most commonly seen at either the L4/5 or L5/S1 vertebral interspaces or at both of these levels. Higher in the lumbar region they may present with unusual symptoms and signs mimicking intraspinal tumours. In this region they are rare and usually occur in elderly people (Aronsen and Dunsmore, 1963).

The initiating factors are probably multiple, but trauma may precipitate the prolapse. The physical force of the precipitating trauma is often mild, though its influence varies inversely with the extent of pre-existing pathological changes in the affected disc. In normal discs, tensile forces of considerable magnitude (60–80 kg/cm²) exist in the posterior part of the annulus; this fact gives strong support to the mechanical theory of the production of ruptures of the posterior annulus (Nachemson and Morris, 1964). In young subjects, heavy lifting while bending may lead to the formation of a small prolapse, whereas in older patients massive disc sequestration may follow simple bodily movements such as bending or twisting of the spine. Disc prolapse may be a complication of posturing of the trunk under anaesthesia for other surgical procedures, such as gall bladder, renal or gynaecological operations.

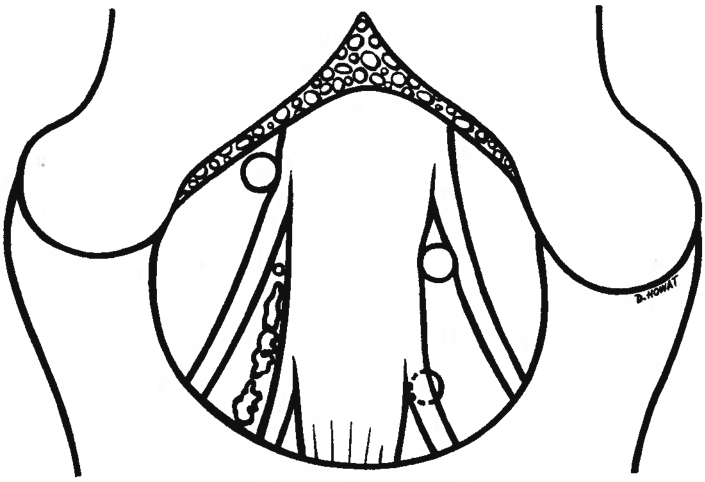


Figure 3.1. A drawing depicting the four common types of disc prolapses found in the lower lumbar region. On the left side a para-rhizal prolapse is shown at the top. Below this, migrating sequestrated disc fragments are shown with a small circular annular defect above them. On the right side an axillary prolapse is illustrated at the top and lower down a sub-rhizal prolapse

3.2. *Pathology*

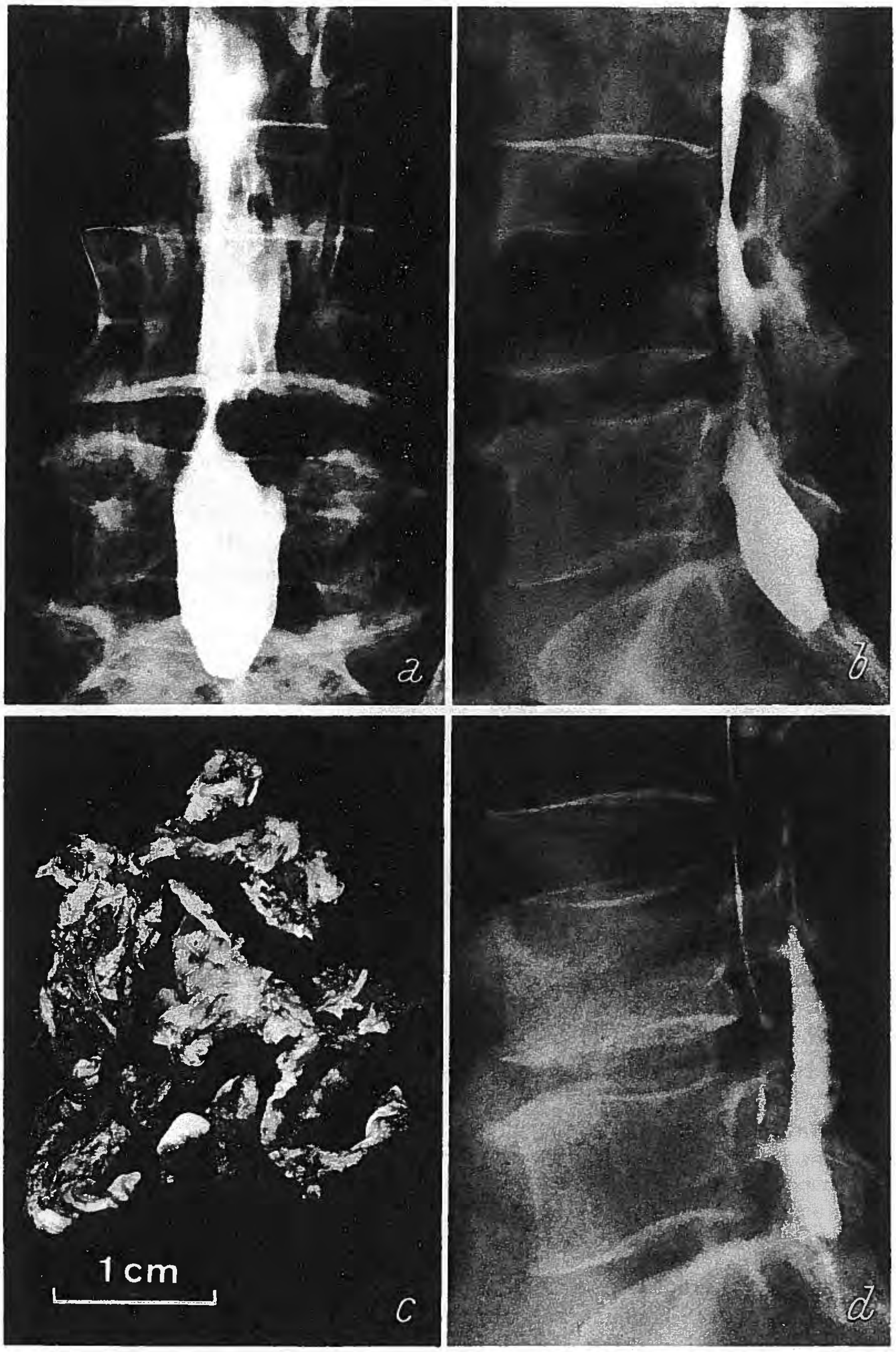
The pathological features of disc prolapse have been described by many writers (Coventry *et al.*, 1945; Reynolds and Katz, 1969; Taylor and Akeson, 1971). The characteristics of prolapses vary with the physical qualities of the affected disc tissue. In young persons, discrete, small, rounded, firm or fluctuant protrusions are found with stretched but intact annular fibres and, when incised at operation, only a small quantity of disc tissue may escape and be removed, leaving in the disc a defect which

Figure 3.2. An antero-posterior radiograph of a lumbar myelogram in a woman aged 53 years, showing a defect at the L5/S1 level. At operation a sequestrated fragment of disc tissue was found in an axillary position, lying between the inner aspect of the 1st sacral nerve root sheath and the lateral margin of the dural sac

admits neither curettes nor disc rongeurs easily. The consistency of such discs is often described as rubbery. Some degenerate annular fibres are usually found with the extruded nuclear tissue in these cases (Fig. 3.2).

Extrusion of variable quantities of disc tissue (1.1–13.5 g) into the spinal canal may be seen when gross degenerative changes have occurred in the disc as a whole. The description of "sequestrated disc fragments" is then applied. The components of such fragments may include nuclear, annular and end-plate material (Figs. 3.3a–d).

Between these two extremes, a variety of pathological changes may be noted. Incomplete sequestration may be associated with marked peri-neural fibrosis, a



Figures 3.3 a–d. Massive disc sequestration following twisting of the lumbar spine-treated by disc excision and posterior interbody fusion. A 53 year-old male jeweller suffered from intermittent back pain for 13 years. While using a powered floor-sanding machine, he twisted his spine and suddenly developed severe left-sided sciatica. **a** and **b** Antero-posterior and lateral radiographs of the lumbar myelogram, showing a large filling defect at the L4/5 disc space. **c** The sequestrated disc fragments removed at operation. **d** Lateral radiograph taken after operation showing the restored normal outline of the dural sac. Bone grafts are seen between the vertebral bodies of L4 and L5; they were inserted through the spinal canal following disc excision

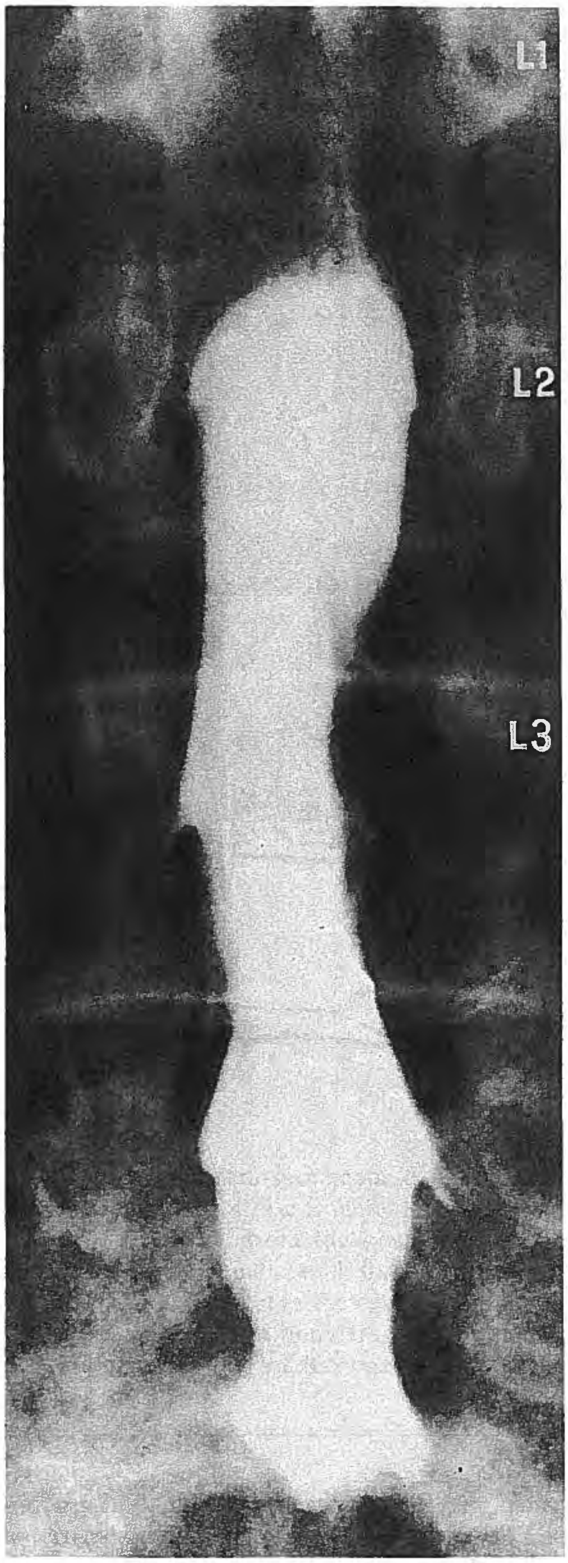
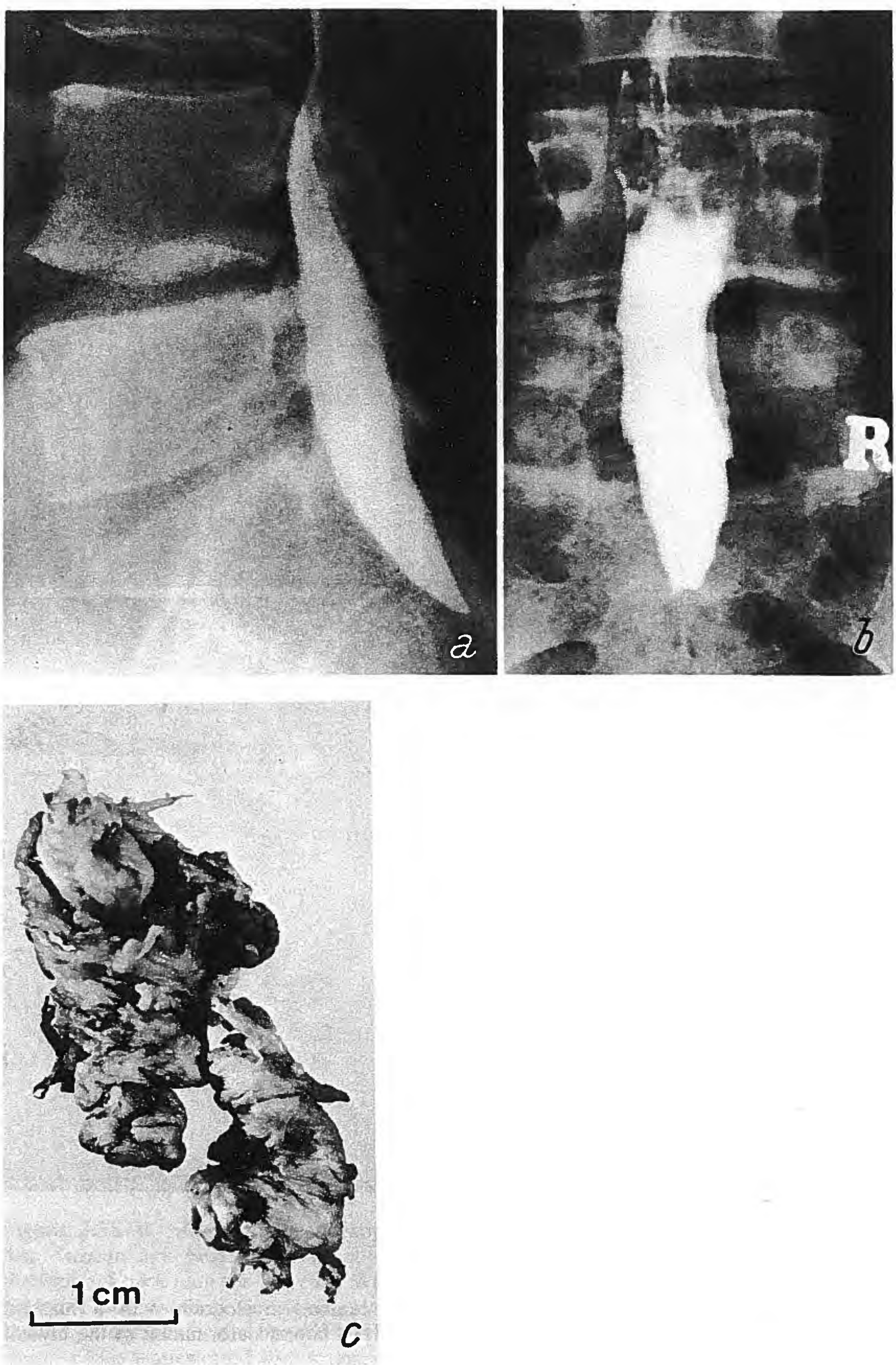
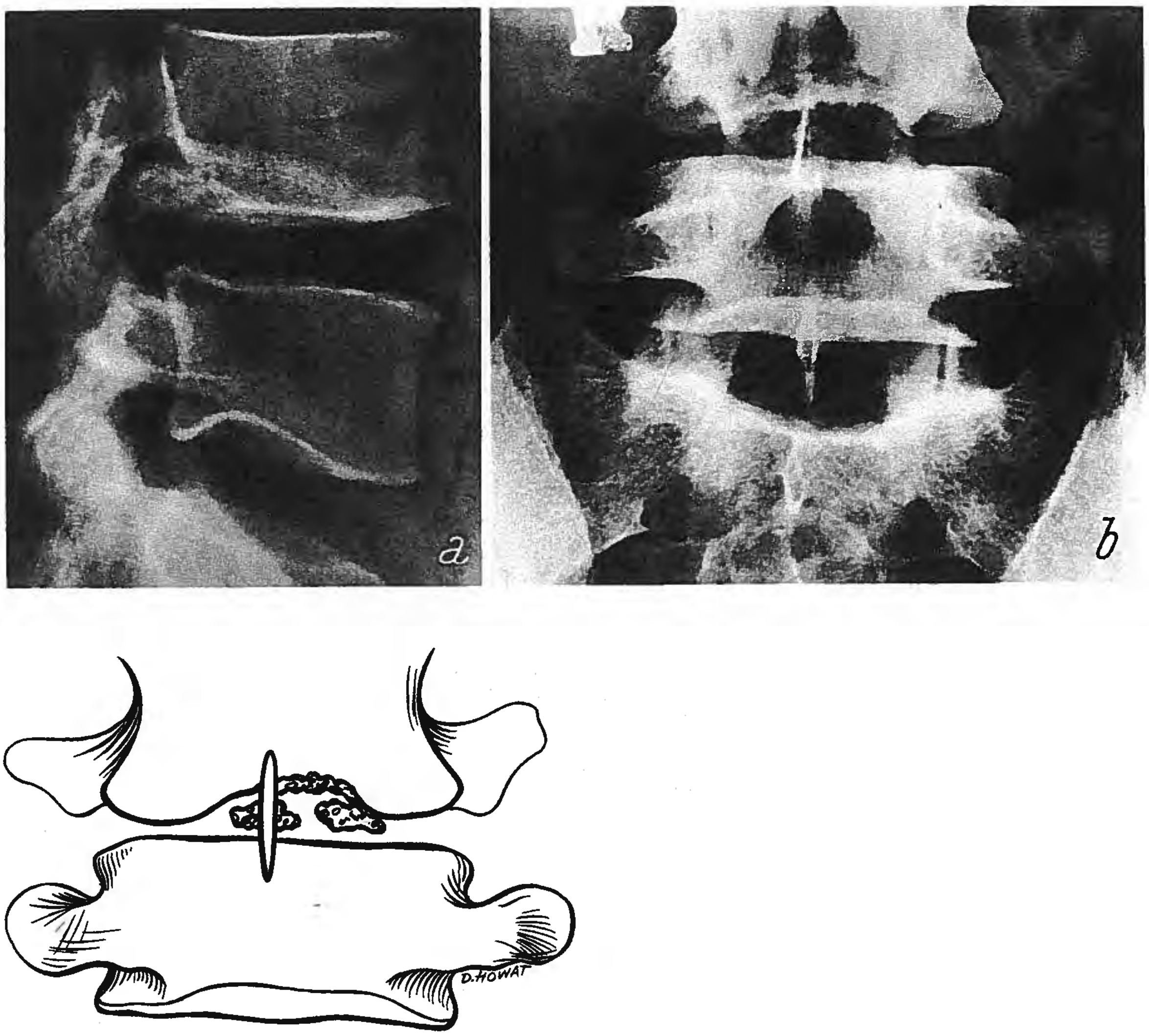


Figure 3.4. Antero-posterior radiograph showing a lumbar myelogram with a massive migrating sequestrated disc from L2/3, producing marked lateral deformation of the myodil column. The patient was a 52 year-old dentist



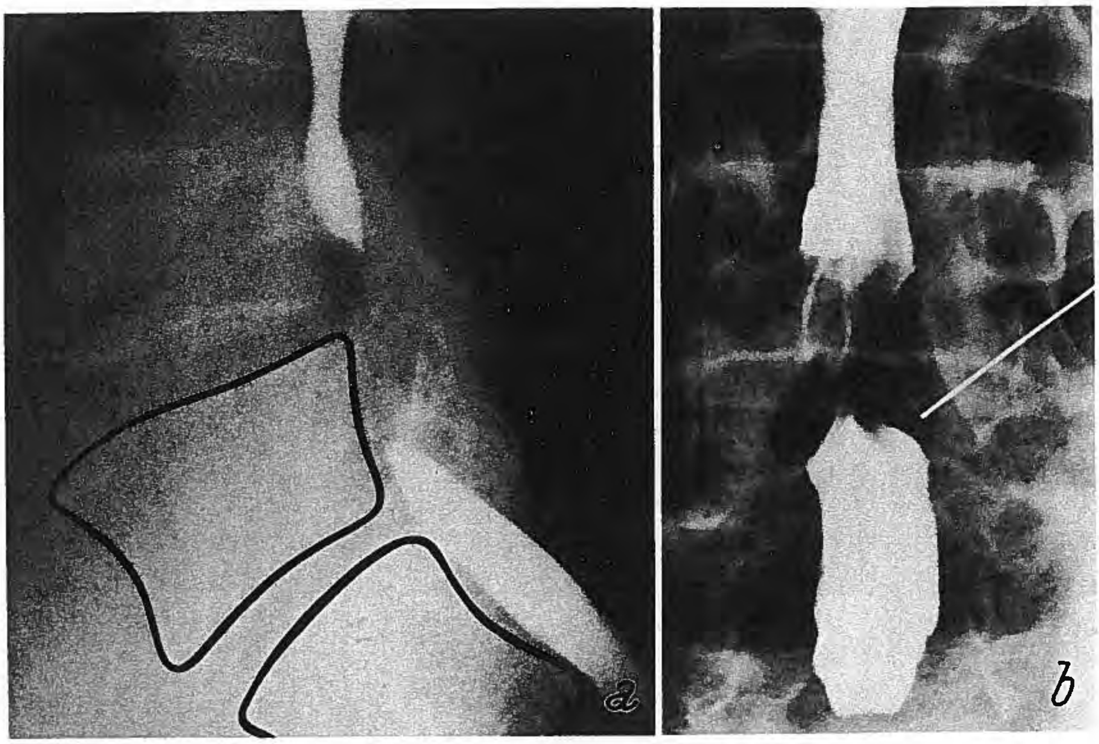
Figures 3.5



c

Figures 3.6 a–c. Intra-spongeous disc herniation with fracture of the vertebral body margin and sequestration of disc fragments into the spinal canal. **a** Lateral radiograph. A large bony fragment separated from the postero-inferior margin of the 4th lumbar vertebral body. It projects into the spinal canal. **b** Antero-posterior view. The L4/5 disc space is narrowed and tilted. There is a defect in the central zone of the vertebral end-plate area of the 4th vertebral body. Below this, two bony fragments can be identified. These findings were confirmed at operation. **c** Drawing of the position of these fragments. (Courtesy of Mr. K. Mills)

Figures 3.5 a–c. Sequestrated L4/5 disc with migrating fragments. **a** and **b** Lateral and antero-posterior radiographs of the lumbar myelogram of a woman, aged 39 years, who had severe right-sided sciatica. The deformation of the dural sac is consistent with the presence of migrating sequestrated disc fragments. It is best seen in the antero-posterior view. **c** The photograph shows the appearance of the sequestrated disc material which was removed at operation, orientated to correspond with its position *in vivo*



Figures 3.7a and **b.** Disc prolapse into a congenital narrow lumbar canal. A 62 year-old man (weight 110 kg) lifted a bag of cement, flexing and rotating his spine. He developed back pain and severe bilateral leg pain; these symptoms were relieved following excision of a small disc fragment and bilateral nerve root canal decompression laminectomy. **a** Lateral and **b** antero-posterior radiographs of the lumbar myelogram, showing gross obstruction of the iofendylate column. Note the symmetrical indentation at the upper end of the lower iofendylate column in (b) (marker), suggesting the association of true spinal stenosis. (Courtesy of Mr. B. Davie)

finding related to physico-chemical changes in the disc (Nachemson, 1969). Calcified nuclear tissue may herniate; or calcification may occur in prolapsed tissue leading occasionally to erosion of the dural sac (Blikra, 1969).

A sequestrated fragment may migrate to another level from the disc of its origin, leaving a clearly defined oval defect in the posterior annulus (Figs. 3.4, 3.5). Sequestrated disc tissue may present posterior to the dural sac (Hooper, 1973).

Rarely, disc tissue may prolapse into the vertebral bodies and re-enter the spinal canal, pushing ahead of it a small fragment of vertebral end-plate bone and cartilage (Figs. 3.6a–c). Knowledge of the varying relationships which prolapsed disc tissue may bear to the neural contents of the spinal canal is essential to the understanding of the varied clinical pictures which many present (Fig. 3.1).

In a sub-rhizal prolapse, the disc fragment lies anterior to the affected nerve root, and this usually causes severe pain with objective motor and sensory signs distally, in the part of the limb supplied by the compressed nerve root (Fig. 3.1).

Prolapses situated between the dural sac and the nerve root sheath–axillary prolapses (Fig. 3.1), or those lying on the outer side of the nerve root sheath–para-rhizal prolapses, may produce symptoms of severe sciatica without abnormal objective physical signs.

Centrally placed prolapses or a large migrating sequestrated fragment in the spinal canal may give rise to physical signs including bowel or bladder dysfunction and neurological signs or symptoms which vary from day to day in one leg or the other. In the lumbar region, cauda equina claudication with the onset of buttock or leg pains after walking short distances may also be found (Verbiest, 1955).

In considering this pathology, the clinician should always give some thought to the shape and size of the patient's spinal canal (Figs. 3.7a, b).

3.3. Clinical Features

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

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

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

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

3.4. Investigations

a) Plain X-Rays

These X-rays always provide essential information on the bony anatomy of the vertebral column, particularly in regard to the arrangement of laminae and the site of the lumbo-sacral junction. They are also important for the exclusion of other lesions such as spondylosis which may cause confusion in diagnosis. Usually they do not provide any useful guide to the site of prolapse, although there may be exceptions; for example, where there has been marked disc degeneration leading to disc space narrowing on one side, as viewed in the antero-posterior projection, the prolapse may be found on the wider side of the disc space.

b) Myelography

Widely diverging views are held on the proper role of myelography in the investigation of lumbar disc prolapses (Epstein, 1969; De Palma and Rothman, 1970). Hudgins (1970) states that its sensitivity is about 75% (25% false negative), and its specificity is roughly 90% (10% false positive). He claims that in patients with good neurological signs or a crossed Lasègue's sign, the predictive value of a normal myelogram is less than 50%.

Myelography probably should be used as a routine pre-operative investigation in cases of suspected disc prolapse. This investigation is invaluable in the investigation of any atypical case and is especially useful in cases of suspected disc prolapse where there is advanced spondylosis shown on the plain X-rays, or in the presence of bony anomalies such as lumbar sacralization. In these cases, myelography will aid in the diagnosis of associated spinal canal stenosis (Fig. 3.7), or it may help to identify the level of origin of a large disc sequestrum (Fig. 3.4). The introduction of water-soluble myelographic media such as metrizamide in recent years has greatly enhanced the accuracy of diagnosis.

c) C.S.F. Examination

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

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

d) Epidurography

The injection of contrast media into the epidural space has been advocated for the demonstration of small disc prolapses. This has been used in assessing non-operative methods of treatment. The poor quality of published illustrations indicates that there are grave limitations to the use of this investigation (Mathews, 1972).

e) Discography

This investigation finds restricted use in the diagnosis of disc prolapses. In atypical cases of severe sciatica with minimal abnormal physical signs and normal myelographic findings, a discogram may help to clarify the diagnosis (Wilson and McCarty, 1969).

f) Intra-Osseous Spinal Venography

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

g) Electrodiagnostic Tests

Technical and interpretative difficulties in the use of electromyography have been described by Simpson (1972). More recently, Japanese workers have developed new methods using fine electrodes for nerve root stimulation in the lumbar region, recording evoked potentials with promising results in the identification of nerve root irritation of differing types (Matsuda *et al.,* 1979).

3.5. Indications for Surgical Treatment

Absolute indications for operations are:

a) Major neurological deficits. Cases of acute cauda equina compressions due to massive disc sequestration or the prolapse of a small fragment of disc tissue into an abnormally small lumbar spinal canal (spinal canal stenosis) may call for spinal canal decompression involving, if necessary, trans-dural excision of disc fragments (Fig. 3.22).

b) Persistent or recurrent pain, with or without abnormal physical signs, in the legs. This is the most common indication for surgery after an adequate trial of conservative treatment.

c) Progressive neurological deficit, such as paraparesis or foot drop may strengthen indications for operative intervention.

d) Persistent spinal deformity, such as lumbar scoliosis or marked lumbar flexion deformity may be found in certain cases of lumbar disc prolapse or spinal tumour.

3.6. Treatment for Lumbar Disc Prolapses

a) Discussion

i) Surgery

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

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

Where most of the disc remnants are removed in some cases of massive disc sequestration, gross vertebral instability can occur. Posterior interbody spinal fusion performed through the spinal canal, either by the technique described by Cloward (1952) or that recommended by Wiltberger and Abbott (1958), offers a solution to a difficult problem (Fig. 3.3d).

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

Authors everywhere agree on a number of matters:

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

ii) Chymopapain

Intra-discal injection of chymopapain (Discase), a proteolytic enzyme, was introduced into clinical practice in 1963 for the treatment of disc prolapse (Smith and

Brown, 1967). Clinical diagnosis is confirmed by discography, following which the enzyme preparation is injected through the discogram needle.

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

b) Technique

i) Pre-Operative Preparation

Full blood examination, including blood grouping and sedimentation rate should be performed. It is wise to insert an intravenous infusion in all patients before operation for disc disorders, though blood transfusion is rarely indicated.

X-rays of the patient's spine should always be available in the operating theatre.

The use of prophylactic antibiotic chemotherapy may be indicated if there has been an antecedent history of serious infection, including previous wound infections.

ii) Anaesthesia

General anaesthesia with muscular relaxation and mechanical ventilation is most commonly employed. Cardiac monitoring is recommended in older patients or whenever it is known that the patient has particular cardiac problems.

iii) Positioning

Of all the factors which may be critical to the success of this operation, none is more important than the position in which the patient is placed before operation commences. A variety of suitable postures is shown in the following illustrations (Figs. 3.8–3.11).

Prone Position

The most versatile and easily managed is the *prone position.* A supporting sponge rubber U-piece is simple to construct and inexpensive. The right arm is shown dependent and supported on a well-padded arm rest which is suspended below the level of the table. Ulnar neuritis may occur unless the arm is carefully postured in this way. The left arm may rest by the patient's side. The table is angled in the centre. The surgeon's assistant and other observers will have unobstructed views of procedures throughout the course of the operation. The entire range of surgical manoeuvres that may be required for the execution of even the most complex operation, including trans-dural excision of prolapsed disc tissue, can be

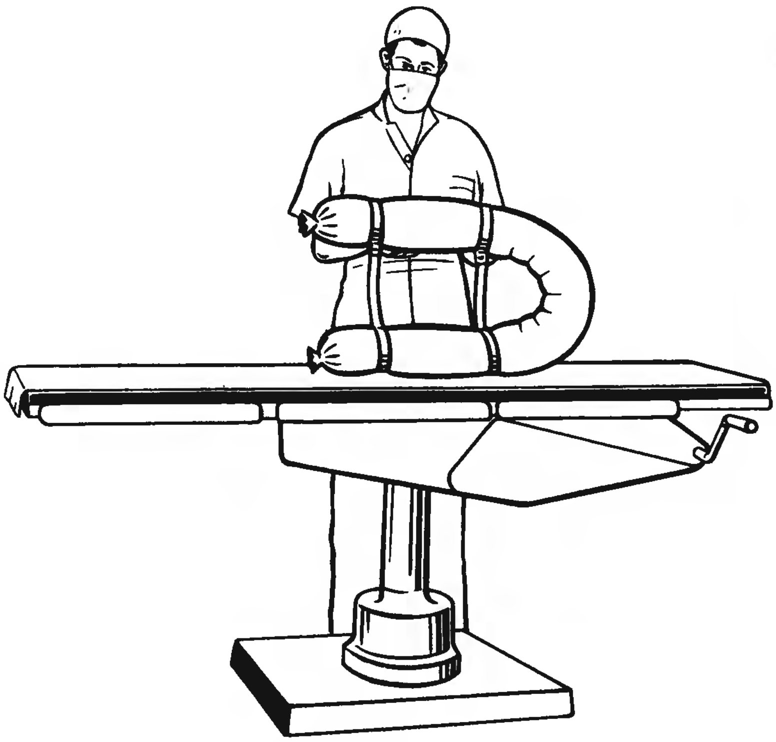


Figure 3.8. A drawing illustrating a simple supporting sponge rubber "U"-piece

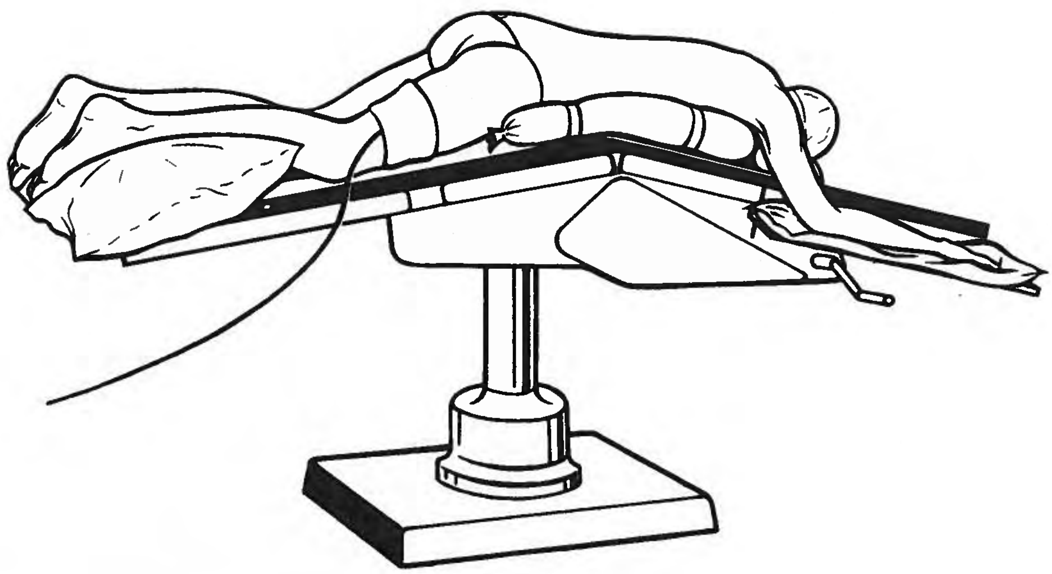


Figure 3.9. The posturing of the patient on this "U"-piece. The right arm is shown dependent and supported on a well-padded arm rest which is suspended below the level of the table. Ulnar neuritis may occur unless the arm is carefully postured in this way. The left arm may rest by the patient's side. The table is angled in the centre

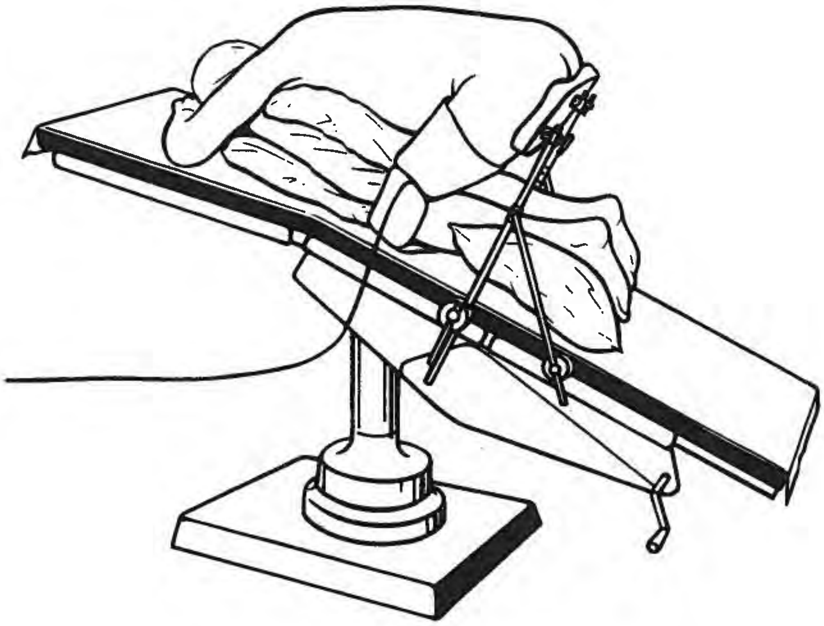


Figure 3.10. A drawing depicting the jack-knife or kneeling position. A simple frame is used to support the buttocks

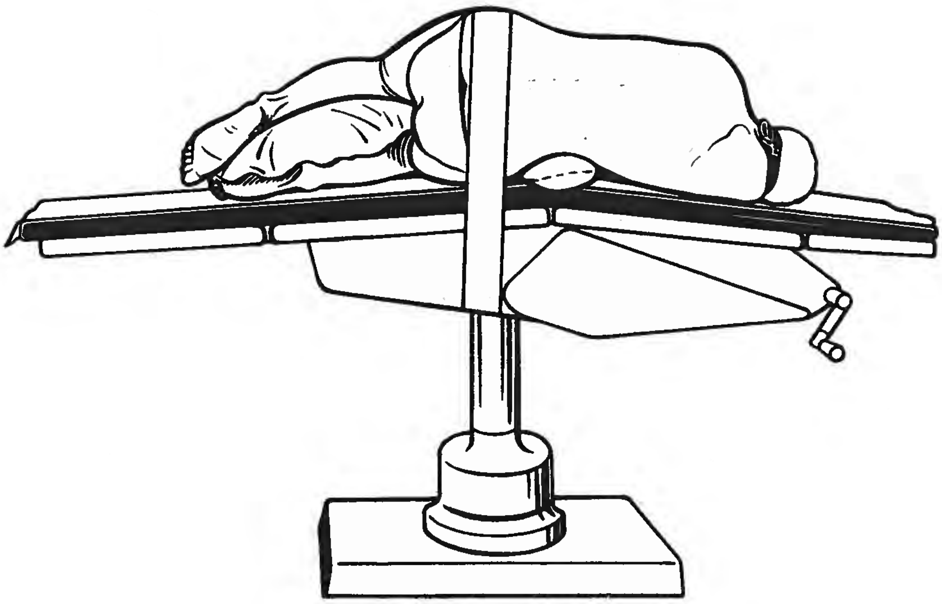


Figure 3.11. The lateral position. The use of this position can be recommended in special circumstances, for example, when the patient is extremely obese or when there are special chest problems which may complicate anaesthesia. Note the pillow between the patient's legs, the restraining strap crossing the iliac crest, the sandbag placed above the dependent iliac crest. The table is angled in the centre. There are objections to the routine use of this position: 1. the assistant surgeon is rarely comfortable and has a restricted view of the operative field; 2. lighting of the wound area may be difficult; 3. haemorrhage control is often more difficult to obtain, as is access to the nerve root canal on the dependent side of the spine

accomplished in comfort and without undue constraints on the duration of the operation.

Jack-Knife or Kneeling Position

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

Lateral Position

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

iv) Instruments (Figs. 3.12, 3.13)

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

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

Figure 3.12. A photograph showing the modified Gelpi retractors, which are recommended for use in almost any situation where the spinal canal is to be explored

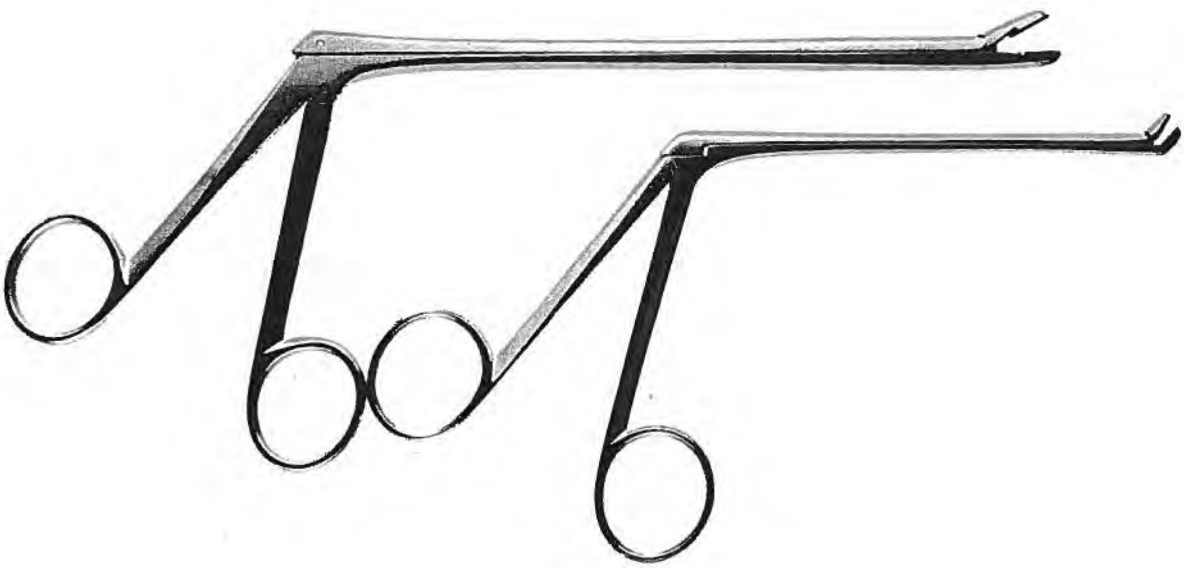


Figure 3.13. A photograph of straight and angled pituitary rongeurs which should be available in various shaft lengths and cup sizes for use in the surgery of disc prolapses

v) Incision

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

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

The skin incision is made in the mid-line or slightly to the right or left of the spinous processes, extending longitudinally a short distance above and below the vertebral interspace to be explored. It is deepened at once through the subcutaneous fat layer to the level of the lumbo-dorsal fascia. In extremely obese patients the depth of the subcutaneous fat layer between the skin and the lumbo-dorsal aponeurosis over the lumbo-sacral area may be 12 cm or more. In such cases this fatty tissue should be carefully handled, avoiding excessive burning with the coagulating diathermy (see "Wound Closure", p. 122).

vi) Separation of Spinal Muscles

An incision is made on one side of the tip of a spinous process, using the cutting current diathermy, passed through a suitable blade-shaped end. The incision continues proximally and distally immediately adjacent to the side of the spinous process *parallel to the adjacent interspinous ligament* and then to the side of the next related spinous process. Bleeding occurs at this stage from posterior branches of the lumbar arteries related to the middle of the side of each spinous process. The muscle mass may be retracted with a closed dissecting forcep placed into the depth of the space, so that the diathermy blade may cut the musculo-tendinous attachments from the inferior surfaces of the spinous processes and from the inter-spinous ligaments near their bases. Throughout this procedure the smoke generated by the diathermy cutting tip may be evacuated with the sucker.

The muscle mass is next separated from the outer surface of each lamina using an appropriate "elevator", such as the Cobb, taking care to preserve the periosteum of the laminae.

Following the use of the muscle elevator which raises the paraspinal muscles laterally to the level of the *apophyseal joint capsules, which should be carefully preserved,* further bleeding may be encountered from posterior branches of the lumbar arteries and veins in the area. This bleeding is readily controlled following the insertion of cotton Raytec swabs (bearing X-ray markers) packed into the depths of the wound along its length (Figs. 3.14–3.16a, b).

The same approach is then repeated on the opposite side of the spinous processes, preserving the interspinous ligaments until the paraspinal muscle mass has been similarly separated from the roof of the spinal canal. Cotton Raytec swabs are again inserted and the self-retaining retractors of the surgeon's choice then prepared for insertion. Some surgeons favour muscle stripping on one side of the spine only (Finneson, 1973).

Unless the technique described is followed carefully, considerable blood loss may occur, even during this preliminary stage of the approach to the disc prolapse.

The cotton Raytec swabs are removed from the lower end of the wound on either side of the S1 spinous process. Hand-held retractors expose the back of the

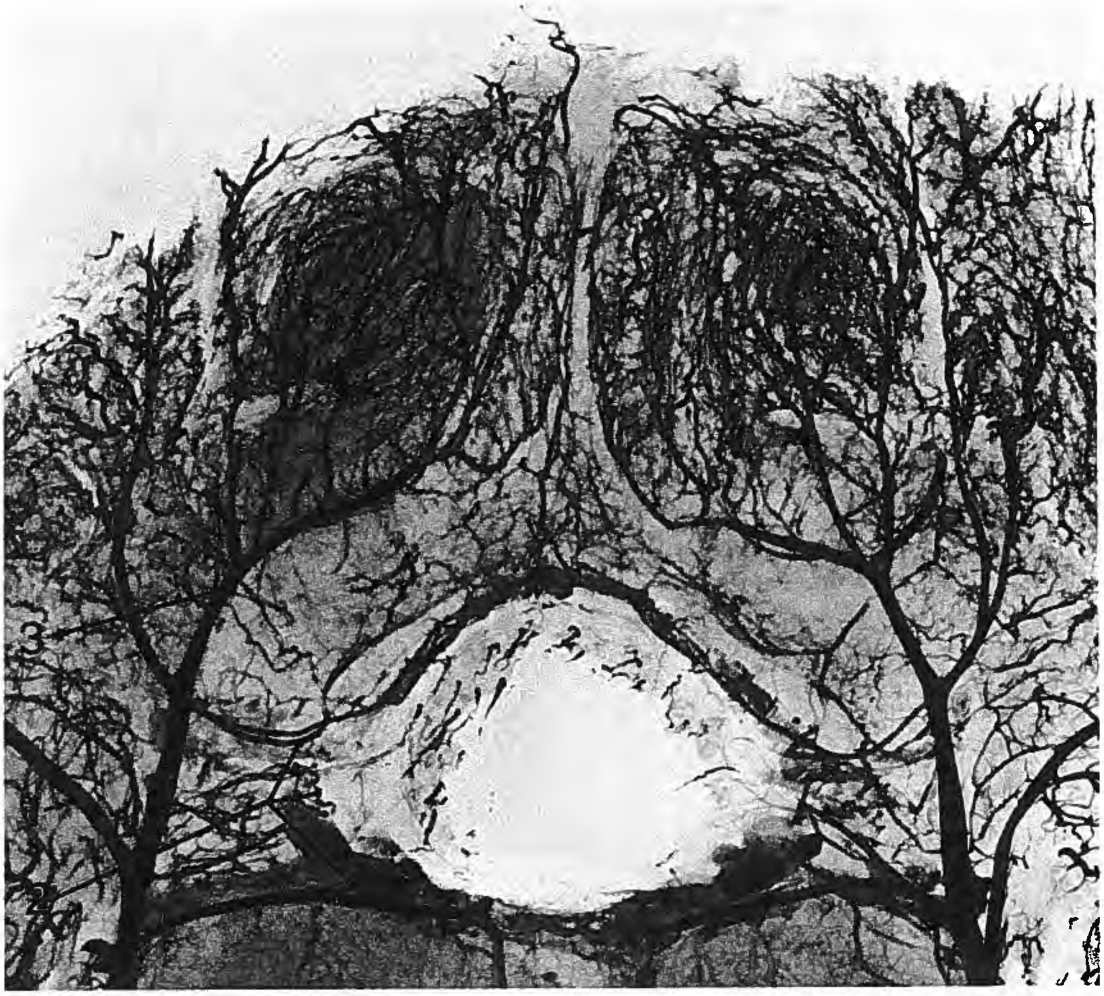


Figure 3.14. A thin transverse section to show details of the arterial distribution in relation to the spinal canal, the vertebral body in front and the lamina and spinous process behind. At the level of the intervertebral foramen, note: **1** the anterior abdominal wall branches; **2** the intermediate or spinal canal branches; and **3** posterior to the intervertebral foramen, the posterior branches in relation to the lamina and spinous process

sacrum allowing the first self-retaining retractor to be inserted and fixed in place. This procedure is repeated at the upper end of the wound and the second self-retaining retractor inserted.

When the self-retaining retractors have been positioned, the surgeon should take note of the time of their application. These instruments obstruct the circulation in the separated paraspinal muscles. At the end of an hour they should be removed for about five minutes to prevent muscle necrosis. During the rest period the wound should be washed out with hydrogen peroxide solution or Ringer's solution.

At this stage, cotton Raytec swabs are again packed firmly along one of the paraspinal gutters while attention is focussed on the opposite side to identify the lumbo-sacral junction. Soft-tissue remnants of muscle fibres and fat are then removed from the interspace which is to be opened. This cleaning-up process can be

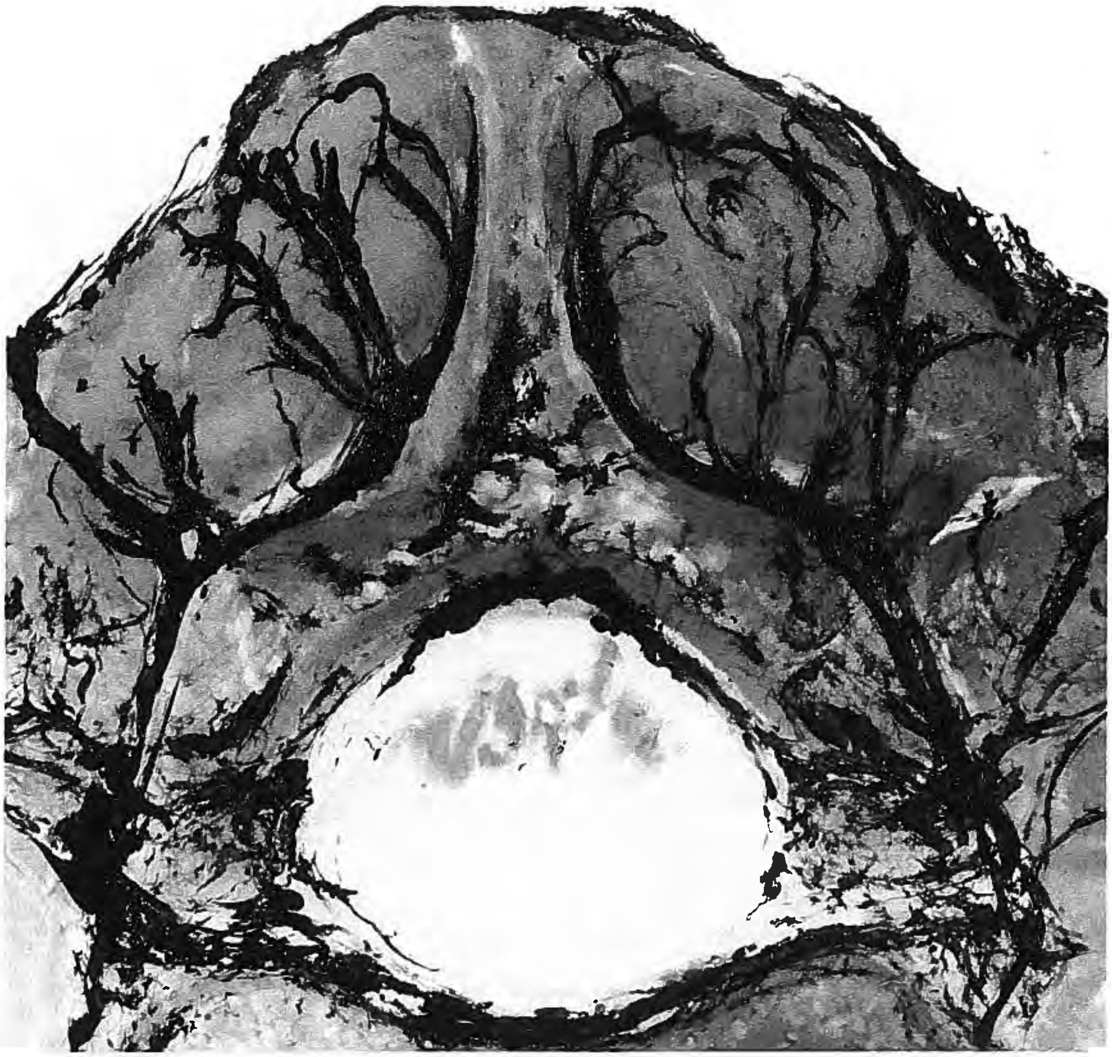
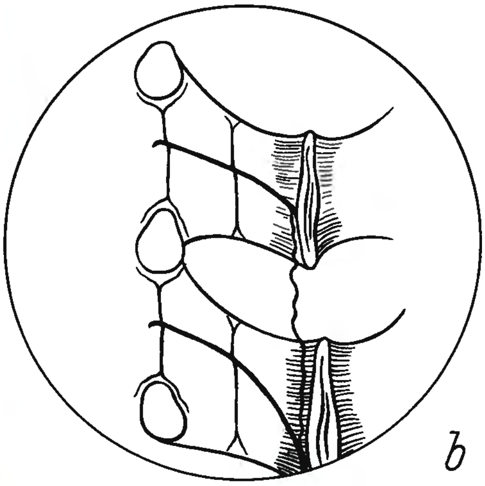


Figure 3.15. A radiograph of a transverse section of a lumbar vertebra from an adult to show the relations of the main stems of the lumbar veins (posterior external vertebral venous plexus) to the spinous process and lamina. [Reproduced by courtesy of J. B. Lippincott & Company from: Clinical Orthopaedics and Related Research, No. 115 (1976)]

Figures 3.16 a and **b.** A photograph of the posterior aspect of the upper lumbar spine of an adult prepared by the Spalteholz method, following injection of the lumbar aorta. The specimen is slightly tilted to the right side to provide a clear view of the posterior spinal branches of three adjacent lumbar arteries. An explanatory diagram is shown alongside, in which the main course of each lumbar artery across the back of the lamina and up the middle of the spinous process is shown with its ascending and descending vertical muscular branches and the arcuate systems formed around the facet joints

Figure 3.17. A radiograph of a thin sagittal section of the lumbar spine, showing the relations of the posterior branches of two lumbar arteries as they course backward behind the intervertebral foramina. These arteries are constant lateral relations of the pars interarticularis of each lamina. In the intervertebral foramen shown on the left, the anterior and posterior spinal canal branches of the lumbar artery can be seen, separated by a clear band, this area being occupied by the nerve root at that level. Note also the branches which encircle the facet joint system and supply it. [Reproduced by courtesy of J. B. Lippincott & Company from: Clinical Orthopaedics and Related Research, No. 115 (1976)]



Figures 3.16

Figure 3.17

accomplished rapidly and neatly by using a straight pituitary rongeur with a 4 mm cup, taking off first the muscle remnants from the interspinous ligament and adjacent lamina and then all the soft tissues from the posterior surface of the ligamentum flavum.

Bleeding is not a problem during these manoeuvres at the lumbo-sacral junction until the extra-synovial fat pad of the apophyseal joint is removed. On avulsing this fat pad, quite brisk arterial and venous haemorrhage will occur. The bleeding vessels are readily identified by the use of a sucker and cotton Raytec swab. The vessels are picked up with the Bayonet forceps and coagulated with the diathermy. When exposure at the L4/5 interspace is required following the initial clearing procedure as described above, the pars interarticularis of the fifth lumbar lamina is exposed. The sucker tip may be used as a dissector at this stage, sucking up remnants of fatty tissue. *The main stem of the posterior branch of the lumbar artery is found constantly at the middle of the outer edge of the pars interarticularis.* From it, arcuate branches pass upwards and downwards towards the capsules of the apophyseal joints (Figs. 3.16a, b, 3.17). Haemorrhage points are easily identified, though care must be taken not to diathermy the main stem far anterior to the anterior margin of the pars interarticularis. Damage to entrant neural arteries at the intervertebral foramen is thereby avoided.

The main stem of the posterior branch of each lumbar artery is accompanied by the corresponding and somewhat larger vein (Crock and Yoshizawa, 1977).

In cases where exposure of both sides of the interspace may be required, the detailed clearing process just described is completed on the opposite side. At this stage, it will be noted that there are some capsular fibres extending medially on to the ligamentum flavum for some distance at its upper margin where it passes beneath

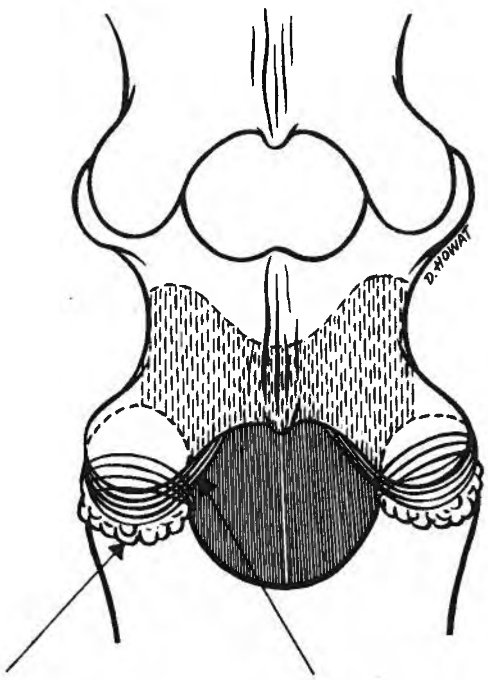


Figure 3.18. A drawing depicting the relations of the ligamentum flavum. The extra-synovial fat pads are shown in exaggerated form. Note the extension of capsular fibres onto the posterior surface of the ligamentum flavum

the inferior margin of the superior lamina of the interspace (Fig. 3.18). These fibres should be removed with a straight pituitary rongeur before opening the ligamentum flavum. Portions of the inferior surface of the superior lamina at the interspace may then need to be excised (using an outward-angled rongeur) and in some cases the interspinous ligament may be removed together with a portion of the inferior surface of the spinous process at the upper level of the interspace (Fig. 3.19). Some surgeons favour the use of chisels or gouges for this particular manoeuvre. Bone wax may be applied to the cut surface of the cancellous bone to control bleeding.

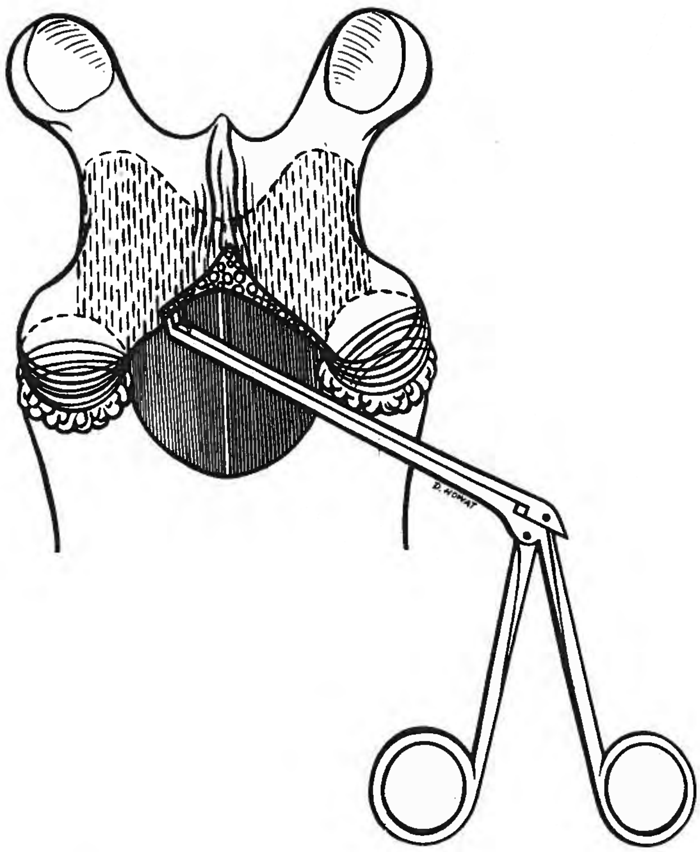


Figure 3.19. A drawing showing the method of removal of portions of the inferior surface of the superior lamina at the interspace, using an outward-angled rongeur. In some cases the interspinous ligament may be removed together with a portion of the inferior surface of the spinous process at the upper level of the interspace

vii) Opening of Spinal Canal

The ligamentum flavum should then be incised vertically in the mid-line using either a No. 11 or 15 blade scalpel. The cut edge of the ligamentum flavum is picked up with a fine-toothed forceps and the incision deepened until either epidural fat or the dura itself is exposed.

The blunt end of the Watson-Cheyne dissector may then be used to widen the opening into the spinal canal. Through the vertical slit in the ligamentum flavum thus created, a small moistened cotton patty is inserted between the ligamentum flavum and the epidural fat, using the curved end of the Watson-Cheyne dissector. The ligamentum flavum is then cut in a lateral direction, first at the lower edge of the interspace, until a flap is raised and turned out laterally.

Even at this early stage of the opening of the spinal canal, the presence of a large prolapse can be suspected when difficulty is experienced during the insertion of the patty or patties, particularly when efforts are made to push them further laterally under the ligamentum flavum as the flap is enlarged.

When the ligamentum flavum has been turned laterally as a flap to the level of the apophyseal joint, a fourth incision is then most commonly made in it, again in a vertical direction to excise the flap.

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

viii) Extending Exposure

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

When the prolapse is large and sub-rhizal at the L5/S1 level, for example, it may be necessary to enlarge the interspace by removal of part of the superior border of the lamina of S1, commencing initially in the mid-line and passing laterally, and to perform a decompression of the S1 nerve root canal by removing the medial portion of the S1 facet flush with the inner margin of the S1 pedicle. In the operation of nerve root canal decompression, the apex of the facet also needs to be removed (see pp. 23–27).

ix) Management of Venous Haemorrhage

During the more complicated manoeuvres of this type, haemorrhage from the internal vertebral venous plexus surrounding the nerve root and lateral to it may occur. This haemorrhage is usually not troublesome when the patient is in the prone position. On occasions, however, the internal vertebral venous plexus may be distended and brisk venous haemorrhage may occur following damage to some of the radicular branches of this system of veins. The detailed anatomy of the anterior internal vertebral venous plexus in the lumbar region is described on p. 17. Venous haemorrhage is always readily controlled with the gentle use of a patty and sucker as illustrated in Fig. 3.20. Occasionally, bleeding from one of the large venous radicles can be troublesome and it may be necessary to identify this using the sucker and a patty. The bleeding points are grasped with the bayonet forceps and coagulated with low-voltage or bipolar coagulating currents.

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

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

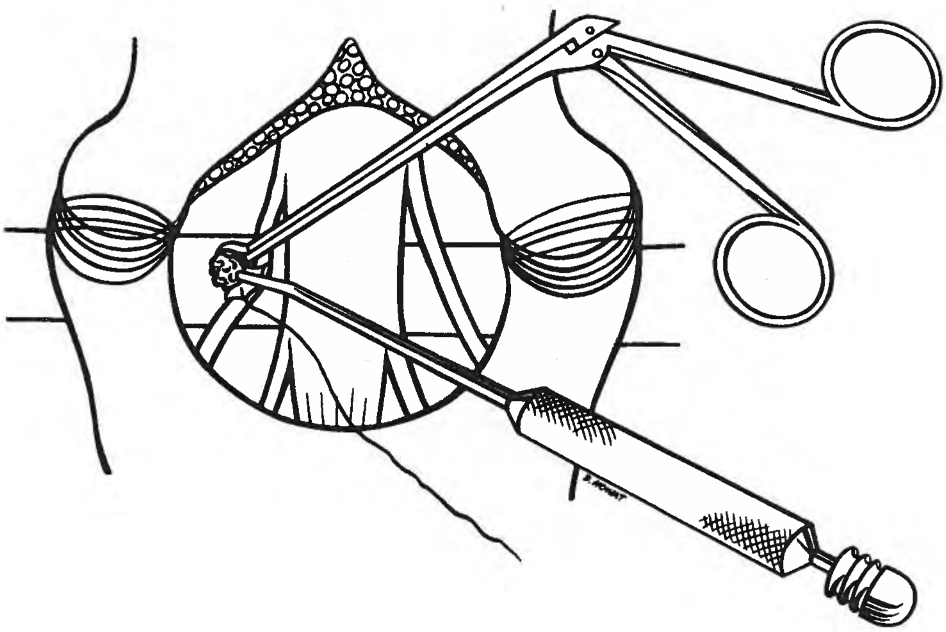


Figure 3.20. A drawing depicting the disposition of the sucker and patty and straight pituitary rongeur at the time of removal of a fragment of prolapsed tissue

x) Excision of Disc Tissue

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

Small Sub-Rhizal Prolapse

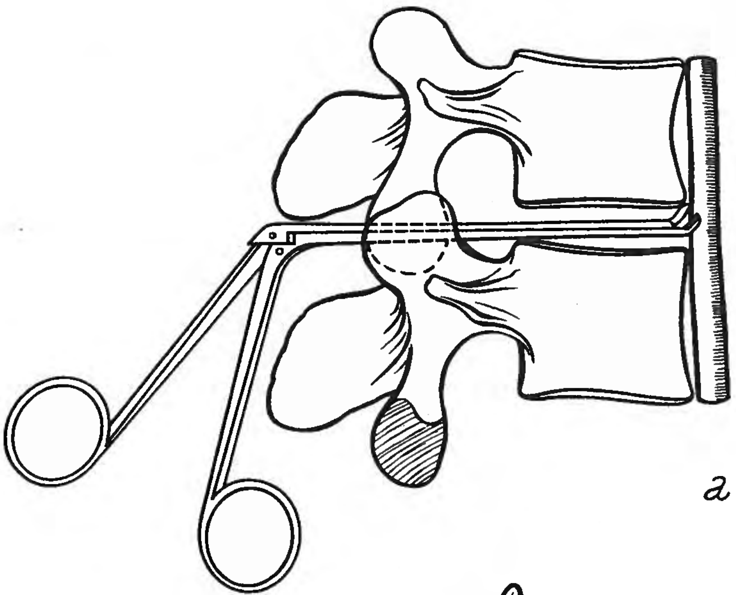
Partial excision of the ligamentum flavum on one side will afford satisfactory access to the canal. Initially, identification of the landmarks of pedicle, disc and affected nerve root is made using the sucker and patty as a medial retractor and the blunt end of the Watson-Cheyne dissector in the lateral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

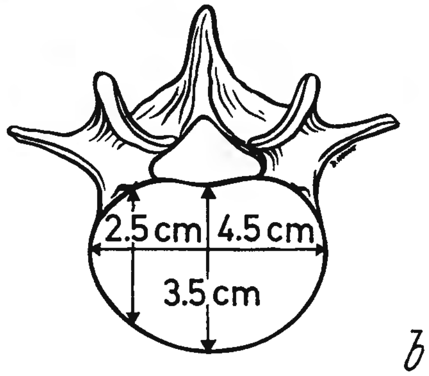
Blunt dissection will separate the epidural fat, and the nerve root can usually be easily retracted medially. The discrete rounded prolapse with intact annular fibres is then outlined and a suitable root retractor inserted. The surgeon may use the sucker with a moist patty on its tip as a retractor laterally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

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

Large Sub-Rhizal Prolapse

In such cases, adequate exposure on the side of the prolapse is essential. Technical details for the enlargement both superiorly and inferiorly have been outlined above. Identification of the affected root may be a problem, because in such circumstances the root is often flattened and its lateral margin not easily identified, being of the





Figures 3.21. a A drawing to highlight the potential danger of penetration of a rongeur through the disc space into the abdominal cavity where great vessels or other intra-abdominal structures may be injured. **b** A drawing to illustrate the dimensions of a lumbar vertebral body in an adult of average size

same colour as the disc prolapse beneath it. Use of an operating loop may be helpful, as it is essential under such circumstances to identify the nerve root sleeve at its junction with the dura above or to identify the main stem of the nerve root at the level of the inferior pedicle. By either method, with the use of an appropriate nerve root dissector, the outer edge of the nerve root can be identified and retracted medially. Very fine straight and curved pituitary rongeurs will be required in such a case to remove the first of the fragments of prolapsed tissue, possibly through a minute incision in intact annular fibres. Only after the initial removal of fragments with small instruments will it become possible to complete the dissection and retraction of the nerve root medially from the bulk of the prolapse.

As the tension on the nerve root is released, retraction becomes easier. The opening in the annular fibres may be enlarged under vision and rongeurs of increasing cup size inserted for removal of free disc fragments from the interspace. The sucker with a patty on the end of it may be used as a retractor held by the surgeon in his left hand, while, with the rongeur in his right hand, the fragments are lifted out from the interspace (Fig. 3.20). In such cases, quite large amounts of the disc material may be removed, but the risk of penetration of rongeurs deep into the interspace with the possibility of damage to intra-abdominal structures is high (Fig. 3.21). The use of ring curettes is recommended in such cases for curettage of loose disc fragments and vertebral end-plate material. When large amounts of disc material have been removed, of the order of several grams of tissue, then it is wise to perform a nerve root canal decompression on both sides of the interspace, completing removal of ligamentum flavum far laterally and removing the inner margin of the superior articular facet of the inferior vertebra at the interspace on each side. In addition, with angled rongeurs it may be necessary to remove the apices of both the superior facets on the inferior side of the interspace. Excision of the whole facet joint in the course of this operation should be avoided.

The Management of Sequestrated Disc Fragments

The finding of free fragments of disc tissue in the spinal canal may pose specific problems at operation. These problems relate, more than anything else, to the site of origin of the disc tissue. If, for example, free fragments of disc tissue are found at the lumbo-sacral level, yet the posterior annular fibres of the L5/S1 disc space are found to be normal, then exploration of the higher interspace is essential. In these circumstances careful palpation of the L5/S1 disc with the blunt end of the Watson-Cheyne dissector, beneath the dural sac towards the mid-line, will be necessary before it can be safely assumed that the disc tissue has not prolapsed from that interspace. If, on the other hand, the L4/5 interspace has been exposed and a rather adherent nerve root retracted from the back of the disc to reveal a circumscribed rounded defect in the annulus, then free sequestrated disc material may be found at the lower interspace.

Central Disc Prolapse

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

Trans-Dural Approach

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

The dural vessels in the mid-line may be coagulated over the length of the proposed dural incision, using low voltage coagulating current. This done, the dura is incised with a No. 15 blade scalpel and a protective probe introduced near the top of the incision. This is followed downwards progressively as the full length of the dural incision is made.

Cerebrospinal fluid is allowed to escape. It should be aspirated from the wound, but *at all times the sucker should now be covered with a patty.* An inexperienced surgeon or an inexperienced assistant may, from any point onwards in this operation, inflict irreversible damage on filaments of the cauda equina. Remembering that the vessels of the cauda equina are minute, only smooth rounded instruments should be used to retract the filaments from the mid-line laterally on each side (Fig. 3.22). At no stage should an unguarded sucker be placed within the dural sac itself as a nerve root may be avulsed up the sucker.

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

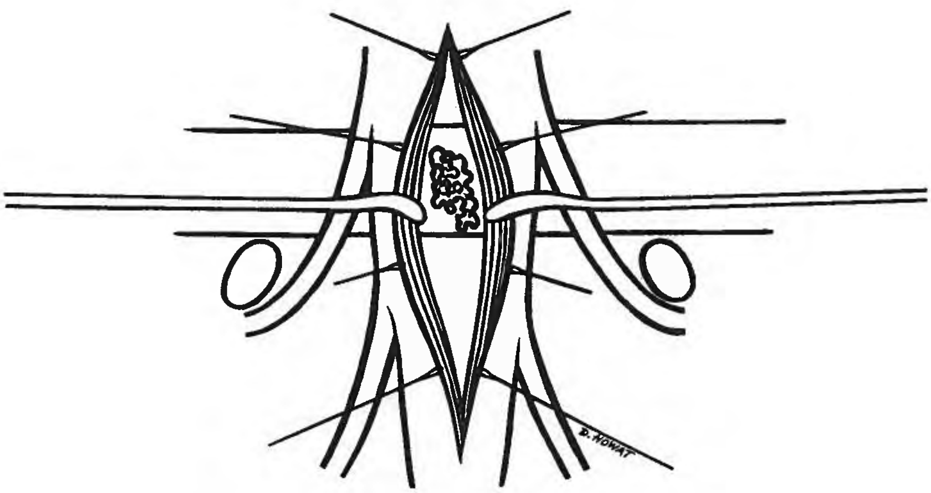


Figure 3.22. A drawing to illustrate exposure of a central disc prolapse trans-durally, filaments of the cauda equina being retracted from the mid-line laterally on each side with smooth rounded instruments

Depending on the volume of disc material that can be removed with straight or angled pituitary rongeurs of varying sizes, so the question of curettage of the disc space may arise. If large quantities of disc material can be removed easily, it is wise to use a ring curette to clear other remnants, recalling once again the risk of instruments penetrating into the abdominal cavity.

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

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

xi) Disc Prolapses Associated With Other Special Problems

Spinal Canal Stenosis

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

Nerve Root and Other Anomalies

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

Isolated Disc Resorption

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

Spondylolisthesis

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

xii) Upper Lumbar Disc Prolapse

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

xiii) Preserving the Bony Canal

In the past it has been common practice to remove either one half side of a lamina or to cut a narrow channel in it between the two ligamenta flava related to it, while seeking an elusive disc prolapse. This interference with the roofing apparatus of the spinal canal is to be avoided, particularly in cases with spinal canal or nerve root canal stenosis, because it may lead to the development of stenosis of the canal following growth of new bone into the area of the laminal defect (see Chapter 9, p. 253).

Exploration of an intervertebral disc space can be accurately and competently performed through a limited inter-laminar exposure, carried out along the lines recommended above (p. 116). If no lesion is found at one level, due to error, then it is better to look at the next level upwards or downwards from the primary exploration without disturbing the integrity of the lamina.

xiv) Wound Closure

The use of suction drainage is recommended routinely, except in cases where the dura has been breached.

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

Dural tears are most likely to occur in complicated cases, for example, where there is associated spinal canal stenosis and opening of the canal proves difficult, or again, in the course of separating an adherent root from a disc prolapse. These defects should be identified carefully and repaired with fine sutures.

Careful attention to wound closure is important. Deep sutures may be placed in the muscle layer, but these should be tied only to the point of approximation of the muscle masses in the mid-line. Most attention should be focussed on tight closure of the lumbo-dorsal fascia with interrupted sutures.

In extremely obese patients with thick layers of subcutaneous fat, the use of multiple sutures in this tissue should be avoided. Excessive use of diathermy in the fatty layer and rough handling of this tissue will result in the leakage of liquified fat from the wound. Infection in this layer may subsequently become troublesome. These problems may be prevented by using three or four heavy grade nylon sutures passed through the skin and full depth of the fatty layers beneath it and tied as "mattress" stitches. When these "tension sutures" have been tied, the skin edges may be approximated with fine interrupted sutures.