Gonstead Disc Model Revisited
Part II: Innervation of the Intervertebral Disc

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Nerves in the Disc?

Much of the focus to search for nerves within the disc has been to determine if pain can be generated within the disc, i.e., discogenic pain. Early neuroanatomicists used stains to isolate nerve tissue that were non-specific and often did not capture fine structures. In spite of these difficulties, these early researchers found and described signs of nerve fibers within the disc that have been confirmed today.[1,2,3,4,5] The development of better laboratory tools and immunohistochemical agents have provided major leaps in microscopic histologic research. Not only have reseachers been able to confidently stain nerve fibers and endings but they have also been able to gain some insight into the function of these observed structures.

The fetal and newborn are reported to have well-innervated and vascularized superficial anular layers. The nerves and vessels diminish during the maturation process.[3] Although there is an extensive nerve supply in the peridiscal area, the number of fibers and nerve endings that penetrate into the disc itself are few in number.[1,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20]

The current questions being asked are two-fold:

1) What is the density, extent and depth of the nerve fibers and receptors within the disc.
2) What is the purpose or function of the nerve fibers and receptors that have been found, both in the normal and degenerated or pathological disc.

We will summarize the current and past research. As in all areas of science that require the use of tissue samples, research findings are sometimes at variance with each other due to variables such as the exact question being asked and the anatomical variations in the specimens obtained. This causes a dilemma for those reviewing and summarizing the literature.

Location of the Nerves Within the Disc

The perianular region has an extensive network of nerve fibers, but few nerves project into the disc itself. The depth to which the fibers travel within the disc is still somewhat controversial. There have been reports of fibers entering the inner anular layers and the nucleus pulposus [21,22,23], but these reports have only been confirmed in damaged discs. [21,24] Researchers have established that nerves are in the outer 3-4 lamellae or 3.5mm of the AF.[1,2,3,10,11,12,14,19,20,21,22,24,25,26,27,28,29,3031,32] Fagan et al have found that the nerves penetrate the disc to a greater depth in the anterior (up to 4 or more laminae) than in the posterior (up to 3 laminae). [27]

The nerves are found predominately in the middle (vertical dimension) one-third of the disc with a few twigs extending into the inferior and superior thirds.[15] Nerve endings appear to populate the superior and inferior disc adjacent to the vertebral bodies.[15]

Another region where nerve fibers have been found is the central region of the vertebral endplate. These are extensions of nerves found in the vertebral body. [27] Perhaps this innervation is associated with the nutrient supply from the endplates into the nucleus pulposus.

The Origins of the Nerves?

Researchers have tracked some of the nerve fibers found in the posterior aspect of the disc to the sinuvertebral (SVN) of Von Luschka or recurrent meningeal nerve.[6,7,8,15,16,17,18] The sinuvertebral nerve is classically described as being formed by the ventral ramus of the spinal nerve and the gray

communicating ramus – since its initial description in the 1850s by von Lushka, the constituents of the SVN are still being disputed. Its fibers are known to ascend or descend one or more segmental levels. Transverse branches have been found that cross-over and anastamose with the contralateral SVN.

The posterolateral disc is innervated from the ventral rami and gray communicating rami.[11,14] In this way, it has both somatic and sympathetic nerve supplies.

The gray communicating ramus and the ventral ramus send fibers into the lateral aspect of the disc which is extensively innervated.[12,14,33] In the cervical spine, the lateral region is innervated by the vertebral nerve, a continuation of sympathetic nerve supply that arises from the cervicothoracic/stellate ganglia.[12]

The anterolateral aspect has a concentration of nerve fibers whose source appears to be the gray communicating rami.[7,27]

In the anterior, the ventral rami, communcating rami and sympathetic trunk appear to innervate this region.[6,7,11,12,13,14]

Ohtori et al found that in the rat, the lower lumbar discs received sensory innervation from T13 to L6 dorsal root ganglia (DRG). The thoracolumbar DRGs innervated the posterior disc via the paravertebral trunk, and the mid- to lower lumbar DRGs innervated the posterior disc via the sinuvertebral nerve.[17] Morinaga et al found that the anterior lumbosacral disc received innervation from sympathetic nerves from the L1 and L2 DRGs.[34]

Types of End-Terminals Found?

Free nerve endings predominate in the disc. Researchers have also found more complex terminals that are smaller than but resemble Pacinian corpuscles (fast adapting, low threshold terminals that respond to sudden changes in stress)[15,20,21,22], Golgi tendon organs (slow adapting, high threshold terminals thought to measure tension and possibly with nociceptive function)[15,22,21], Ruffini endings (slow adapting, low threshold terminals probably associated with positioning, pressure, and velocity of movement)[20], and Vater-Pacini corpuscle-like endings (Jackson) been found in the outer two to three anular layers. The number of end terminals are primarily found in the lateral, anterolateral, and posterolateral aspects of the disc.[3,9,22]

What Are the Nerve Doing There?

The use of immunohistochemical stains have not only confirmed the presence of the nerves within the disc, but provide some insight into their function or what stimuli they respond to. It is likely that nociception and proprioception are primary functions of many of the nerves found within the disc. Calcitonin genetic-related peptide (CGRP), Substance P (SP), and vasoactive intestinal peptide (VIP) immunoreactive nerve fibers have been found in the disc.[9,22] Although many of the aforementioned neuropeptides are often associated with the vascular system, in and around the disc, they are often found in non-vascular tissue. CGRP and SP are associated with nocicepti on[9,22], among other functions. Yasuchika et al found that CGRP containing nerves predominated in the disc.[34] Cavanaugh found type C (unmyelinated) and A-delta (small, myelinated) fibers in the disc, which in other areas can carry nociceptive impulses.[10]

To what are the receptors principally stimulated by? Mendel et al state that compression and deformation may stimulate many of the receptors.[15] McCarthy opines that the nociceptive receptors may be primarily stimulated by noxious chemicals in the extruded material from the nucleus pulposus, rather than by pressure or temperature.[31]

McCarthy and others state that there is limited vascular supply in the mature, healthy outer anular layers and that some of the discal nerve supply may innervate these vessels. He states that CGRP is vasodilatory, Substance P increases vessel wall permeability, and both attract white blood cells[31], although McCarthy et al have noted that CGRP-reactive fibers found in the disc are sensory rather than sympathetic.[31] Yasuchika et al found an increase in CGRP neurons in inflamed discs and opines that this increase may

be associated with discogenic pain.[34] It is possible that when trauma injures a disc, this neurovascular component may be an element in the inflammatory process that ensues to cause the D1 or swollen disc. If vascular and biochemistry changes along with ongoing facilitation, anular damage, and biomechanical dysfunction continue unabated, the result may be the desiccation that occurs in disc degeneration. If this is the situation, then early restoration of optimal intersegmental and global spinal function is vitally important.

Damaged Discs

Damaged discal material has yielded vascular structures and accompanying nerve fibers as AF tissue repair takes place with vascular granulation tissue.[35] The network of nerve fibers has been found to be more extensive than in undamaged or control discal material. Palmgren opines that both afferent and efferent nerves exist in damaged regions of the disc as nerve terminals responded to antibodies of synaptophysin (sensory), substance P (sensory), and C-flanking peptide of neuropeptide Y (sympathetic). (32) Freemont et al, found nerve fibers into the inner AF and the NP of damaged discs, but found nerve fibers only in the outer and middle 1/3 of normal control discs.[24] Coppes et al also found nerve fibers in the inner AF and at the border of the NP of damaged discs.[21] Johnson et al also found ingrowth of nerves into discs along with blood vessels.[30]

The consensus appears to be that innervation may extend into the middle 1/3 of damaged AF, and some innervation is found deeper in some specimens. When there is disruption in the anular layers, Johnson et al found nerves following the contours of the disruptions into inner layers of the disc.[30] Many nerve fibers have been found to accompany blood vessels that enter the damaged discs.[19,24,32] We now know that both sensory and autonomic nerves are found in damaged discs, the function of these nerves are unknown, although there has been speculation that nociception, vasomotor, and a role in vascular and proteoglycan cell genesis and/or proliferation are likely functions as studies found response to Substance P[19,22,32], protein gene product 9.5 (PGP 9.5), growth associated protein 43 (GAP 43), C-flanking peptides of neuropeptide Y.[19] Freemont et al did not find GAP 43 in intact discs.[24]

Schwann cells have also been found in damaged disc, largely in damaged areas with vascularization. They might be proceeding and promoting nerve growth into damaged areas of the disc.[30]

Comments

Nerves have been found in the inner layers of the anulus or even the nucleus pulposus in damaged discs. In intact or healthy discs, nerve fibers are found only in the outer anular layers.

As to the purpose of the nerve supply to the disc, it appears to be proprioception, nociception, and vasoregulation. In the damaged discs, there might be vasomotor and nociceptive involvement of some nerves.

As a chiropractor, whether or not discogenic pain may be due to nociceptive stimulation of nerves within the disc, the importance of optimal proprioception by intra- and peridiscal nerves to the health of the spine cannot be overstated. Chiropractic correction of vertebral subluxations probably has an important role for optimal proprioception.

Key Points

- Nerve fibers and complex receptors and free nerve endings, although sparse, are found in the outer anular laminae of the intact disc.
- In damaged discs, nerve fibers have been found in deeper regions of the disc which is also infiltrated by vascular vessels.
- Nociception and proprioception appear to be the primary functions. In the damaged disc, vasomotor control may be involved.

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