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An Original Contribution

Histologic Characterization of Coblation Nucleoplasty Performed on Sheep Intervertebral Discs

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Objective: To characterize the histologic effects of coblation nucleoplasty on sheep intervertebral discs.

Design: In vitro histologic study.

Methods: Five sheep lumbar discs treated with nucleoplasty and two control discs were evaluated. Specimens were received frozen and thawed to room temperature. A segment consisting of the intervertebral disc and vertebral body above and below the disc was dissected. Using a posterolateral approach, a Perc-DLE™ SpineWand™ attached to a standard radiofrequency power generator was bluntly advanced to the annulonuclear junction of each disc. The SpineWand was advanced initially in cauterization mode 8mm into the disc and withdrawn in coagulation mode. The SpineWand was reinserted 8mm into the disc and secured in place. The specimens were fixed in 10% buffered formalin for 1-2 weeks. They were then decalcified in 10% ethylenediaminetetraacetic acid (EDTA) and embedded in paraffin. Specimens were subsequently stained with H&E, Alcian Blue, and Trichrome stain. They were examined under light microscopy and polarized light.

Results: There were no gross changes in disc appearance. In the experimental disc, the fenestration created by the procedure left a 1mm diameter hollow channel through which tissue was cauterized leaving little visible debris or residual material. In the area immediately surrounding the channel, the fibrocartilage cells and the collagen matrix arrangement remained intact and resembled the control untreated disc tissue. There was no loss or re-distribution of proteoglycans, no alterations in collagen orientation, nor any indication of damage to the matrix surrounding the probe channel.

Conclusion: Radiofrequency nucleoplasty creates a hollow channel leaving surrounding soft tissue intact in the immediate post-procedure period. In vivo studies will be necessary to delineate the longitudinal histologic effects of radiofrequency nucleoplasty on discs.

Key Words: Histology, Nucleoplasty, Percutaneous Disc Decompression

Chronic low back pain (LBP) and radicular pain remains a serious medical problem. Historically, due to a limited understanding of the diverse and often multi-factored etiologies of chronic low back pain and radicular pain, treatment options have been limited and nonspecific. However, utilizing advanced imaging modalities and recent advances in technology with precision injection techniques, physicians have gained important insights into this difficult clinical entity. In a majority of cases, physicians are now able to identify the anatomic source of a patient's chronic LBP with or without radiculopathy as either a herniated intervertebral disc with resultant nerve root compression or a painful degenerative intervertebral disc (1-10).

Traditional medical treatments for patients with chronic LBP and/or radiculopathy have included trials of oral medications, exercise therapies, manual therapies, back school, lifestyle modifications, epidural steroid injections, and intradiscal steroid injections. Patients who have failed to improve with these conservative modalities have been offered a choice of living with the chronic disabling pain or aggressive surgical intervention with the potential for significant patient morbidity and failure rates as high as 40% (11). Over the past several years, there has been a growing interest in developing non-surgical and minimally invasive methods as simpler and less expensive alternatives to surgery. These have included a variety of methods used to perform percutaneous disc decompression, such as chemonucleolysis, automated percutaneous lumbar discectomy, and percutaneous laser discectomy (12-18). These procedures attempt to achieve partial removal of the nucleus to decompress herniated discs, relieve pressure on nerve roots and therefore offer relief from disc pain.

Radiofrequency nucleoplasty is a minimally invasive procedure that utilizes new technology to ablate and coagulate soft tissue in the disc. Radiofrequency nucleoplasty is designed to decompress painful contained disc protrusions, relieving pressure from nerve roots and providing patients with relief from disc and nerve root pain. In regards to a contained disc protrusion, partial removal of the nucleus has been shown to provide patients with significant pain relief (19, 20). The histologic effects of this new therapy on the intervertebral disc have not yet been characterized.

Materials and Methods

Two sheep lumbar spines were harvested. Specimens were received frozen and thawed to room temperature. Seven segments consisting of the intervertebral disc and vertebral body above and below each disc were dissected. Using a posterolateral approach, a Perc-DLE™ SpineWand™ attached to a standard radiofrequency power generator was bluntly advanced to the annulonuclear junction of 5 of the discs (2 were left for control). In cauterization mode the SpineWand was advanced 8mm into the disc and withdrawn in coagulation mode using a standard pow-

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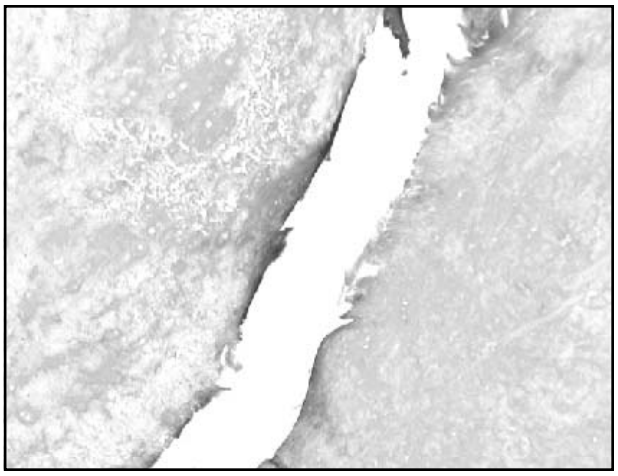

Fig 1. Light micrograph, trichrome staining at 450X magnification, hollow channel with no residual tissue in the channel.

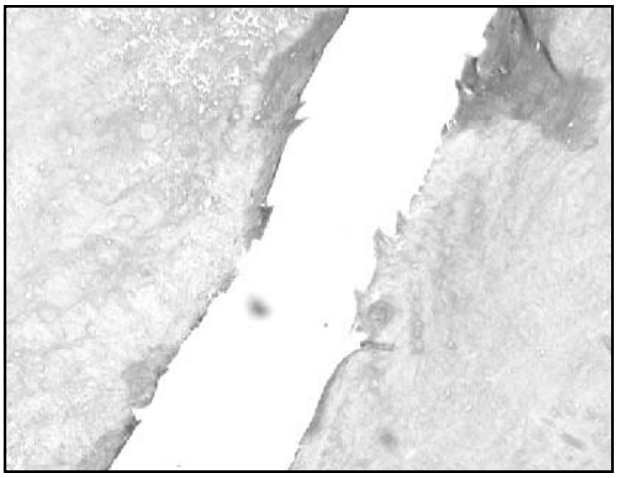

Fig 2. Light micrograph, Sirius Red staining at 450x magnification, fibrocartilage cells and the collagen matrix arrangement remained intact and resembled that of the untreated control disc tissue.

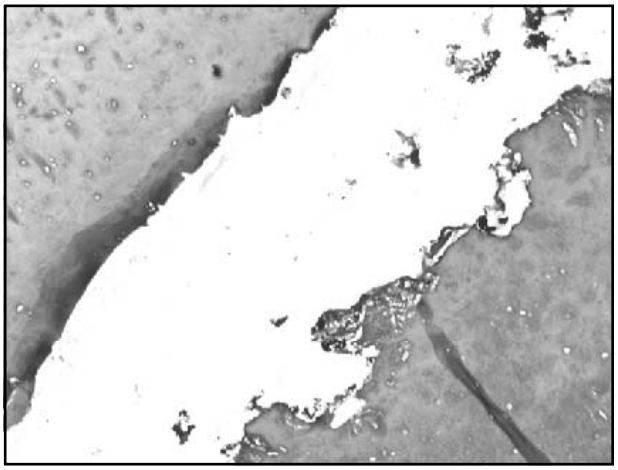

Fig 3. Light micrograph, Alcian Blue staining at 450x magnification, no loss or re-distribution of proteoglycans, no alterations in collagen orientation, nor any indication of damage to the matrix surrounding the channel.

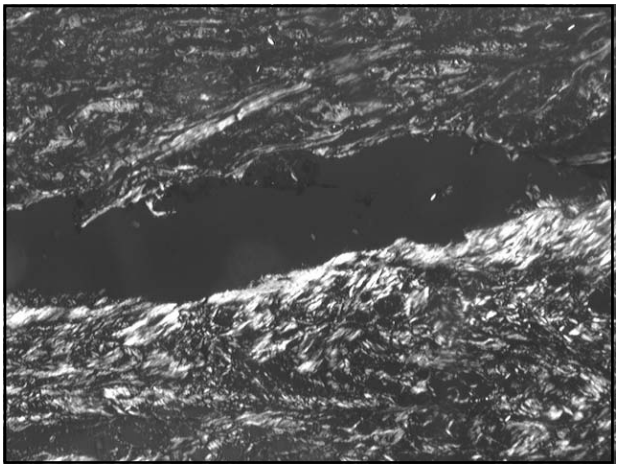

Fig 4. Light micrograph, polarized light at 180x magnification, collagen orientation and orientation remained intact.

er. The SpineWand was then reinserted 8mm into the disc and secured in place to ensure proper localization of the channels created. The specimens were fixed in 10% buffered formalin for 1-2 weeks. The specimens were then decalcified in 10% ethylenediaminetetraacetic acid (EDTA) and embedded in paraffin. Each specimen was subsequently stained with standard H&E, Alcian Blue (pH 5.5), Sirius Red and Masson's Trichrome stain. They were examined under light microscopy and polarized light. Diameter of each channel was measured using computer software. The study protocol was performed with approval of the Institutional Review Board of the parent institution.

Results

There were no gross changes in disc appearance. In the experimental disc, the fenestration created by the procedure left a maximum 1 mm diameter (range 0.6 mm to 1.0 mm) hollow channel through which tissue was cauterized leaving little visible debris or residual material (Fig 1). In the area immediately surrounding the channel, the fibrocartilage cells and the collagen matrix arrangement remained intact and resembled that of the untreated control disc tissue (Fig 2). There was no loss or re-distribution of proteoglycans (Fig 3), no alterations in collagen orientation (Fig 4), nor any indication of damage to the matrix surrounding the probe channel. The end plates remained unaffected.

Discussion

Nucleoplasty or partial removal of the nucleus has been shown to decompress herniated discs, relieving pressure on nerve roots and in some cases relieving discogenic pain (12, 19-21). Intradiscal Radiofrequency Nucleoplasty (SpineWand, Arthrocare, Sunnyvale, CA) is a

novel method of using a patented coblation technology for the ablation and coagulation of soft tissue, combining both approaches for the partial removal of the nucleus. The spine wand is placed using a standard extrapedicular discographic technique, through an introducer needle. After the spine wand has been placed, coblation ablates tissue via a low-temperature, molecular dissociation process to create a small channel within the disc. On withdrawal the channels are thermally treated producing a zone of thermal coagulation.

This study represents the first histologic characterization of nucleus pulposus treated with coblation nucleoplasty procedure. Fibrocartilage cells and the collagen matrix arrangement immediately surrounding the newly created channels remained intact. There was no loss or re-distribution of proteoglycans, no alterations in collagen orientation, nor any indication of damage to the matrix surrounding the probe channel. The clean hollow channel created by coblation nucleoplasty procedure within the nucleus measures approxiamtely 1 mm in maximum diameter which is slightly narrower than the 1.07 mm diameter of the Spine Wand. This measurement may be underestimated since the preparation process of dehydraing and decalcifying the specimen is known to shrink the specimen by 10-15% (22,23).

Intradiscal thermal energy has been shown to initiate changes in the collagenous and annular structures of the degenerative disc (24-26,29). Shah et al (25) showed in human caveric lumbar discs that denaturation, shrinkage and coalescence of the annular collagen occur when annulus is treated with intradiscal electrothermal therapy (IDET). There was extensive collagen disorganization and chondrocyte damage when treated annulus was studied under electron microscopy. Nucleus pulposus remained grossly unaffected, mainly due to placement of the catheter in the annulus. In contrast, Kleinstueck et al (26) reported no apparent alteration of the annular architecture when examined using a polarized light microscopy. This discrepancy remains to be resolved with additional studies including quantitative measurements of annular collagen cross-linking. Percutaneous laser disc decompression (PLDD) is also an ablative procedure that reduces intervertebral disc volume and pressure (13,14,30,31,32). PLDD induces vacuolization and vaporization of nucleus pulposus with eventual fibrocartilaginous replacement of the ablated tissue. In an animal study, Nerubay et al (30) showed 10-55% decrease in intradiscal pressure at the L2-L3 disc and 40-69% decrease at the L4-L5 disc. Eight out of the 20 discs treated, however, showed end plate damage.

This study has several important strengths and limitations. The study was performed on sheep intervertebral discs *in vitro*, not on human cadaveric specimens. Sheep spines, however, have been validated to be a good animal model for human spines (27,28). The control specimens did not have sham procedure performed, and we were unable, therefore, to distinguish the mechanical effects of blunt dissection from the thermal and ablative effects of the procedure. Control specimens revealed fissures within the nucleus pulposus. To ensure proper localization of the channel created by the procedure, the Spine Wand was reinserted into the channel and this may have added additional mechanical effect to the histologic findings. Lastly, this study does not provide any additional information regarding how nucleoplasty procedure provides pain relief in patients. Presumably, nucleoplasty provides intradiscal volume and pressure reduction. While Chen et al showed marked intradiscal pressure reduction in young healthy discs, only very small intradiscal pressure reduction was shown in severely degenerated discs (19).

Conclusions

Radiofrequency nucleoplasty using coblation technology creates a 1 mm diameter hollow channel in the nucleus pulposus leaving surrounding soft tissue intact in the immediate post-procedure period. In vivo studies will be necessary to delineate the longitudinal histologic effects of radiofrequency nucleoplasty on discs.

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