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The human lumbar dorsal rami

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INTRODUCTION

Over the past decade there has been a renewed interest in disorders of structures supplied by the lumbar dorsal rami as possible causes of low back pain. Textbooks of anatomy give only abridged descriptions of these nerves (Cruveilhier, 1877; Testut, 1905; Hovelacque, 1927; Lockhart, Hamilton & Fyfe, 1965; Cunningham, 1972; Gray, 1973). There have been previous studies of the lumbar dorsal rami, but each has focused only on particular aspects, usually the innervation of the zygapophysial joints (Pedersen, Blunck & Gardiner, 1956; Lazorthes & Juskiewenski, 1964; Lewin, Moffett & Vildik, 1962; Bradley, 1974) or the cutaneous distribution of the lateral branches (Johnston, 1908; Etemadi, 1963).

This study was undertaken to provide a comprehensive description of the lumbar dorsal rami and to relate their anatomy to the interpretation and therapy of low back pain.

METHODS

The lumbar dorsal rami and their branches were studied in four adult embalmed cadavers and in two postmortem cadavers. From the post mortem specimens, the lumbar vertebral columns and surrounding muscles were excised *en bloc* about 10 hours after death and fixed by immersion in 10 % formalin. The nerves were dissected with the aid of a ×40 dissecting microscope.

In the embalmed specimens, the lateral branches were identified where they pierced the dorsal layer of thoracolumbar fascia. They were traced distally into the skin of the buttock. Proximally they were traced through the erector spinae to their origin from the dorsal rami. During this process the muscles were carefully resected fibre by fibre to preserve any intramuscular branches. Medial branches were traced from their origin, distally into the multifidus. When searching for articular branches, the medial branches were traced meticulously under the microscope and the multifidus was resected, as necessary, to allow access to the nerves. At other times the muscular distribution to the multifidus was specifically studied, using a method which did not necessarily preserve articular branches. This method involved resecting from the field all the fascicles of multifidus attached to a given spinous process, and then determining which medial branches had been cut during the resection, and which had been preserved.

In the post mortem specimens, the dorsal rami were dissected by way of a ventral approach. The ventral rami were traced back to their origin and the spinal nerves

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were identified. The dorsal rami and their branches were then traced distally. This approach allowed the branches arising in the intertransverse space to be studied accurately. As well, the specimens were divided along a sagittal plane and a search was made for articular branches to the ventral aspects of the zygapophysial joints, dissecting the intervertebral foramen by way of a combined lateral and medial approach.

There was no doubt that the major branches of the dorsal rami were indeed neural structures because of their clear continuity with the spinal nerves. To establish this for the putative articular branches, segments of these nerves were excised from post mortem specimens and submitted to histological examination.

Tissue samples were rinsed in 0·1 M cacodylate buffer (pH 7·4), fixed in 1 % osmium tetroxide, rinsed in cacodylate buffer, dehydrated in alcohol and 1, 2 epoxypropane, and embedded in Araldite. Transverse sections were cut at 1–2 μm, stained with 1 % toluidine blue in 1 % borax solution, and examined under the light microscope.

To establish that the dissectable articular nerves were indeed continuous with intracapsular nerve fibres, blocks of tissue including the joint capsule and periarticular tissue were removed from the post mortem specimens. These blocks were free of bone, to avoid the need for decalcification, and were obtained in the following way: The superficial fibres of multifidus were resected to expose the dorsal aspects of two consecutive zygapophysial joints, and the longissimus was resected to expose their lateral aspects. The periosteum of the articular processes and the dorsal joint capsule were incised transversely across the middle of each joint. Starting at the spinous processes and interspinous ligament, the periosteum and remaining fibres of multifidus were elevated from their attachment to bone. This stripping was continued laterally across the lamina and the inferior articular processes. Stripping the periosteum from the articular processes also elevated the medial capsular attachment. Starting at the root of each superior articular process, the periosteum was elevated and the stripping was extended medially until the remaining lateral capsular attachment was detached. Between the two joints, the periosteum was stripped as far as the lateral edge of the lamina and ultimately was incised along this edge. All the soft tissue between the two initial transverse incisions was then free to be lifted out of the specimen, leaving only a naked vertebral lamina and the caudal and rostral halves of two consecutive zygapophysial joints. The tissue sample contained the respective caudal and rostral half capsules and all the fat, deep fibres of multifidus, and nerves which lay between two joints.

The sample was embedded in ice, and using a freezing microtome, sections were cut at 100–300 μm along a coronal plane. They were then stained with silver, using the technique of Schofield (Carleton, 1967), and examined under the light microscope.

RESULTS

The anatomy of the L 1–4 dorsal rami is different from that of the L 5. Therefore, these levels are described separately below.

L 1–4 *dorsal rami*

The L 1–4 dorsal rami projected at almost a right angle to the spinal nerve. Each was only about 5 mm long, and ran dorsocaudally through the intertransverse space, deep to the intertransversarii mediales. In the intertransverse space each divided into 2 or 3 branches.

When there were three branches they were termed the medial, lateral and inter-

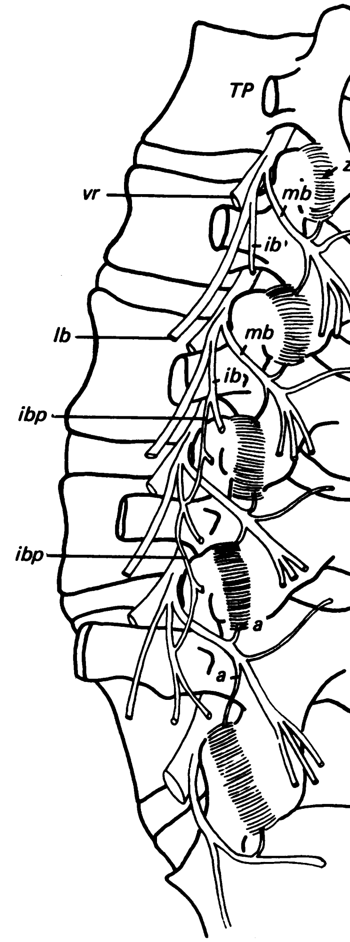


Fig. 1. A diagrammatic representation of a dorsolateral view of the left dorsal rami and their branches. Only the proximal portion of the branches is shown. More distally, they enter and supply the back muscles. The muscular distribution of the medial branches is shown in Fig. 8. *TP*, transverse process; *zJ*, zygapophysial joint; *vr*, ventral ramus; *lb*, lateral branch; *ib*, intermediate branch; *mb*, medial branch; *ibp*; intermediate branch plexus; *a*, articular branch; *is*, interspinous branch.

mediate (Figs. 1, 2A). When two arose, there was a medial branch and a short common stem for the lateral and intermediate branches (Figs. 1, 2B). Triple branching was the rule at the L 4 level, and the predominant pattern at L 3 (Fig. 3). Double branching predominated at L 1 and L 2 but triple branching also occurred (Fig. 3).

The lateral branches crossed the subadjacent transverse process approximately opposite the level of the accessory process, and pursued a sinuous course caudally, laterally and dorsally through the iliocostalis lumborum. They innervated that muscle and eventually the L 1–3 branches emerged from its dorsolateral surface, pierced the dorsal layer of thoracolumbar fascia and became cutaneous. The L 4 lateral branch remained entirely intramuscular. The L 1 and 2 lateral branches crossed the iliac crest in the subcutaneous tissue in parallel with the T 12 cutaneous branch. The L 3 lateral branch was bound down to the iliac crest by a bridge of connective tissue just lateral to the origin of iliocostalis lumborum.

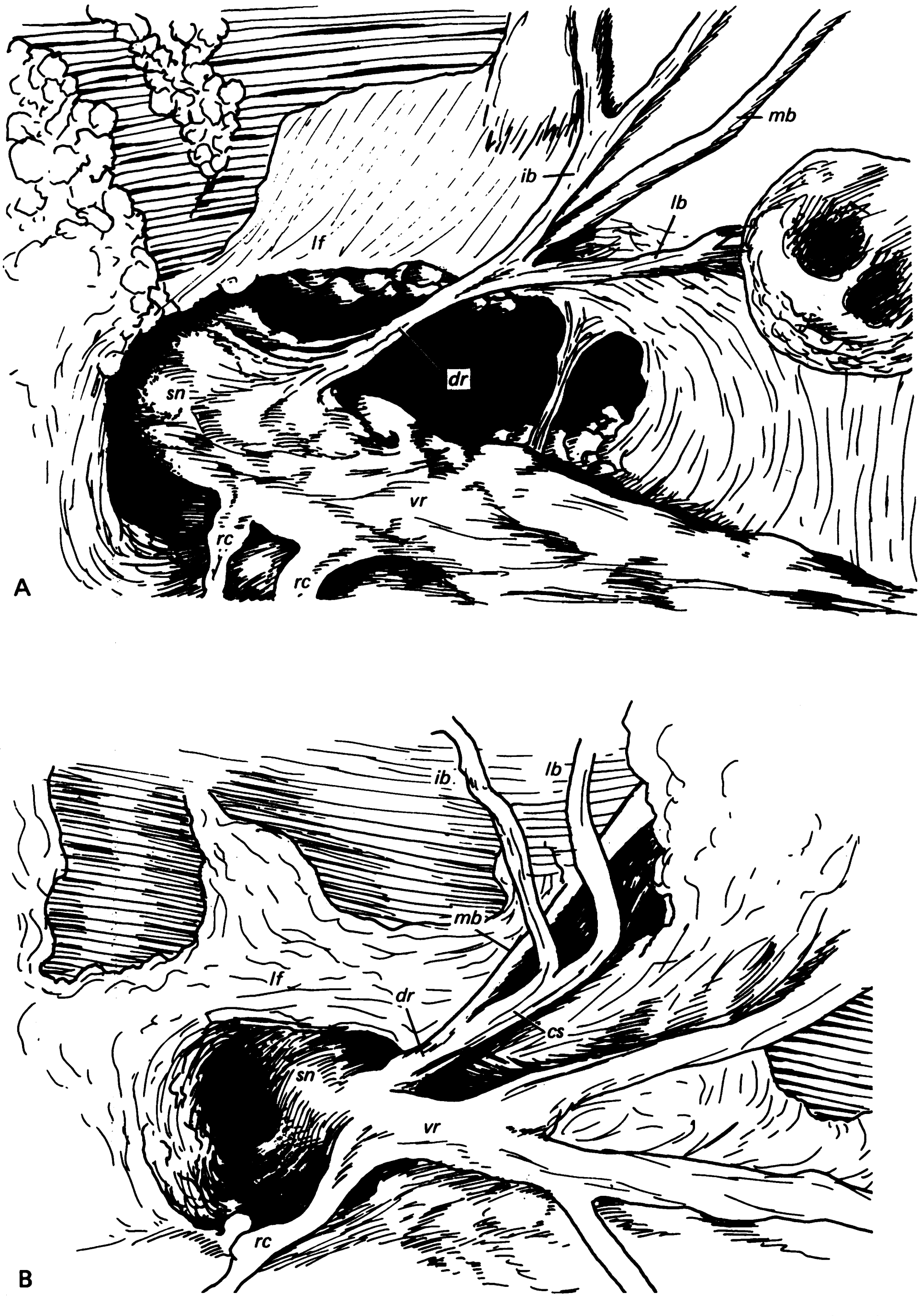


Fig. 2. Branching patterns of lumbar dorsal rami. (A) Close up lateral view of a left L4 dorsal ramus showing triple branching. (B) Close up lateral view of a left L1 dorsal ramus showing double branching. *sn*, spinal nerve; *vr*, ventral ramus; *rc*, rami communicantes; *dr*, dorsal ramus; *mb*, medial branch; *cs*, common stem for lateral and intermediate branches; *ib*, intermediate branch; *lb*, lateral branch; *lf*, ligamentum flavum.

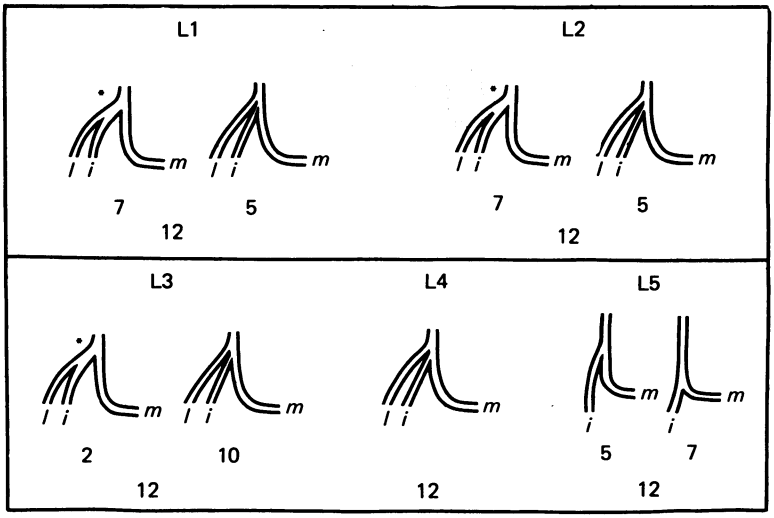


Fig. 3. Schematic illustration of the branching patterns of the lumbar dorsal rami. The numerals indicate the number of specimens showing the illustrated pattern, and the total number of specimens studied, at each level from L 1 to L 5. The medial branch (*m*) was always a separate branch. The intermediate (*i*) and lateral (*l*) branches arose from the dorsal ramus either separately or from a common stem (*). The lengths of the common stems were: at L 1: 1, 3, 3, 4, 4, 6, and 8 mm; at L 2; 2, 2, 2, 4, 4, 6, 7 mm; and at L 3: 1 and 2 mm.

The intermediate branches ran dorsally and caudally from the intertransverse spaces and were distributed to the lumbar fibres of longissimus thoracis. Within longissimus the L 2–4 intermediate branches formed intersegmental communicating loops from which the muscle was innervated (Figs. 1, 4). This feature was found in four of the six specimens studied. In one specimen the L 3 branch also contributed to the communicating loops (Fig. 4B).

At, or just proximal to the origin of the medial branch, each dorsal ramus gave off a tiny branch to the intertransversarii mediales (Fig. 5). This branch arose from the most medial funiculi of the dorsal ramus and so had the appearance of being an early branch of the medial branch of the dorsal ramus.

Each definitive medial branch passed dorsally and caudally through the intertransverse space towards the superior border of the root of the subadjacent transverse process. From there it continued dorsally and caudally, lying against the groove formed by the junction of the root of the transverse process with the root of the superior articular process (Fig. 6A). In this region the nerve, with its companion artery, was bound to the periosteum by a layer of connective tissue which coated the superior articular process and transverse process.

Opposite the caudal border of the zygapophysial joint the medial branch turned medially through a groove between the mamillary process and accessory process (Fig. 6A). The nerve was held in the groove by the mamillo-accessory ligament (Bogduk, 1981 *a*) which bridged these two processes (Fig. 6B). Beyond the mamillo-accessory ligament the medial branch ran medially and caudally across the vertebral lamina. It lay deep to multifidus and was embedded in loose areolar and adipose tissue. In this region articular branches to the zygapophysial joints and an interspinous branch arose.

Proximal zygapophysial nerves passed to the rostrally related joint and innervated

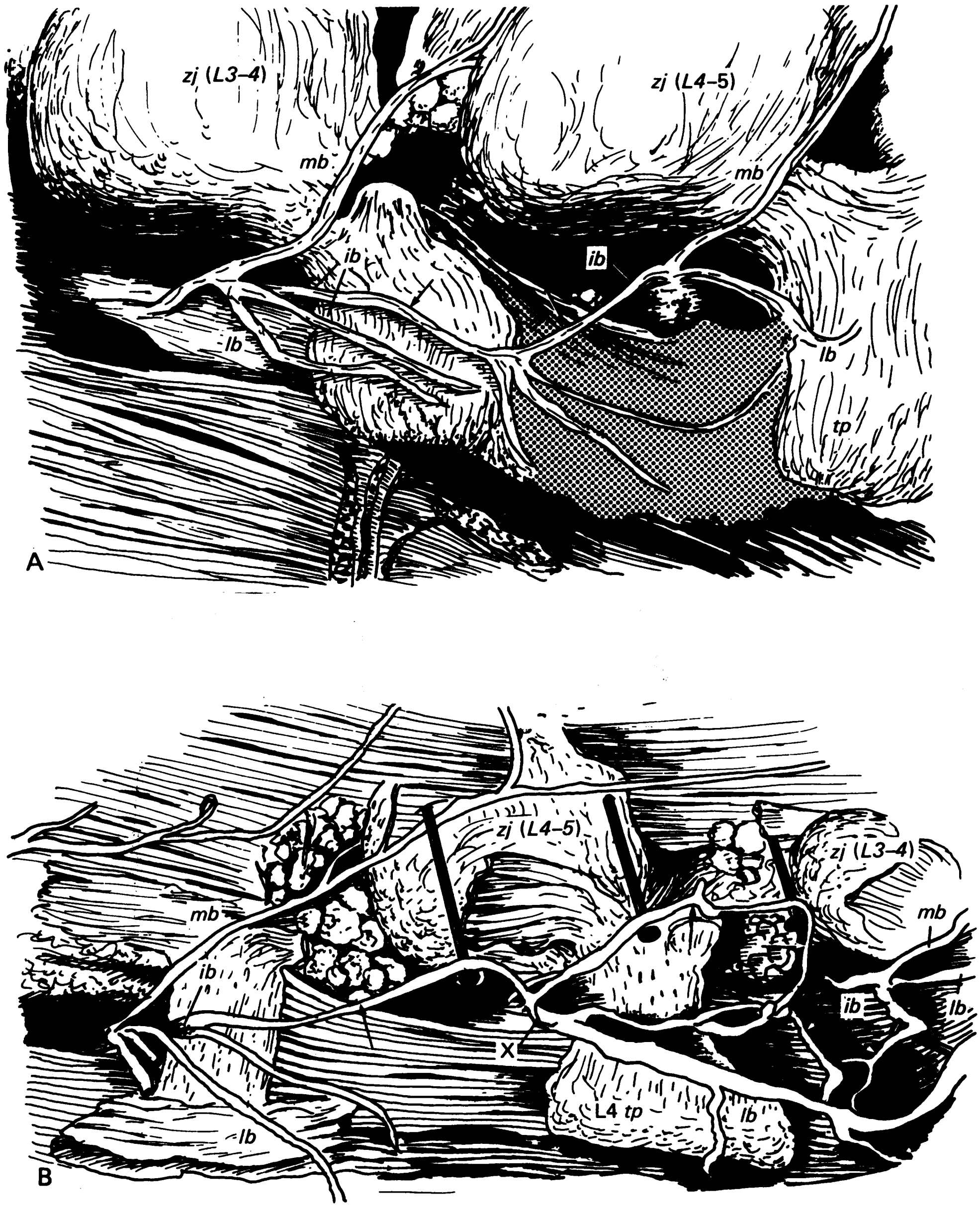


Fig. 4. The intermediate branch plexus. (A) A communicating loop (arrowed) between L 3 and L 4 intermediate branches. (B) Communicating loops (arrowed), (lifted on pins) between L 2, 3, and 4 intermediate branches, with an additional contribution (X) from the L 3 lateral branch. *zj*, zygapophysial joint; *tp*, transverse process; *mb*, medial branch; *lb*, lateral branch; *ib*, intermediate branch.

it from its caudal aspect (Fig. 1, 7). Distal zygapophysial nerves innervated the caudally related joint from its rostral aspect (Figs. 1, 7). The proximal zygapophysial nerves approached the joint in the plane between the intertransversarii and the most lateral fibres of multifidus. The distal zygapophysial nerves ran deep to the fibres of multifidus which covered the zygapophysial joint. The interspinous branch

Fig. 5. The nerve to intertransversarii mediales (*nim*) seen arising from the medial fasciculi of the dorsal ramus (*dr*) and entering the deep surface of the intertransversarii mediales (*IM*). (Key as in Fig. 2).

(Figs. 1, 8) left the medial branch, and wove medially between the fascicles of multifidus to innervate the interspinous muscle and ligament.

The medial branch ultimately entered the multifidus muscle via its deep surface. Only certain fascicles of multifidus were innervated by a given medial branch: those which attached to the spinous process bearing the same segmental number as the medial branch (Fig. 8). The medial branch broke up into a separate division for each fascicle which it innervated. Each division continued longitudinally within its own particular fascicle and at no time were these end branches found to leave their own or to communicate with other fascicles.

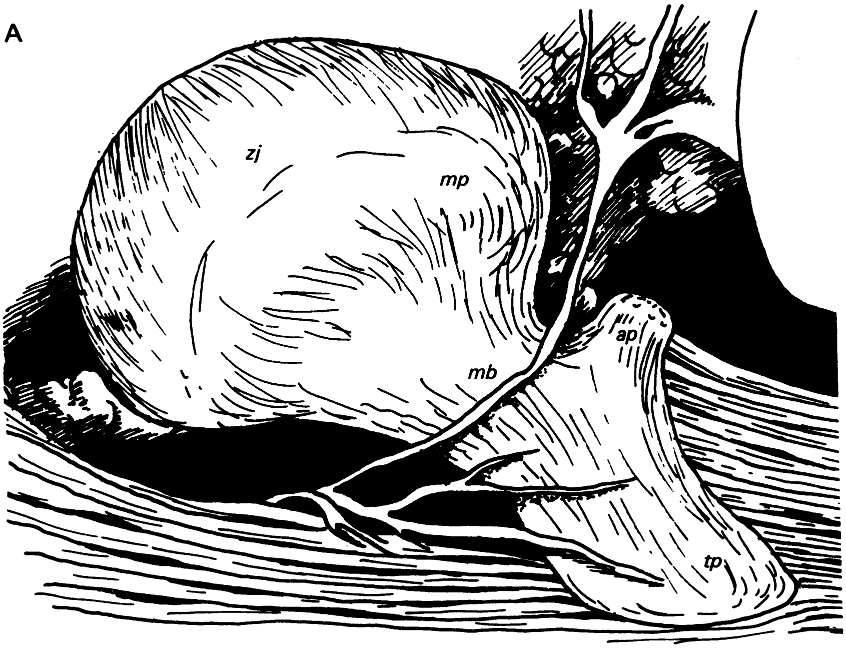
L 5 dorsal ramus

The L 5 dorsal ramus was longer than those at higher levels. Having arisen from the spinal nerve it arched over the rostral and dorsal aspect of the ala of the sacrum, lying in the groove formed by the junction of the ala with the root of the superior articular process of the sacrum. Along this course it divided into two branches – a medial and an intermediate (Fig. 9). It lacked a lateral branch. The division occurred either opposite the caudal border of the L 5–S 1 zygapophysial joint or slightly more proximally (Fig. 3). The intermediate branch innervated those fibres of longissimus thoracis which arose from the medial aspect of the dorsal segment of the iliac crest, and communicated with the S 1 dorsal ramus. The medial branch curved medially around the caudal aspect of the lumbosacral zygapophysial joint, which it innervated, and ended in multifidus.

Articular nerves

Four putative articular branches were excised and examined microscopically to confirm their neural origin. In the transverse sections, despite early autolytic changes

A



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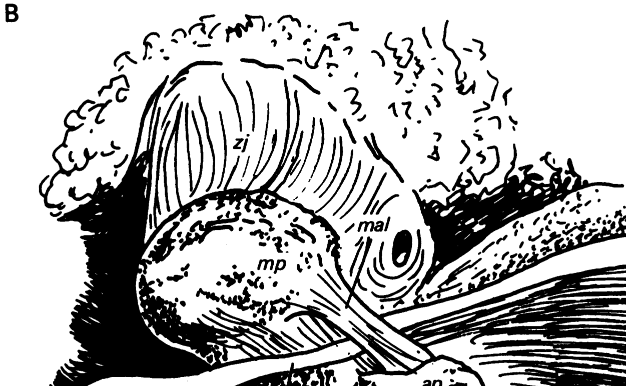

Fig. 6. A left dorsolateral view of the proximal part of the course of the medial branch. In (A) the medial branch is seen crossing the root of the transverse process. In (B) the mamillo-accessory ligament has been left *in situ* to show how it binds the medial branch in the mamillo-accessory notch. *zj*, zygapophysial joint; *tp*, transverse process; *mp*, mamillary process; *mal*, mamillo-accessory ligament; *mb*, medial branch; *ap*, accessory process.

Fig. 7. The articular branches of the medial branch (c.f. Fig. 1 for orientation) A suture has been looped around the L 3 medial branch. *mb*, medial branch; *pzn*, proximal zygapophysial nerve; *dzn*, distal zygapophysial nerve; *is*, origin of branch to interspinales; *zj*, zygapophysial joint.

in the axons, the nerves were identifiable on the basis of distinct epineurial sheaths and Schwann cell nuclei.

In the frozen sections, the medial branch could be traced through the connective tissue surrounding the zygapophysial joint. Nerve fibres were confirmed to leave the medial branch and enter the joint capsules in the manner revealed by dissection.

Articular branches were identified entering only the rostral and caudal aspects of the zygapophysial joints. Ventrally, where the ligamentum flavum formed the joint capsule, no articular branches could be identified. The space between the joint and the spinal nerve was filled with large lobules of adipose tissue and a little connective tissue. This tissue was so readily resectable that any nerves transversing it would not have been injured in the process.

DISCUSSION

Although at variance with traditional descriptions (Gray, 1973; Cunningham, 1972; Hovelacque, 1927; Lockart *et al.* 1965; Testut, 1905; Cruveilhier, 1877), the formation of three branches by the L 1–4 dorsal rami, as described here, is not surprising. Triple branching is the pattern observed in the cat (Bogduk, 1976*a*; Carlson, 1978),

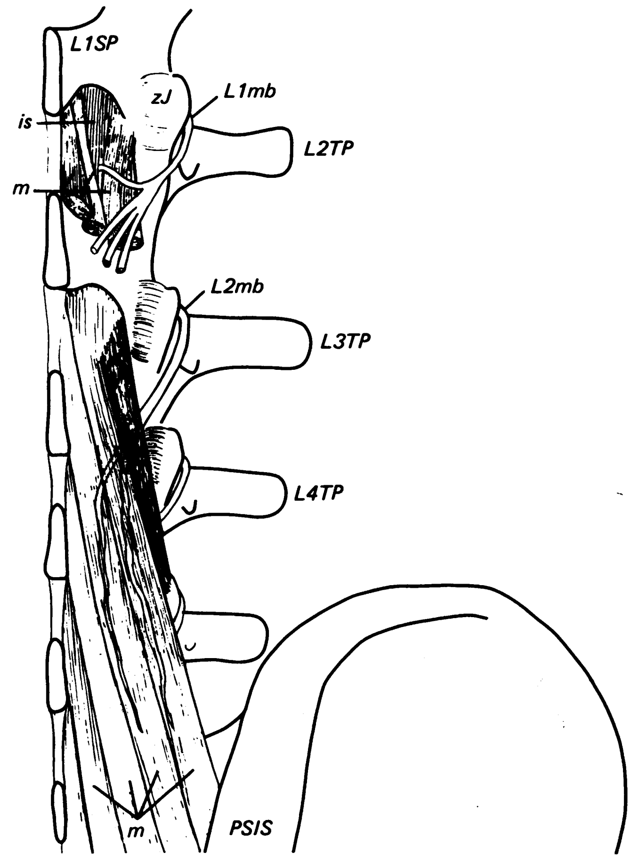

Fig. 8. A graphic illustration of a dissection showing the muscular distribution of lumbar medial branches. The fasciculi of multifidus which attached to the L 1 spinous process were transected and removed from the field. Branches to these fasciculi from the L 1 medial branch had to be cut during this procedure. The L 1–2 interspinalis remained intact as did its nerve supply. The L 2 medial branch remained intact and was distributed to those fasciculi of multifidus attaching to the L 2 spinous process. Further dissection revealed a repetition of this pattern of distribution for the remaining lumbar medial branches. *PSIS*, posterior superior iliac spine; *SP*, spinous process; *TP*, transverse process; *zJ*, zygapophysial joint; *m*, fascicles of multifidus; *is*, interspinalis; *mb*, medial branch.

and monkey and dog (Bogduk, 1974). The lateral, intermediate and medial branches are specifically distributed to the iliocostalis, longissimus and multifidus, respectively. This separation of nerve supply is consistent with the embryological cleavage of the primitive back muscles into three divisions (Winckler, 1948). Furthermore, it complements the morphological segregation of the lumbar fibres of iliocostalis and longissimus by the lumbar intermuscular aponeurosis (Bogduk, 1980*a*). It is most likely that, in the past, the intermediate branches have been regarded simply as muscular branches of the lateral branches. However, close dissection reveals their separate origin from the dorsal rami or from a short common stem with the lateral branch. Moreover, their exclusive distribution to the lumbar fibres of longissimus warrants their distinction as a separate named branch.

The absence of a lateral branch at L 5 is also not surprising because the iliocostalis does not attach to the fifth lumbar vertebra, only the first to the fourth (Bogduk,

Fig. 9. A dorsal view of a left L 5 dorsal ramus. The ilium was resected to reveal the ramus as it crossed the ala of the sacrum. *zJ*, zygapophysial joint; *I*, ilium; *S1*, S 1 dorsal foramen and ramus; *dr*, L 5 dorsal ramus; *ib*, intermediate branch; *mb*, medial branch.

1980*a*) and its origin lies rostral to the caudally running L 5 dorsal ramus. This is comparable to the lack of an L 7 lateral branch in the cat (Bogduk, 1976*a*) and monkey and dog (Bogduk, 1974). The intermediate branch of the L 5 dorsal ramus was so named in the present study because it, like the intermediate branches at more rostral levels, exclusively innervated the longissimus.

There was no discrepancy between the present and previous studies (Johnston, 1908; Etemadi, 1963) in the description of the lateral branches of the lumbar dorsal rami. The intermediate branch plexus within the lumbar fibres of longissimus has not been described previously although it was illustrated by Bradley (1974).

A clinical application of the anatomy of the lateral branches relates to the operation of 'rhizolysis' (Rees, 1971, 1975; Toakley, 1973; Brenner, 1973; Houston, 1975; Bogduk, Colman & Winer, 1977; Fuentes, 1978; Collier, 1979). In this procedure, parasagittal incisions are made percutaneously through the erector spinae as a treatment for low back pain. Because the lateral branches course obliquely through erector spinae they are liable to transection by such incisions. At the L 4–L 5 level the only effect of transection would be denervation of iliocostalis. However, at upper lumbar levels the cutaneous fibres of the L 1–3 lateral branches could be incised. The risk of producing numbness or even anaesthesia dolorosa over the buttock, or causing neuromata in the proximal ends of the cut nerves should, therefore, be realised (Bogduk, 1981*b*).

Maigne (Maigne, 1972, 1974; Maigne, Le Corre & Judet, 1978) has written extensively on the significance of tenderness at the points where the lumbar lateral branches cross the iliac crest. He reports finding cellular infiltrates about the nerves at these sites in patients with upper lumbar zygapophysial joint disorders, but detailed histological reports of this phenomenon are lacking.

The source of innervation of the lumbar intertransversarii mediales has not been specified in the past. Because of its origin from the medial funiculi of the dorsal ramus, the human nerve to intertransversarii is comparable to the same nerve in the cat (Bogduk, 1976*a*) in which it is a branch of the medial branch. The medial origin of their nerve supply justified the inclusion of the lumbar intertransversarii mediales into the medial muscular group along with multifidus.

The constancy of the course of the L 1–4 medial branches across the roots of the transverse processes has been noted by others (Bradley, 1974; Pedersen *et al.* 1956; Lazorthes & Juskiewenski, 1964; Sunderland, 1978; Fox & Rizzoli, 1973) and this anatomical fact has allowed the development of accurate percutaneous techniques whereby conduction along these nerves may be interrupted as a treatment for low back pain (Bogduk & Long, 1979, 1980). One of the factors contributing to this constant course is the binding of the medial branch by the mamillo-accessory ligament. Although not described in major textbooks (Gray, 1973; Cunningham, 1972) this ligament has been noted previously (Pedersen *et al.* 1956; Lazorthes & Juskiewenski, 1964; Bradley, 1974; Bogduk, 1976*b*; Sunderland, 1978; Ninghsia Medical College, 1978) and its morphology and significance are discussed elsewhere (Ninghsia Medical College, 1978; Bogduk, 1981*a*).

A variety of articular nerves to the zygophysial joints have been described in the past. Pedersen *et al.* (1956) described only one type of articular nerve, which corresponded to the proximal zygapophysial nerves of the present study. Their study is the most often quoted in the literature and has been incorporated into Hollinshead's textbook (1969). Stillwell (1956) described, in the monkey, an additional set of articular nerves to the joint below the medial branch: the distal zygapophysial nerves of the present study. A similar dual innervation of human zygapophysial joints was subsequently described by Lewin *et al.* (1962), Bradley (1974), Sunderland (1978) and Lazorthes & Juskiewenski (1964). Lazorthes & Juskiewenski, however, also mentioned branches to the ventral capsule from the dorsal ramus proper, and Emminger (1972) illustrated an example of multiple filaments radiating to the joint from a dorsal root ganglion. No such nerves were found in the present study. The space ventral to the joint was remarkably free of articular nerves. The branch illustrated by Lazorthes & Juskiewenski (1964) strikingly resembles that which, in the present study, was found to be the nerve to the intertransversarii mediales.

The significance of clarifying the pattern of innervation of the lumbar zygapophysial joints is that it is integral to the rationale of denervating these joints in the treatment of low back pain. Since articular branches arise only from the medial branches of the dorsal rami, these latter nerves are appropriate target points for percutaneous denervation techniques (Bogduk & Long, 1979, 1980; Oudenhoven, 1974, 1979).

It has been held that the lumbar medial branches from different levels freely 'anastomose' within multifidus (Edgar & Ghadially, 1976; Pedersen *et al.* 1956). Such an 'anastomosis' was not observed in the present study. Each medial branch remained wholly within the fascicles of multifidus which it entered, and only those muscle fibres attaching to the vertebra of the same number as the nerve were innervated. This applied to the intertransversarii mediales and interspinales as well as the multifidus.

Johnston's paper (1908) was quoted by Pedersen *et al.* (1956) as attesting to the anastomosis between medial branches. However, it is notable that Johnston's description specifically related to thoracic levels and not to lumbar levels. The confirmation of anastomoses by Pedersen *et al.* (1956) themselves was based on studies of serial sections of embryos. It may have been that this technique did not allow recognition of the specific fascicles of multifidus innervated by given medial branches and so the pattern described in the present study was not observed. It is understandable that without careful inspection the medial branches may appear to overlap within multifidus, for the muscle fascicles from different levels themselves overlap considerably. But if the fascicles from a single spinous process are identified then their nerve supply is found to be unisegmental.

This myotomal pattern of innervation is comparable to that found in the cat, where electrical stimulation of individual medial branches causes distinct and predictable bands of multifidus to contract (Carlson, 1978; Bogduk, 1980*b*). Each band is relatable to those fibres radiating from the spinous process of the same number as the stimulated medial branch (Bogduk, 1980*b*). Clinically, this myotomal pattern of innervation in the human may be of value in diagnostic paraspinal electromyography.

SUMMARY

The L 1–4 dorsal rami tend to form three branches, medial, lateral, and intermediate, which are distributed, respectively, to multifidus, iliocostalis, and longissimus. The intertransversarii mediales are innervated by a branch of the dorsal ramus near the origin of the medial branch.

The L 4 dorsal ramus regularly forms three branches while at the L 1–3 levels the lateral and intermediate branches may, alternatively, arise from a short common stem.

The L 5 dorsal ramus is much longer than the others and forms only a medial and an intermediate branch.

Each lumbar medial branch innervates two adjacent zygapophysial joints and ramifies in multifidus, supplying only those fascicles which arise from the spinous process with the same segmental number as the nerve.

The comparative anatomy of the lumbar dorsal rami is discussed and the applied anatomy with respect to 'rhizolysis', 'facet denervation' and diagnostic paraspinal electromyography is described.

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NOTE ON ILLUSTRATIONS

To meet printing requirements, Figures 2, 4 to 7 and 9 were drawn from photographs of actual specimens. The actual photographs may be obtained at cost in colour or black and white upon request to the senior author.