

ANOMALIES OF THE LUMBOSACRAL NERVE ROOTS

AN ANATOMICAL INVESTIGATION AND MYELOGRAPHIC STUDY

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Lumbosacral nerve root anomalies have been documented in the literature for over 30 years; however, no significant quantitative studies have been undertaken so far. We describe parallel studies of 100 cadaveric specimens and an equal number of metrizamide myelograms. The anatomical specimens were prepared by wide deroofting of the lumbar canal to permit precise examination of individual nerve roots and their intradural and extradural connections. The incidence of nerve root anomalies was 14%, the L5-S1 level being most commonly involved. In sharp contrast the incidence of nerve root anomalies determined by myelography was only 4%. The anomalies were classified into four groups and the diagnostic and practical implications of our findings are discussed.

Lumbosacral nerve root anomalies have been documented in the literature for over 30 years (Zagnoni 1949). Little significance has, however, been attributed to these anomalies because of the paucity of studies and the low incidences reported, ranging from 0.34% to 2.7% (Ethelberg and Riishede 1952; Bonola and Bedeschi 1956; Postacchini, Urso and Ferro 1982). Niedre and Macnab (1983) have stated that anomalous nerve roots should be suspected in all failed operations for disc lesions; this could be very significant for, in the USA, 200 000 patients every year have operations for herniated discs and of these as many as 33% may result in failure (Scarff *et al.* 1981). It is clearly imperative to know the true incidence of nerve root anomalies and the various types; this might improve the success rate of spinal operations considerably. A redefinition of the anatomy of the lumbosacral spine seems to be indicated in the hope of improving diagnosis.

Review of previous studies revealed certain difficulties in diagnosing nerve root anomalies. The majority of reports have been based on operative findings, where the scope of investigation was limited to the particular nerve roots explored (Ethelberg and Riishede 1952; Deyerle and May 1954; Reynolds 1954; Bonola and Bedeschi 1956; McElvenny 1956; Cannon, Hunter and Picaza 1962; Keon-Cohen 1968; Rask 1977; Neidre and Macnab 1983). Other reports have been based on myelography using a water-soluble contrast medium.

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Reports based on both diagnostic methods are biased since only those patients with low back symptoms are normally investigated (Bernini, Wiesel and Rothman 1980; Postacchini *et al.* 1982).

Another method of diagnosing lumbosacral root entrapment advocated by Scarff *et al.* (1981) is the use of dermatomal somatosensory evoked responses. This, however, presupposes a reliable knowledge of the anatomy.

We undertook an anatomical examination of 100 randomly selected human lumbosacral spines, and a parallel review of 100 metrizamide lumbar myelograms; the aim was to assess the adequacy of myelography as a method of diagnosing nerve root anomalies.

MATERIALS AND METHODS

Anatomical study. One hundred cadavers were dissected in the Department of Anatomy of the University of Toronto. There were 59 male cadavers, ranging in age from 53 to 92 years, and 41 female cadavers, ranging in age from 51 to 92 years. The soft tissues were stripped off the spinous processes and laminae on both sides from T10 to the sacrum. The spinous processes were then removed with a Stryker saw so that the laminae on either side could be cut through (also with the Stryker saw) immediately lateral to the spinous processes. This "deroofting" allowed direct visualisation of the contents of the spinal canal. The remainder of the laminae as well as the articular processes were removed using an osteotome, hammer and rongeurs, without damaging the spinal cord or nerve roots. Each nerve root was carefully dissected from its point of emergence from the spinal cord to its passage of exit from the spinal canal through an intervertebral foramen. The exposed segments of cord and nerve roots were examined, after which the dura was incised longitudinally to allow direct visualisation of the

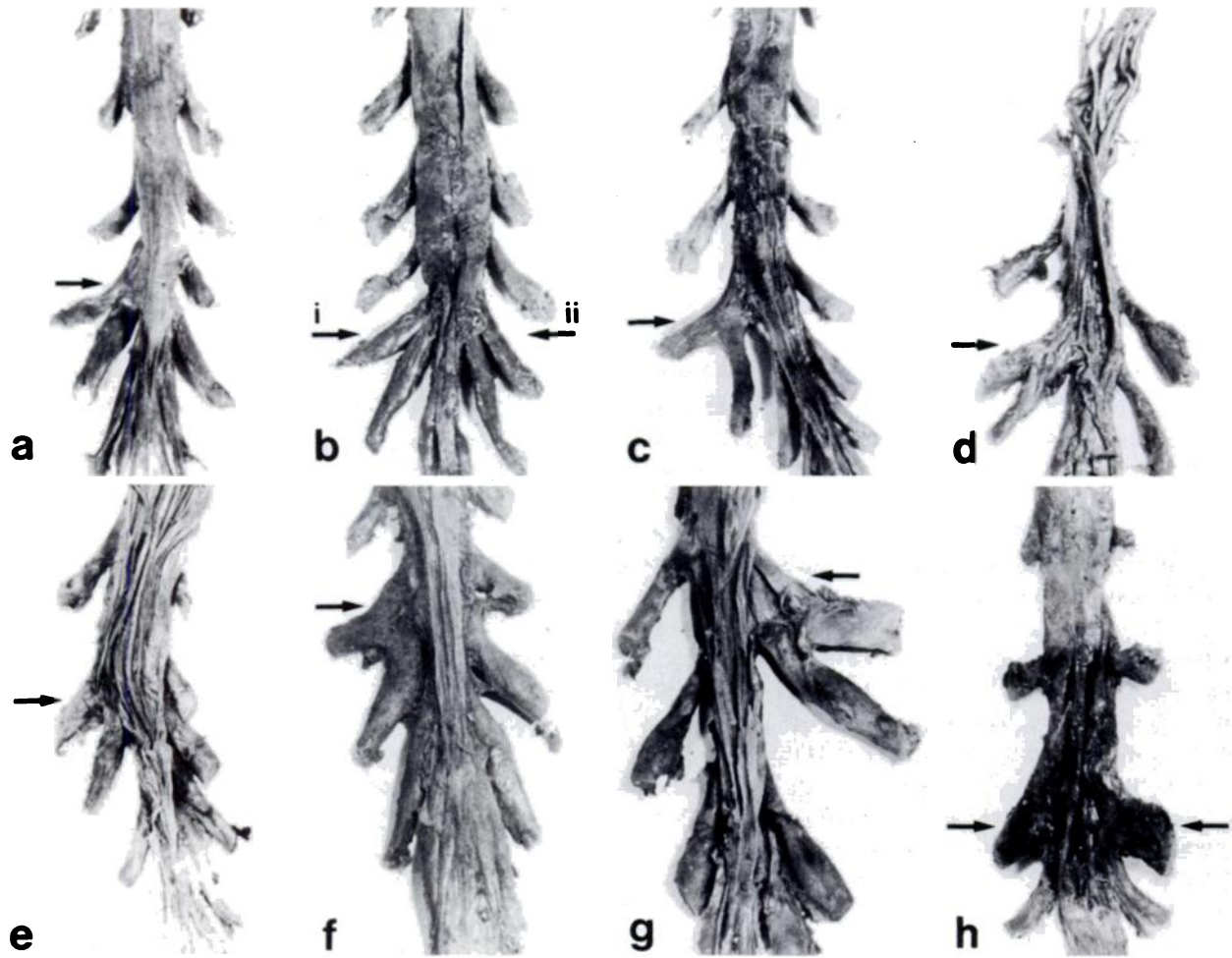


Fig. 1

a, bii—Closely adjacent nerve roots which, on these photographs, appear identical to the conjoined nerve roots, but can be separated on dissection.
bi, c to h—Conjoined nerve roots. *h* shows bilateral conjoined nerve roots arising from the L5-S1 level; these nerve roots remain conjoined and leave the vertebral canal through the S1 neural foramina.

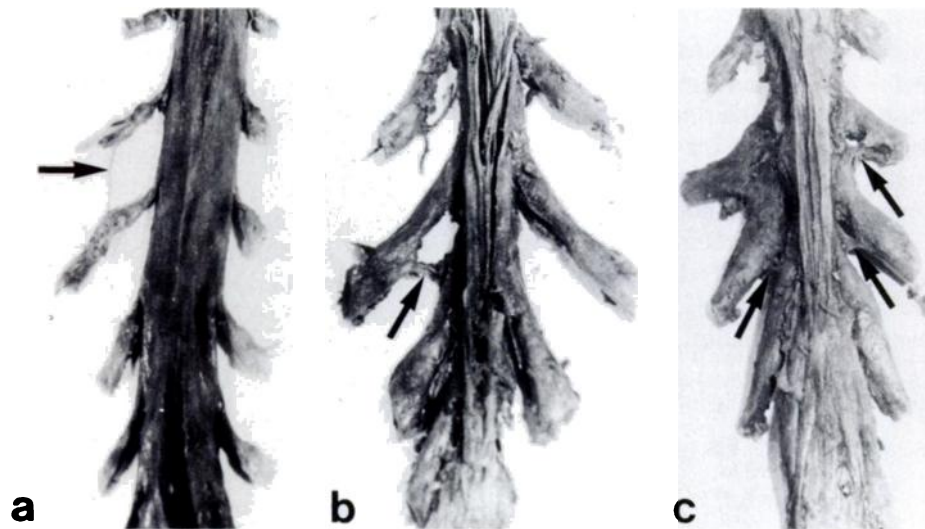


Fig. 2

a and b—Single extradural anastomoses are indicated by arrows. *c*—This specimen shows three extradural anastomoses (arrowed) and a conjoined nerve root.

conus medullaris, cauda equina and spinal nerve rootlets. All intradural and extradural interconnections between nerve roots were excised and examined histologically to determine the presence or absence of neural tissue.

Myelographic study. Metrizamide myelograms of the lumbar spines of 100 patients were reviewed; all had presented at the Toronto East General and Orthopaedic Hospital with low backache, radicular pain or scoliotic spinal deformities during the years 1981 and 1982. This group comprised 68 men, ranging in age from 18 to 80 years, and 32 women, ranging in age from 25 to 71 years. The advantage of water-soluble metrizamide over oil-based contrast media is that it is less viscous and can run further down the subarachnoid root sleeves, thus giving better definition of the nerve roots.

RESULTS

Anatomical study. The anatomical dissections revealed a total of 23 nerve root anomalies in 14 lumbosacral spines (14% incidence). Analysis of the specimens revealed the following. (1) Eight anomalies consisting of conjoined roots (Figs 1bi and 1c to 1h). In all but one of these, the rootlets were found to be contained within a common arachnoid sheath. After following an extradural course of varying length, the roots either separated, each going to its appropriate intervertebral foramen, or remained conjoined and left the vertebral canal through one neural foramen. Six of these examples involved L5-S1 roots. (2) Two anomalies consisting of closely adjacent nerve roots (Figs 1a and 1bii). These adjacent roots were, in fact, adherent to each other and difficult to separate; in these instances, the rootlets were contained in separate arachnoid sheaths. (3) Five extradural anastomoses between nerve roots (Fig. 2). Neural tissue could be identified histologically in only one of these. (4) Eight intradural anastomoses between nerve rootlets (Fig. 3). Histological examination confirmed the presence of neural tissue in seven of these.

The salient characteristics of the nerve root anomalies are summarised in Table I. This demonstrates that the L5-S1 roots are the most frequently involved (52.2%);

Table I. Analysis of lumbosacral nerve root anomalies detected by anatomical dissection

Specimen	Conjoined roots	Closely adjacent roots	Extradural anastomoses	Intradural anastomoses	Neural tissue
1	Left L5-S1				
2	Left L5-S1		Left S1-S2 Right L5-S1 Right S1-S2		Absent Absent Absent
3	Right L5-S1				
4				Left L5-S1 Right L5-S1	Present Present
5				Left L5-S1 Left S1-S2	Absent Present
6				Left L4-L5	Present
7			Left L5-S1		Absent
8	Left S1-S2			Left S2-S3	Present
9	Left L5-S1 Right L5-S1				
10	Left S1-S2	Right S1-S2			
11	Left L5-S1				
12			Left L1-L2		Present
13		Left L5-S1			
14				Left L3-L4 Right S1-S2	Present Present

the S1-S2 level is involved in 30.4% of anomalies. These findings agree with those of Postacchini *et al.* (1982). There was an equal proportion of single and multiple anomalies, with a majority (69.6%) occurring on the left. The most commonly occurring anomalies are those of conjoined roots (a total of eight) and intradural anastomoses (also eight). There was no difference between the male or female specimens.

Myelographic study. In sharp contrast to the findings of anatomical dissection, the myelograms revealed only four examples of anomalous nerve roots. These consisted of the following; (1) two conjoined roots, one located at the left S1-S2 level (Fig. 4), and the other at the right S1-S2

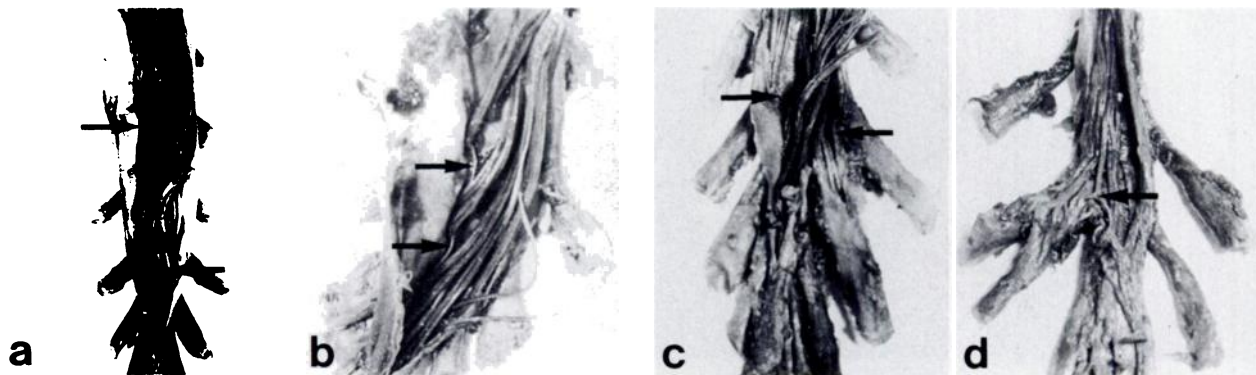


Fig. 3

a, b and c—Two intradural anastomoses are indicated in each. d—One intradural anastomosis was found at the base of a conjoined root in this specimen.

level (Fig. 5); and (2) two closely adjacent roots, one located at the left L5-S1 level (Fig. 6), and the other at the left S1-S2 level (Fig. 7).

DISCUSSION

The present study has demonstrated that anomalies of lumbosacral nerve roots occur in a significant proportion (14%) of the general population. This incidence contrasts markedly with that in previous reports (Ethelberg and Riishede 1952; Bonola and Bedeschi 1956; Postacchini *et al.* 1982). The incidence of anomalies in our anatomical studies differs dramatically from that in our myelographic studies (14% versus 4% respectively). There are two possible reasons for this. First, most of the conjoined roots dissected revealed the abnormal cluster of rootlets to be very tightly ensheathed by the arachnoid sleeve. The difficulty in dissecting these rootlets leads one to doubt the likelihood of any contrast medium flowing freely through the anomalous sleeves. Secondly, the low incidence of extradural anastomoses detected by metrizamide myelography may derive both from difficulties in interpretation as well as from shortcomings in technique.

Based on the results of this study and previous reports in the literature, we have classified four types of anomalies.

Type I. Intradural anastomosis between rootlets at different levels (Fig. 8).

Type II: Anomalous origin of nerve roots (Fig. 9): (a) cranial origin; (b) caudal origin; (c) combination of (a) and (b) affecting more than one nerve root (closely adjacent roots); and (d) conjoined nerve roots.

Type III. Extradural anastomosis between nerve roots (Fig. 10).

Type IV. Extradural division of the nerve root (Fig. 11). The anomalous roots involved in Types II, III and IV may or may not leave the vertebral canal through their appropriate intervertebral foramina.

Our results appear to have wide implications. The high incidence of nerve root anomalies may require a redefinition of the anatomy of the lumbosacral spine. Confirmation of the presence of anastomoses between different levels clearly dispels any notion of the existence of "absolute innervation".

Nerve root anomalies may cause symptoms at more than one level as a result of pressure by, for example, a herniated intervertebral disc. Pressure on an abnormally situated nerve root may also give an incorrect indication of the level of disc herniation. A number of authors have reported cases of anomalous nerve roots in patients presenting with symptoms of intervertebral disc herniation, but in whom no obvious disc pathology was found at operation (Ethelberg and Riishede 1952; Cannon *et al.* 1962; Keon-Cohen 1968; Rask 1977); the results of decompression were poor, only a few patients being relieved of their symptoms. Two reasons have been

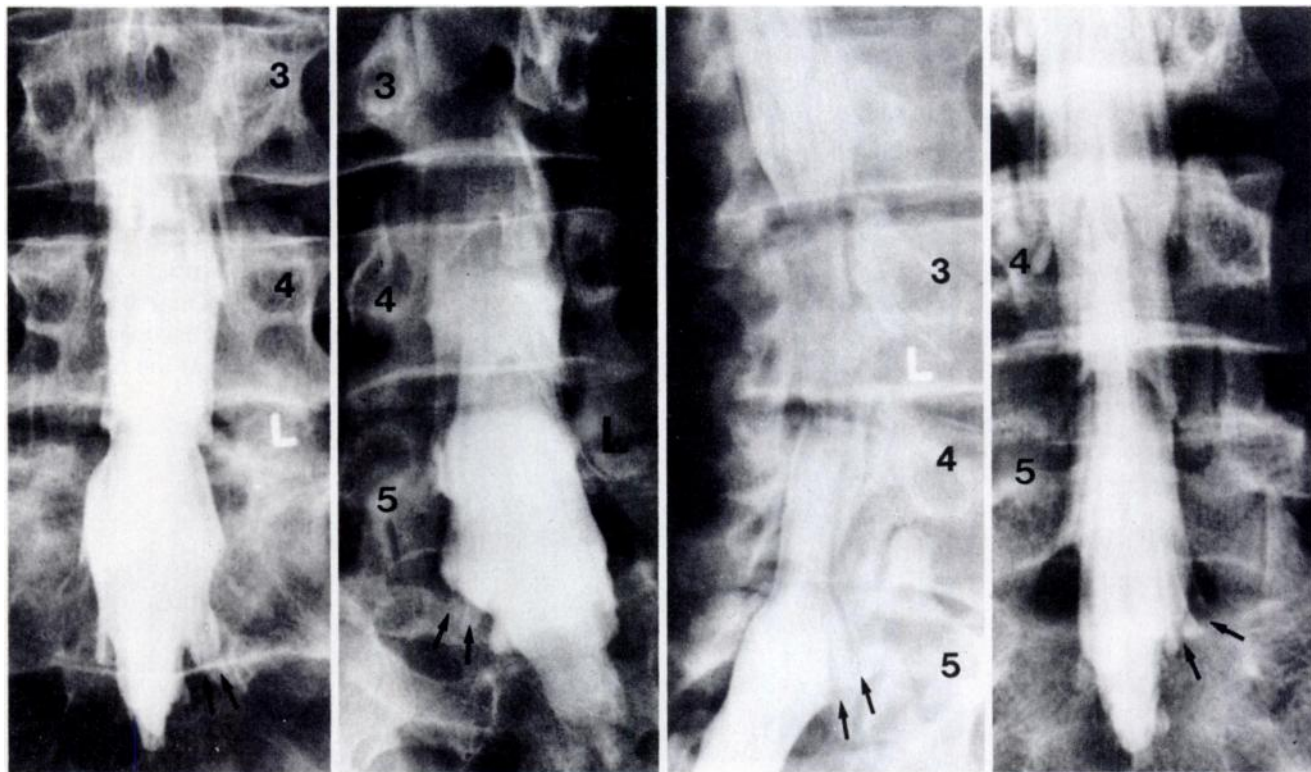


Fig. 4

Fig. 5

Fig. 6

Fig. 7

Radiographs of the lumbosacral spine showing nerve root anomalies. Figure 4—A conjoined root on left side at S1-S2. Figure 5—A conjoined root on the right side at S1-S2. Figure 6—Closely adjacent roots on the left side at L5-S1. Figure 7—Closely adjacent roots on the left side at S1-S2.

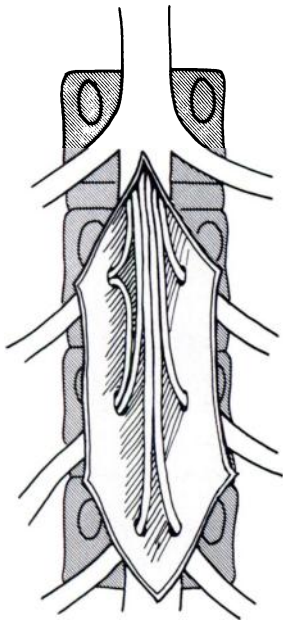


Fig. 8 (Type I)

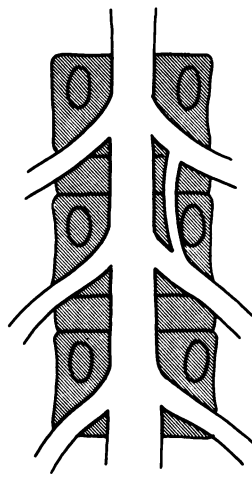
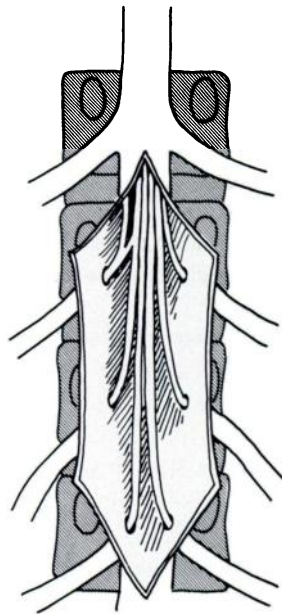
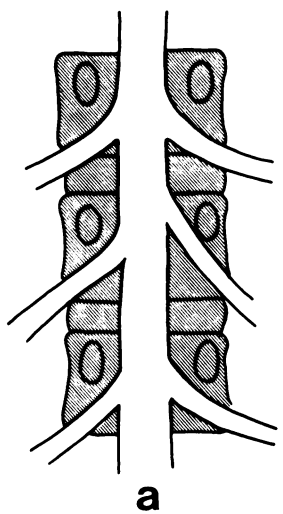
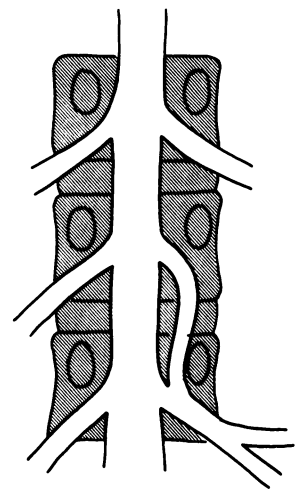
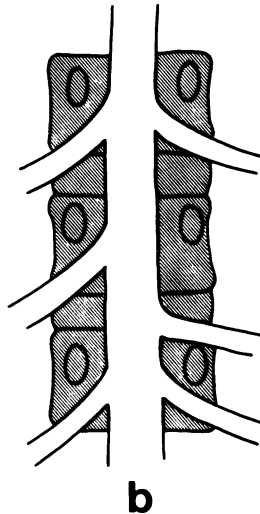


Fig. 10 (Type III)



a



b

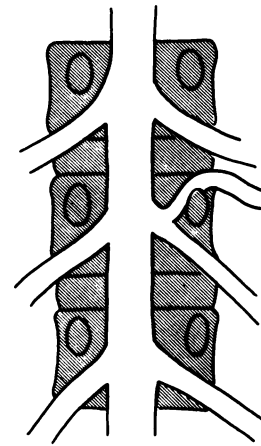
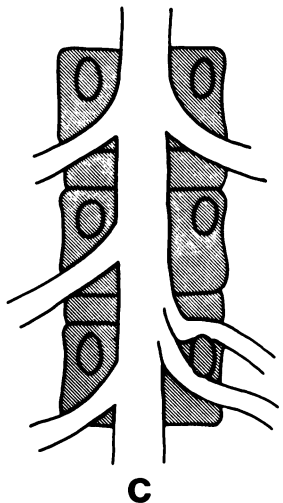
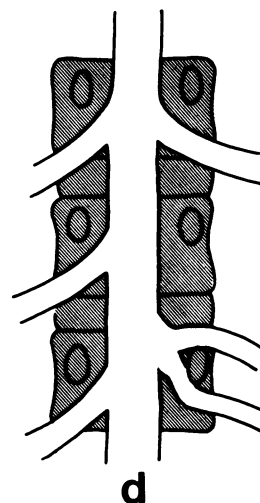


Fig. 11 (Type IV)



c



d

Fig. 9 (Type II)

Diagrams illustrating lumbosacral nerve root anomalies.

Figure 8—Type I: intradural anastomosis.

Figure 9—Type II: (a) cranial origin, (b) caudal origin, (c) closely adjacent nerve roots; (d) conjoined nerve roots.

Figure 10—Type III: extradural anastomosis.

Figure 11—Type IV: extradural division.

postulated: (1) the anomalies themselves may somehow cause pain; and (2) the anomalous roots occupy most of the space in the vertebral canal so that even slight bulging of an intervertebral disc or swelling of a root may cause symptoms. Transfeldt and Simmons (1982) showed how mobile the spinal cord was during normal flexion and extension; this suggests that traction symptoms could be created in anomalous roots even with normal movements of the spine. All surgeons operating on the spine should

be aware of these anomalies; awareness may prevent traction injuries to the roots. Reynolds (1954) has shown that sectioning some of these anomalous roots may result in irreversible motor and sensory loss.

Our study emphasises the need for research into better techniques for diagnosing nerve root abnormalities; and, with an incidence as high as 14%, we are bound to ask whether we have been looking at true anomalies or merely at variations of the normal.

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