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Innervation of lumbar zygapophyseal joint synovial folds

In a study of lower lumbar zygapophyseal facet joints, nerves have been demonstrated in the synovial folds by means of a silver impregnation method. The diameter of the nerves ranged from 0.6 to 12 microns; the number of fibers per nerve ranged from 1 to 5. They generally run a course separate from blood vessels, indicating that they are afferent nerves which probably have a nociceptive function. This finding may be relevant to low back pain.

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Synovial folds projecting into the joint cavity are filled by vascular adipose tissue and occupy potential spaces which vary according to the changing shape of the joint cavity during movement (Tondury 1972, Gray 1980). Villous projections increase the surface area of the synovial membrane (Ghadially & Roy 1969, Giles & Taylor 1982). If pinched between the opposed articular facets of zygapophyseal joints, the tips of these synovio-adipose structures undergo fibrous change (Engel & Bogduk 1982, Giles & Taylor 1982). The synovial inclusions in the infero-medial recesses of lumbosacral zygapophyseal joints are particularly large and vascular (Giles & Taylor 1982).

The fibrous capsule of the zygapophyseal joints is well innervated (Hadley 1976, Wyke 1979, 1981, Nade et al. 1980). It is less certain whether the ligamentum flavum, which forms the ventral portion of the joint capsule, is innervated. Hirsch et al. (1963) and Ramsey (1966) identified a small number of free neural structures described as nerve endings, but Jackson et al. (1966) could not find any nerve endings. The question of innervation of the synovial membrane is even more contentious. According to Mooney & Robertson (1976) the zygapophyseal joint synovial membrane contains a rich nerve supply, but their claim is not supported by histologic evidence. Hadley (1976) and Wyke (personal communication 1983) did not find nerves in the synovial folds of the zygapophyseal joints. Indeed, Wyke (1981) emphasized that there are no receptor nerve endings of any kind in the synovial tissue or in the intraarticular menisci in these joints in mature individuals.

We present preliminary findings of a histologic investigation of synovial folds from the L4–5 and lumbosacral zygapophyseal joints of 10 adults and discuss the possible clinical importance of the findings.

Materials and methods

The posterior part of the zygapophyseal joint capsule, with part of the ligamentum flavum, and the adjacent synovial fold (Figure 1) were removed at the L4–5 and L5-S1 spinal levels during routine laminectomies on 10 adults aged 27–61 years. The patients were healthy apart from nucleus pulposus extrusion.

Silver impregnation studies

The specimens were immediately placed in buffered 10 per cent formalin solution for 1 hour, then photographed as whole mounts (as controls) using a Wild 400 photomacroscope at known magnifications from x2 to x20.5. The specimens were then transferred to fresh 10% formalin solution over marble chips for 4 days. Each specimen was then placed in pyridine (3 min), washed in water (5 min), then impregnated with silver using Schofield's(1967) method. All the formalin solutions used had 0.1–0.2 grains of sodium chloride added (Wilson, personal communication 1985).

Each of the 10 pieces of tissue was then examined as a whole mount by means of a Wild M400 pho-

tomacroscope. Pieces of capsule/ligamentum flavum with adjacent synovial folds, which showed silver-impregnated black structures, were photographed, then resected, dehydrated in alcohol, and cleared in either xylene or methylbenzoate: toluene 1:1 (2 h), and toluene (2 h). Those resected parts which showed clearly defined neural tissue were mounted in DePex and photographed using high-power light microscopy. Other pieces of tissue containing neural structures which could not be clearly seen in the whole mounts were embedded in Paraplast wax for 3.5 h (2 changes), and finally in wax at 60°C under a 56 cm vacuum. The wax blocks were trimmed and serial sections were cut at a thickness of 30 microns, then cleared in toluene (2 min), and mounted in Eukitt mounting medium for further examination and photography.

Measurement of stained structures

The diameter of structures stained black by the silver impregnation method were carefully measured using a Wild M400 photomacroscope with a calibrated scale. The diameters of silver-impregnated nerves in 30 micron thick serial sections were accurately measured using a Leitz Mikrometer scale in conjunction with the Leitz Orthomat microscope. A montage was made to show the course of the nerves.

Results

The surgical material consisting of joint capsule/ligamentum flavum with adjacent synovial folds showed these folds to be highly vascular (Figure 2). Seven of the 10 silver-stained specimens showed clearly defined nerves in the synovial folds (Figure 3).

A silver-impregnated whole mount of an intraarticular synovial inclusion, mounted in DePex (Figure 5) showed a paravascular nerve plexus, plus a nerve fiber and a small nerve which are not related to blood vessels traversing the synovial cells. In smaller silver-stained nerves where individual fibers could be counted (Figures 4 and 6) the number of fibers varied from 1 to 5, and fiber diameters ranged from 0.6 to 2.5 microns.

Discussion

The silver impregnation method showed clearly defined nerves which projected well beyond the joint capsule into the synovial folds. The nerve diameters ranged from 0.6 to 12.0 microns in the synovial folds.

The only motor nerves in the synovial folds would be vasomotor nerves to the numerous blood vessels. However, most of the nerves shown in our study were independent of blood vessels and are at some distance from the blood vessels. The axons of myelinated fibers in adults range in diameter from less than 1 to 20 microns (Landon & Hall 1976, Landon 1982), whereas unmyelinated fibers range in diameter from 0.2 to 3.5 microns (Ochoa 1976, Landon 1982). Small unmyelinated nerve fibers (C fibers) having a diameter of 0.5 to 1.0 micron are nociceptive, as are small myelinated Aδ fibers) with a diameter of up to 4 microns (Guyton 1966). Therefore, the small fibers demonstrated here are afferent nerves which probably have a nociceptive function;

Figure 1. A 100 um thick horizontal section from the left L5-S1 zygapophyseal joint of a 54-year-old male. The rectangle represents the material removed during laminectomy, i.e., the ligamentum flavum with part of the fibrous joint capsule and joint synovial fold inclusion. C = cauda equina; D = dura mater; IAP = inferior articular process of L5; IVD = intervertebral disc; JC = joint capsule; LF = ligamentum flavum; N = nerve root ganglion (spinal ganglion); SAP = superior articular process of the sacrum. The black arrow indicates a highly vascular connective tissue structure, known as an intraarticular synovial fold inclusion, projecting into the joint recess.

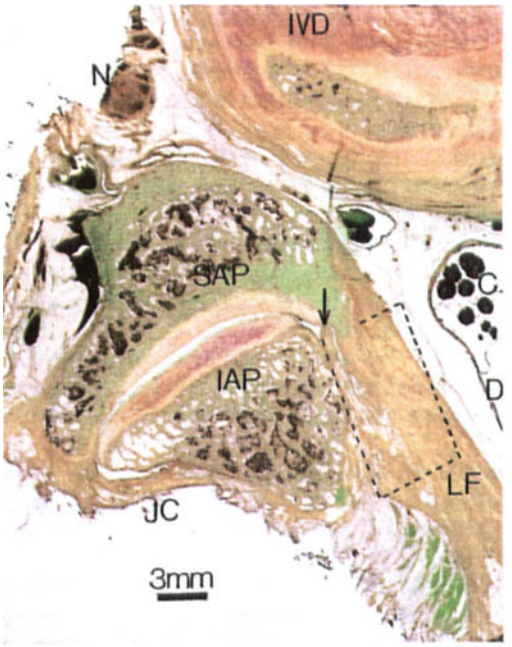
Figure 2. An unstained, fresh, whole-mount surgical specimen from the lumbosacral joint of a 35-year-old female, showing the highly vascular synovial tissue and synovial fold (SF) with the internal surface of the joint capsule/ligamentum flavum (CLF) behind it and some septa (S). The stainless steel probe is for stabilizing the specimen. (Reproduced from Giles et al. (1986), courtesy of S. Karger AG, Basel).

Figure 3. A whole-mount, silver-impregnated specimen from the L5-S1 zygapophyseal joint of a 27-year-old female, showing the joint capsule/ligamentum flavum (CLF) with nerves (N) projecting from it into the synovial folds (SF) adjacent to a septum (S). The average diameter of the nerves is 11.4 um. The nerve in the rectangle is shown highly magnified in Figure 4.

Figure 4. The average diameter of each fibre is 1.5 μm.

Figure 5. A whole-mount, silver-impregnated intraarticular synovial inclusion from the L5-S1 zygapophyseal joint of a 40-year-old male.
A. Numerous capillaries are noted and the area within the rectangle is shown in Figure 6.

Figure 6. A highly magnified section of the rectangle in Fig. 5. Note (i) the extensive nerve plexus (NP) on the capilllary (C), (ii) the synovial fold fat cells (FC); (iii) the free nerve fiber (N1), with an average diameter of 1.7 um, traversing the synovial fold, (iv) the small nerve (N2), and (v) the reticular fibers (RF) adjacent to the fat cells.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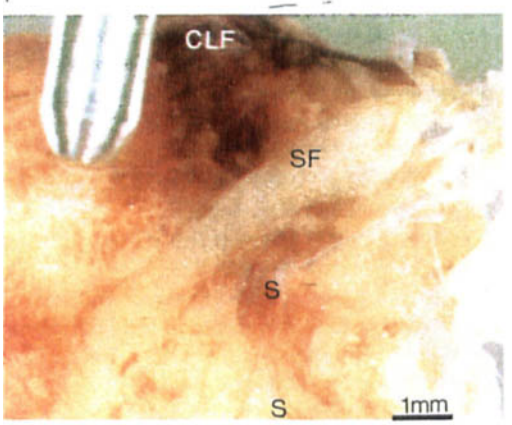
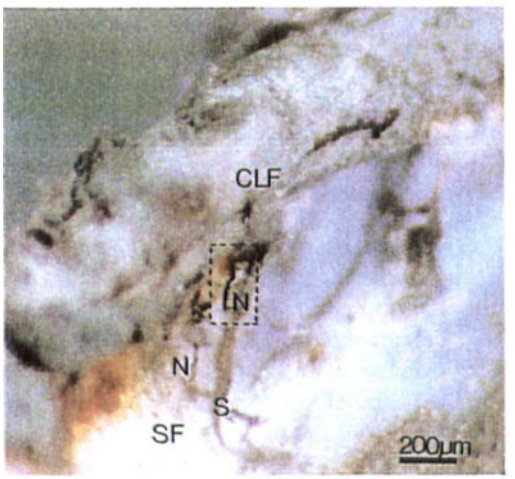
N
SAP
C
IAP
D
LF
JC
3mm

1


CLF
SF
S
S
1mm

2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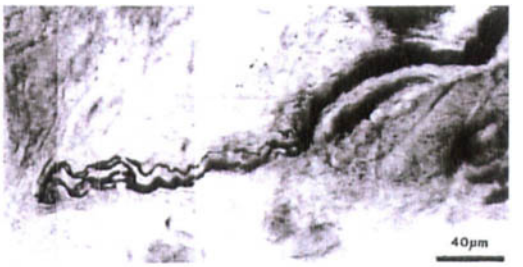
N
N
S
SF
200µm

3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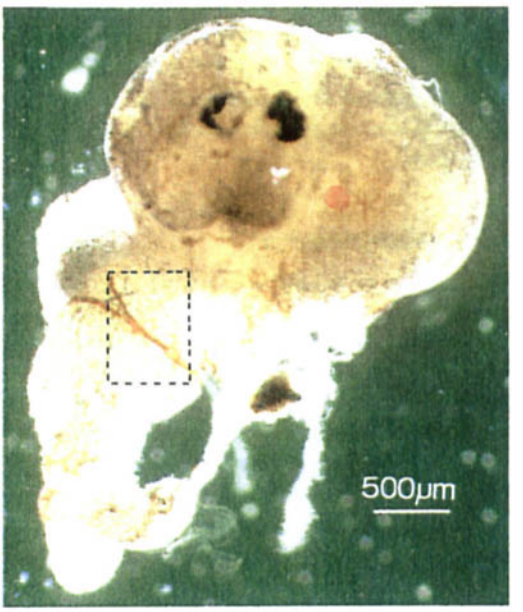
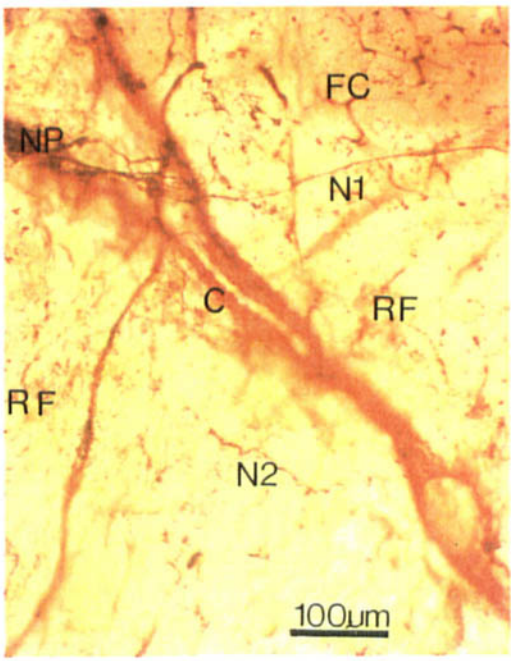
4


500µm

5


FC
NP
N1
C
RF
RF
N2
100µm

6

they have the same size as C fibers and small diameter myelinated fibers, and do not usually accompany blood vessels.

It is reasonable to assume from this study that all human zygapophyseal joint synovial folds are innervated.

Entrapment of intraarticular synovial inclusions which protrude between moving parts of zygapophyseal joints has been implicated as a cause of low back pain (Kos & Wolf 1972, Giles & Taylor 1982). Therefore, the demonstration of nerves, unrelated to blood vessels, in the synovial folds and joint inclusions has potential clinical significance in relation to low back pain.

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