Sensory innervation of human thoracolumbar fascia

An immunohistochemical study

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We have studied the human thoracolumbar fascia by using antiserum against neurofilament protein (NFP) and S-100 protein to identify sensory nerve fibers and their endings. Seven surgical specimens from 7 patients were studied with light microscopy. In addition to free nerve endings, two types of encapsulated mechanoreceptors (Ruffini's and Vater-Pacini corpuscles) were identified. These findings support the hypothesis that the thoracolumbar fascia may play a neurosensory role in the lumbar spine mechanism.

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Recent studies have proclaimed a significant role for the thoracolumbar fascia in the biomechanics of the lumbar spine. In theoretic studies of the lumbar spine mechanism, Gracovetsky et al. (1981) postulated that the thoracolumbar fascia acts in concert with the posterior ligaments of the lumbar spine to support the flexed vertebral column, and that the tension developed in the fascia is controlled by the abdominal muscles that arise from it.

In addition to its mechanical functions, the thoracolumbar fascia might perform a sensory role, influencing or initiating postural and/or protective muscular reflex activity. Floyd and Silver (1955) showed by electromyographic techniques that in full trunk flexion the erectores spinae muscles relax completely, and they postulated the existence of a reflex inhibitory mechanism caused or controlled by afferent impulses arising from mechanoreceptors located in spinal posterior ligaments.

Although questions of lumbar spine mechanism and flexion-relaxation phenomenon are very important, questions of the innervation of the thoracolumbar fascia in man have so far received little attention in the literature (Stilwell 1957, Hirsch et al. 1963). Stilwell (1957) found large pacinian corpuscles and groups of smaller pacinian-like and Golgi-Mazzoni corpuscles, but Hirsch et al. (1963) identified only fine free fibers and complex unencapsulated endings. These previous studies were performed mainly by using silver-nitrate and methylene-blue staining methods, which do not stain neural tissue specifically. We therefore decided to take another look at the sensory innervation of the human thoracolumbar fascia using immunohistochemical techniques.

Material and Methods

Thoracolumbar fascia specimens were harvested from 7 patients (1 woman and 6 men, aged 30 to 46 years) undergoing various surgical procedures. Four tissues were fixed for 24 hours in 10 percent formaldehyde buffered at pH 7.4. Three others were immediately frozen in isopenthane (2-methyl butane) at –60 °C for 20 seconds and stored at –60 °C until use. Serial, 5-µm-thick cryostat sections, made with a 10 to 15-µm gap between adjacent sections, were mounted on slides previously coated with poly-L-lysine (Huang et al. 1983). Endogenous peroxidase activity was quenched with methanol containing 0.3 percent hydrogen peroxide for 10 minutes. The sections were treated with 1.5 percent normal goat serum (in PBS, pH 7.4) for 20 minutes to block nonspecific binding, and then incubated for 4 hours at room temperature with prediluted antiserum against 68, 160, and 200 kD polypeptide subunits of neurofilament protein (NFP) and S-100 protein, which were raised in mouse and rabbit respectively and commercially supplied by Dimension Laboratory (Missisauga, Ontario, Canada). The antibody reaction site was visualized by using avidin-biotin-peroxidase complex (ABC) staining (Hsu et al. 1981), and diaminobenzidine was employed as chromogen. Finally, the slides were counterstained in

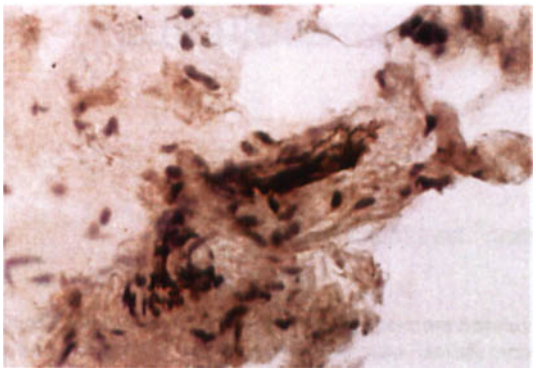

Figure 1. NFP-immunoreactive nerve bundles, ×275.

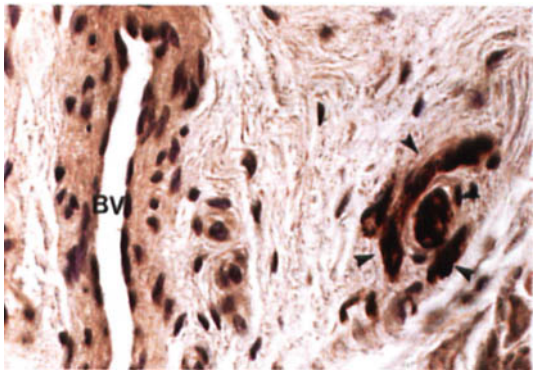

Figure 2. S-100 immunoreactivity in thoracolumbar fascia tissue fixed in 10 percent formaldehyde. The inner core and lamellar cells of the pacinian corpuscles are immunoreactive to S-100 protein (arrowheads). BV Blood vessel, ×275.

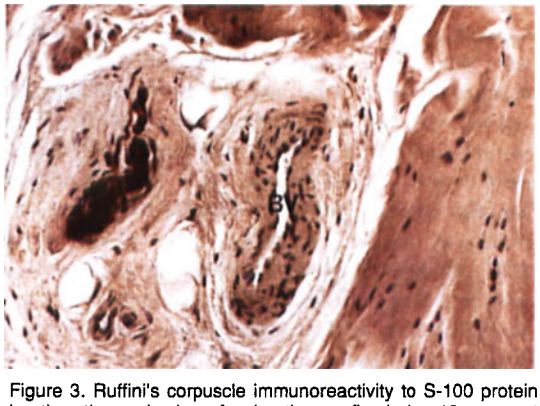

Figure 3. Ruffini's corpuscle immunoreactivity to S-100 protein in the thoracolumbar fascia tissue fixed in 10 percent formaldehyde. BV Blood vessel, ×110.

Harris hematoxylin, washed in running tap water, dehydrated in ethanol, cleared in xylene, and mounted. All the experimental controls were performed, and they supported the specificity of staining. The sections were examined under a light microscope.

Results

Our results indicate that the thoracolumbar fascia is well innervated. The sections, stained with neurofilament antiserum, which is considered to be a specific marker of nerve fibers (Osborn 1983, Seiger et al. 1984), showed nerve-bundle NFP immunoreactivity (Figure 1). No specialized nerve terminal was found in the NFP-antiserum-treated sections. However, two mechanoreceptors, i.e., Ruffini's corpuscles and Vater-Paccini corpuscles surrounding blood vessels, were observed in this tissue with S-100 protein antiserum. Pacinian corpuscles display immunoreaction to S-100 protein, which stained the inner core and the lamellar system of the capsule (Figure 2). The Ruffini receptor is characterized by its single axon and a dense arborization of nerve tissue within the collagen bundles (Figure 3).

Discussion

Mechanoreceptors have been identified in human interspinous, supraspinous and flaval ligaments (Yahia et al. 1988, Yahia and Newman 1989) by gold chloride staining and electron microscopy. To our knowledge, there are only two histologic studies on the human thoracolumbar fascia (Stilwell, 1957, Hirsch et al. 1963). Methylene-blue positive elements were found by Stilwell (1957) in the thoracolumbar fascia, such as numerous free nerve endings and large pacinian corpuscles. Hirsch et al. (1963) spoke of "complex unencapsulated endings" without providing any illustrations.

We observed two types of mechanoreceptors: Ruffini's corpuscles or receptors of Type I and Vater-Pacini corpuscles or receptors of Type II, and also nerve bundles. The S-100 protein immunoreactivity in the pacinian corpuscle was exclusively localized in the inner core and lamellar cells. These data are in agreement with those of Iwanaga et al. (1982) and Vega et al. (1989, 1990) on immunohistochemical studies of pacinian corpuscles. S-100 protein belongs to the family of Ca^{2+} binding proteins, which has been considered specific for glial and Schwann cells (Isobe et al. 1983), and could serve as a marker for these cells in situ (Stefansson et al. 1982). The mechanoreceptors were found close to blood vessels and in loose connective tissue adjacent to dense collagen bundles. Only nerve bundles were observed with NFP antiserum, whereas over and above mechanoreceptors, S-100 protein antiserum also demonstrates free nerve endings and nerve bundles. Our study demonstrates with a specific immunostaining method the presence of neural

elements in human thoracolumbar fascia. The presence of pacinian and Ruffini's receptors suggests that the thoracolumbar fascia could be involved in the control of the lumbar spine mechanism.

References

Floyd W F, Silver P H S. The function of the erectores spinae muscle in certain movements and postures in man. *J Physiol* 1955; 129: 184–203.

Gracovetsky S, Farfan H F, Lamy C. The mechanism of the lumbar spine. *Spine* 1981; 6: 249–62.

Hirsch C F, Ingelmark B E, Miller M. The anatomical basis for low back pain. *Acta Orthop Scand* 1963; 33: 1–17.

Huang W M, Gibson S J, Facer P, Gu J, Polak J M. Improved section adhesion for immunocytochemistry using high molecular weight polymers of L lysine as a slide coating. *Histochemistry* 1983; 77 (2): 275–9.

Hsu S M, Raine L, Fanger H. Use of avidin biotin peroxidase complex (ABC) in immunoperoxidase techniques: a comparison between ABC and unlabeled antibody (PAP) procedures. *J Histochem Cytochem* 1981; 29 (4): 577–80.

Isobe T, Ishioka N, Kocha T, Okuyama T. Chemical structure and molecular evolution of S-100 proteins. *Prot Biol Fluids* 1983; 30: 21–4.

Iwanaga T, Fujita T, Takahashi Y, Nakajima T. Meissner's and pacinian corpuscles as studied by immunohistochemistry for S-100 protein, neuron-specific enolase and neurofilament protein. *Neurosci Lett* 1982; 31 (2): 117–21.

Osborn M. Intermediate filaments as histologic markers: an overview. *J Invest Dermatol* (Suppl 1) 1983; 81: 104–9.

Seiger A, Dahl D, Ayer LeLievre C, Bjorklund H. Appearance and distribution of neurofilament immunoreactivity in iris nerves. *J Comp Neurol* 1984; 223 (3): 457–70.

Stefansson K, Wollmann R L, Moore B W. Distribution of S-100 protein outside the central nervous system. *Brain Res* 1982; 234 (2): 309–17.

Stilwell D L. Regional variations in the innervation of deep fascia and aponeuroses. *Anat Record* 1957; 127 (4): 635–53.

Vega J A, Dubovy P, del Valle Soto M E, Hernandez L C, Perez Casas A, Malinovsky L. Immunohistochemical study of pacinian corpuscles using monoclonal antibodies for neurofilament protein, glial fibrillary acidic protein and S-100 protein. *Cell Mol Biol* 1989; 35 (6): 627–33.

Vega J A, J J, del Valle M E, Hernandez L C, Bengoechea M E, Perez Casas A. Immunohistochemical study of cat pacinian corpuscles: co-localization of vimentin and S-100 protein like in the inner core. *Cell Mol Biol* 1990; 36 (4): 415–20.

Yahia L H, Newman N, Rivard C H. Neurohistology of lumbar spine ligaments. *Acta Orthop Scand* 1988; 59 (5): 508–12.

Yahia L H, Newman N. A light and electron microscopic study of spinal ligament innervation. *Z Mikroskop anat Forsch Leipzig* 1989; 103 (4): 664-74.