NORMAL AND PATHOLOGICAL ANATOMY OF THE LUMBAR SPINAL NERVE ROOT CANALS

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A description of the normal anatomy of the lumbar spinal nerve root canals and the intervertebral foramina is presented. The pathological anatomy of these structures in isolated disc resorption, spondylolysis, congenital hypertrophy of the first sacral facets and in localised osteoarthritis of the lumbar facet joints is described. The use of simple terminology for their description is suggested.

In the 1970s there were two outstanding changes which influenced the management of spinal disorders. First, significant advances occurred in investigative methods: safer water-soluble contrast agents became available, leading to improved myelography; computerised tomography heralded a revolution in non-invasive imaging of the spinal canal; ultrasonic measuring techniques were applied to the spine; and epidural venography attained some popularity. Secondly, there was a growing interest in the clinical problems attributed to spinal stenosis, with an emerging awareness of differences in symptoms and signs produced by stenosis of the central canal and of the so-called lateral canal. In this area of spinal disorders the use of terminology has remained vague, lacking in precision particularly when applied to descriptions of operative techniques.

The purpose of this paper is to describe the anatomy of the nerve root canals of the lumbar spine, to outline a number of common pathological conditions which may lead to deformity of these canals and of the related intervertebral foramina, and to describe the essential surgical manoeuvres required to decompress them. A series of line drawings, constructed from anatomical specimens and from observations made at operation, illustrate the normal and pathological anatomy and demonstrate the extent of operations to decompress the spinal nerve root canals and intervertebral foramina.

NORMAL ANATOMY

The lumbar nerves run obliquely downwards and laterally from the lateral aspect of the dural sac, emerging at their respective intervertebral foramina lying inferior to the lumbar pedicle in the upper part of the foramen. 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 spaces. It is bounded above and below by the vertebral pedicles. Its floor from above downwards is formed by the postero-inferior margin of the superior vertebral body, the intervertebral disc and the posterosuperior margin of the inferior vertebral body.

Its 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. 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.

The 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 dural sac, the hiatus through which the component motor and sensory nerve roots pass to the spinal nerve has the 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). 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 angles from the sides of the dural sac. The concept of a nerve root canal is of greatest significance in relation to the two lowermost lumbar and first sacral nerves.

In Figure 1 the origin of the 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...
Normal anatomy. Figure 1—A drawing of the normal lumbosacral junction. Note the spinal nerve root canal of S1 outlined in green on the left side of the diagram. The line marked by AA represents the plane of section for drawings illustrated in Figures 3, 6 and 9, which are viewed from within the spinal canal. Figure 2—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. Figure 3—A drawing showing the relations of the S1 spinal nerve root canal viewed from within the spinal canal.

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.

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 lumbosacral angle. From above downwards (Fig. 1) 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. 4). The nerve root is then covered behind by the ligamentum flavum passing downwards to be covered by the anteromedial aspect of the S1 facet (Fig. 2).

In life, epidural fat surrounds the spinal nerve root throughout its course to the intervertebral foramen.

The arterial and venous relations of the spinal nerve root are of great importance (Fig. 2); these have been described and illustrated in detail by Crock and Yoshizawa (1977).

**PATHOLOGICAL ANATOMY**

The normal anatomical relationships described above may be altered by the development of pathological states, in any part of the nerve root canal or the intervertebral foramen, which produce compressive lesions that may cause symptoms. The changes which may occur in four readily recognisable clinical conditions will now be described briefly and the surgical techniques for the relief of the various stenotic lesions will be illustrated.

**Isolated disc resorption.** When the vertical height of the lumbosacral disc space is greatly reduced, as in this condition (Crock 1970), changes occur in the floor and
Isolated disc resorption. Figure 5—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. 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 6—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 7—A drawing showing an oblique view of facets at the L4–5 and L5–S1 levels. Note the facet subluxation which accompanies isolated disc resorption at the lumbosacral junction bringing the apex of the S1 facet into proximity with the pedicle of the fifth lumbar vertebra. The articular surfaces of the facet joints are outlined in blue.

Isolated disc resorption. Figure 8—A drawing showing the restoration of normal neurovascular 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 section of the neural arch of L5 may or may not require excision. The outline of the cut surfaces of bone are shown in stippled green and black. Figure 9—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 through the intervertebral foramen.

The roof of the S1 nerve root canal and also in the L5–S1 intervertebral foramen (Figs 5 and 6). A narrow transverse bulging ridge formed by posterior fibres of the remaining annulus fibrosus and posterior longitudinal ligaments obstructs the floor of the S1 nerve root canal. Coupled with the movement upwards of the S1 facet towards the pedicle of L5 (Fig. 7), 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. 6).

In some cases, hypertrophy of the bony ridge for the upper attachment of the ligamentum flavum 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. 4).

Appreciating these various contributory 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 organised (Figs 8 and 9; see the description by Venner and Crock, page 491 of this issue).
Spondylolysis. The spondyloytic defect found in the lamina of L5, usually in association with spondylolisthesis, may produce bilateral stenosis of the root canals and also stenosis of the intervertebral foramen with involvement of the spinal nerves of both L5 and S1. The pathological anatomy and its surgical solution are illustrated in Figure 10.

Congenital hypertrophy of the S1 facet. Congenital enlargement of the S1 facets may produce stenosis at the L5–S1 intervertebral foramen. The surgical solution is to excise the ligamentum flavum and the medial aspects and apices of the S1 facets (Figs 8 and 9).

Osteoarthritis of the lumbar facets. In advance localised osteoarthritis of the L5–S1 facets, stenosis of the nerve root canal may occur, aggravated by secondary pathological changes in the ligamentum flavum. Again, the surgical solutions to these problems lie in partial facetectomy with particular attention to excision of the medial and apical aspects of the S1 facets and the pathological ligamentum flavum.

DISCUSSION

There have been many important contributions to the literature on spinal stenosis since Verbeist’s descriptions appeared in 1954. Epstein, Epstein and Lavine (1962) published an important paper in which they described the technique of surgical decompression of the lumbar spinal canal. However, in the literature a wide variety of terminology is used to describe the anatomy, pathology and surgical techniques which have been set out in this paper. Terms such as the “hidden zone”, the “lateral recess”, “lateral canal stenosis”, “lateral lumbar nerve root entrapment”, and “wide laminectomy” are commonly used and there is evidently no general agreement on the precise meaning of many of these phrases. For example, in describing radiographs of the lumbar spine after operative failures, the term “wide laminectomy” may cover a bewildering range of surgical assaults on the spinal canal.

Examining the concept of the “lateral recess”, attention is focused on the gutter formed between the back of the vertebral body, the medial wall of the pedicle and the overhanging shelf of the superior articular facet. The use of the term recess in this context implies the description of a walled cavity. Critical examination of the descriptions of anatomy and pathology set out in this present work shows that only the distal segment of an individual spinal nerve root lies in a lateral recess and, further, that the spinal nerve root may be affected by a variety of pathological processes proximal to the inferior pedicle at the intervertebral space—well clear of this “lateral recess”. Similar criticisms apply to the concept of the “hidden zone” (Macnab 1977), the use of which fails to highlight problems which may effect the nerve root (depending on its length) even as high up as the anterior surface of the superior lamina at a particular intervertebral space.

The aim of this paper, therefore, has been to clarify relevant anatomical concepts and to relate the pathological processes which may lead to the development of stenotic lesions in the spinal nerve root canals and lumbar intervertebral foramina to the regional anatomy. On this basis rest the techniques of operations for the relief of stenosis of the nerve root canals. Terminology is proposed, the use of which should lead to a clearer understanding of the disorders under discussion and to precise descriptions of the surgical techniques used in their treatment.

REFERENCES