



Chapter 17

Intervertebral Disc Space Preparation for Nucleus Arthroplasty™ Technologies

Alejandro Reyes-Sánchez, MD

HEAD OF SPECIAL SURGERY DIVISION
National Rehabilitation Institute
Mexico City, Mexico 10700

Reginald J. Davis, MD, FACS

CHIEF OF NEUROSURGERY
Baltimore Neurosurgical Associates, PA
Baltimore, MD 21204

Rick Delamarter, MD

MEDICAL DIRECTOR
The Spine Institute
Santa Monica, CA 90404

KEY POINTS

- Nucleus Arthroplasty™ technology is relatively new with very little information on proper disc preparation.
- Nucleus arthroplasty requires the surgeon to focus special attention on sparing the annulus, maintaining endplate integrity, and nucleus pulposus removal.
- The annulotomy associated with nucleus arthroplasty surgery may be performed anteriorly or posteriorly; each method has its own advantages and disadvantages.
- Damage to the endplates during nucleus removal may induce Modic changes that impact endplate mechanical properties potentially leading to endplate subsidence.
- Atraumatic nucleus removal can be performed using a variety of techniques; a number of new technologies have emerged to address this need.

INTRODUCTION

Disc space preparation has historically been guided by placement of interbody fusion devices and more recently, total disc replacements (TDR). The hallmark disc preparation for these devices is destruction of the cartilaginous endplate to stimulate bony integration with little attention paid to annular integrity. In the case of interbody fusion, the intended result is bony ingrowth with subsequent elimination of motion.¹ Conversely, while bony ingrowth is promoted to fix the endplate components of the TDR, the intent is for motion to be maintained. With the introduction of nucleus arthroplasty, careful attention to annulus sparing techniques and maintenance of the cartilaginous endplate are paramount to a successful outcome. Accordingly, surgical techniques have been tested and developed to accomplish these goals. This chapter is intended to inform the reader on the latest developments in disc space preparation for nucleus arthroplasty.

The process of preparing the disc space for the introduction of a nucleus replacement device can be simply divided into the following five steps:

- 1) Annulotomy
- 2) Nucleus Pulposus Evacuation
- 3) Cartilaginous Endplate Protection
- 4) Verification of Nucleus Evacuation
- 5) Assessment of the Evacuated Disc Space

1) ANNULOTOMY

It is well known that producing a transverse annulotomy incision can result in a propagation of a radial tear with resultant instability, while the use of a vertical incision has a significantly reduced impact on overall annular stability and disc function.² Some surgical techniques for nucleus arthroplasty require the creation of an annular flap. The annular incision should be carefully planned and positioned to maximize later repair and maintain overall integrity of the annulus. Ideally, the incision should be created to allow adequate access to the disc space to ensure removal of the greatest volume of degenerated tissue, while maintaining a reasonable volume of viable annular tissue for suture closure to enable more rapid healing and restore normal segmental stability.

Posterior Approach:

When approaching the annulus posteriorly, direct repair is difficult, if not impossible. Annular repair devices for use in such instances are being developed. But in the interim, it is desirable to make a small incision that can then be carefully dilated to allow for nucleus removal and subsequent device placement. There is evidence indicating that this technique may allow the annular tissue to fibrose forming organized scar tissue that acts like a plug to aid in preventing device extrusion through the annulotomy site. Device extrusion can also be minimized by ensuring that the final location is not directly in line with the axis of implantation.

It is also very important to minimize the removal and/or disruption of posterior ligamentous and bony structures. Thus, the amount of laminar bone removal, facet removal, and muscular dissection should be kept to a minimum to reduce posterior instability. Preservation of the posterior spinous and interspinous ligaments also helps to achieve this goal. A total laminectomy can cause significant segmental instability when compared to a carefully performed laminotomy.³

Anterior Approach:

The anterior approach offers several advantages with regard to annular integrity when compared to the posterior approach. The annulus tends to be thicker, more robust and free of herniations, tears or defects. The tissue quality in this region allows the creation of an annular flap that can be later sutured closed versus the tissue removal associated with a box style annulotomy. Ideally, the flap is created by making a through cut laterally at the border of the psoas muscle and then projecting the outer six to ten layers of the annulus medially such that the attached or hinged portion is located at the border of the anterior longitudinal ligament (ALL). This produces a flap that is roughly 5-7mm in thickness with a length of 17-18mm laterally. Creating the flap in this manner maintains the structural integrity of the ALL and allows for subsequent suture reinforcement to form a physical barrier to device expulsion. An "I" shaped incision is then made through the remaining layers to access the disc space. Care must be taken to protect the nerve when making the through cut at the psoas due to the close proximity of the nerve root (~5mm).

2) NUCLEUS PULPOSUS EVACUATION

Nucleus arthroplasty, unlike a simple discectomy, requires that varying amounts of nucleus pulposus be removed based on the device being considered. Further, unlike preparation for interbody fusion or total disc arthroplasty, this nucleotomy must be accomplished without disrupting the cartilaginous endplates or further damaging the fibrous annulus. Historically, nucleus evacuation has been achieved by a variety of means. Automated percutaneous lumbar discectomy (APLD) is one such technique. When performing APLD, the patient is placed under IV sedation. Fluoroscopic guidance is then used to guide a 2mm tubular dissector into the center of the nucleus pulposus. The instrumentation removes the disc material by combining suction with an enclosed guillotine cutting blade that is positioned at the tip. Once an initial passage has been created, more aggressive dissectors of larger diameter can be used; however, the degree of nucleus removal with this technique is currently not satisfactory for nucleus arthroplasty procedures.

Similarly, minimally invasive and percutaneous removal techniques have been employed using laser ablation and bi-portal mechanical removal. Enzymatic dissolution with chymopapain has also been employed in certain instances, but is not currently available in the United States. While all these techniques require only minor disruption of the annulus, these approaches are also quite limited in ability to provide adequate nucleus removal.

Currently, the application of mechanical resection modalities remains the standard. The use of 5mm pituitary rongeurs with a straight, upbite and downbite orientation provides the most consistent nucleus cleanout. Removal is initiated in a straight longitudinal fashion and subsequently towards each quadrant within the nuclear space. Special attention must be given to the area immediately adjacent to the annulotomy which is the most difficult to reach. The most common finding in the degenerated disc is desiccated nucleus material that can be difficult to distinguish from annulus fibrosus when using the rongeur. As it is critically important to avoid damaging the annulus to preserve the nuclear container, caution must be exercised. Of significant benefit is the injection of saline into the disc space. The saline is rapidly absorbed by the remaining nucleus which then swells, becoming easier to grasp and remove. When using a posterior approach, advanced imaging should be used to identify the location of any potential herniations or extruded fragments so the surgery can be performed while maintaining as much annular integrity as possible. If a lateral approach (ALPA) is used,

UNLIKE PREPARATION FOR INTERBODY FUSION OR TOTAL DISC ARTHROPLASTY, THIS NUCLECTOMY MUST BE ACCOMPLISHED WITHOUT DISRUPTING THE CARTILAGINOUS ENDPLATES OR FURTHER DAMAGING THE FIBROUS ANNULUS.



Figure 1

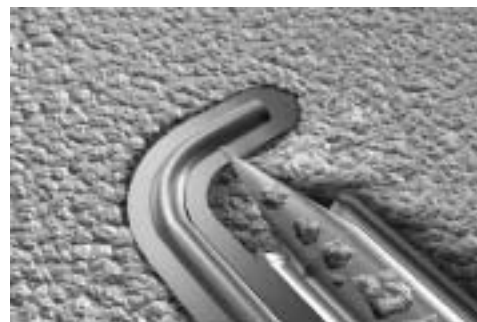


Figure 2

care must be taken to ensure that there are no breaches in the posterior annulus or extruded fragments in the canal.

Other technologies for more automated tissue resection are evolving and may eventually be appropriate for intradiscal use. These include the Spine-Jet™ (HydroCision®—Billerica, MA, USA) and the MDS® FlexTip® tissue shaver (Endius®—Plainville, MA, USA).

HydroCision: When used for nucleus arthroplasty, the proprietary fluidjet technology of the SpineJet MicroResectors will selectively hold, cut and remove the nucleus pulposus quickly and safely without damaging the surrounding annulus. It incorporates a retrograde-flowing fluidjet directed into an evacuation tube forming a precise 1.5mm tissue-cutting window that will only consume tissue entering it. The high velocity fluidjet (600 mph) creates a Venturi effect that simultaneously pulverizes and removes the tissue away from the surgical site (Figures 1 & 2).

Endius: The Endius FlexTip, consisting of a flexible shaver blade and flexible hand held rongeurs, provides surgeons with efficient and effective disc removal, while improving the levels of control and maneuverability within the intervertebral disc space. The FlexTip shaver blade allows tissue to be efficiently removed when performing a full or partial nucleotomy. Simultaneous suction and irrigation, combined with an automated steerable distal tip that articulates up to 90° in one direction, allows the surgeon to perform a complete discectomy efficiently using only one instrument (Figures 3 & 4).

Such systems can potentially be enhanced by pre-administration of an enzymatic agent facilitating nucleus digestion and removal. Automated and effective removal of nucleus pulposus will greatly enhance efficiency and, ultimately, the clinical outcomes of nucleus arthroplasty procedures.



Figure 3



Figure 4

3) CARTILAGINOUS ENDPLATE PROTECTION


Maintaining the integrity of the cartilaginous endplate is of the utmost importance when considering nucleus arthroplasty. Extreme care must be taken to avoid damage to the cartilaginous surfaces during nucleus pulposus evacuation as damage may induce postoperative Modic changes. Modic endplate changes, generally associated with painful pathology in the minds of most spine specialists, are well recognized yet poorly understood. There is limited clinical data regarding the correlation of postoperative Modic changes and long-term outcomes. However, such changes will be viewed as undesirable, rightfully or wrongfully so, until full clinical and physiological understanding of this phenomenon emerges. It is therefore imperative to minimize endplate trauma to enhance outcomes.

Treatment of the endplate for the use of a nuclear arthroplasty device must be completely different from the procedures used to prepare the endplate for contact with ingrowth surfaces or fusion devices. The issue of implant subsidence noted in total disc or nucleus replacement procedures may in a large part be due to injury of the vertebral endplate during the surgical preparation. As such, the use of bone rasps or curettes should be avoided. In addition, any distraction necessary to gain access to the intervertebral space should be limited to the apophyseal ring region where the bone is much stronger, as opposed to the center portion, where fracture or subsidence are more likely to occur. Improper placement of the distractor can cause microfractures in the subchondral bone significantly increasing the risk of implant subsidence. It should also be noted, that care must be taken during the subsequent disc space sizing and implant insertion procedures as these activities may also result in endplate microfractures.

4) VERIFICATION OF NUCLEUS EVACUATION

As noted previously, removal of the degenerated nucleus represents a crucial step when considering the use of a nucleus replacement device. Prior to device insertion, the space must be evaluated to ensure adequate nucleus removal. This can be accomplished using various methods that incorporate the use of fluoroscopy. The most effective method is the use of contrast medium in combination with anterior-posterior and lateral fluoroscopic imaging.⁴ However, the ability to effectively use contrast may be limited by factors such as the surgical approach,

THE ISSUE OF IMPLANT SUBSIDENCE NOTED IN TOTAL DISC OR NUCLEUS REPLACEMENT PROCEDURES MAY IN A LARGE PART BE DUE TO INJURY OF THE VERTEBRAL ENDPLATE DURING THE SURGICAL PREPARATION.



IN ORDER TO OBTAIN A TRUE ASSESSMENT OF THE DISC SPACE AFTER NUCLEUS EVACUATION, IT IS BEST TO MEASURE THE SPACE INTRA-OPERATIVELY, WITH ATTENTION GIVEN TO ASSESSING THE DISC SPACE IN ITS NATURAL LORDOTIC STATE.

patient positioning that may not allow retention of the medium within the disc space, or other issues such as the potential for allergic reaction. As an alternative, a ball end probe can be used in conjunction with fluoroscopic imaging to define the borders of the evacuated space. The use of the probe has the advantage of providing the surgeon with the tactile feel necessary to detect differences in tissue quality along the borders of the disc space. While the probe is easy to visualize in anterior-posterior and lateral views, the limited size of the probe tip and its relatively small contact area make it difficult to positively confirm complete evacuation of the volumetric space. An ideal method would be to visualize the disc space directly using endoscopic methods to ensure nucleus evacuation while assessing the integrity of the annulus fibrosus. However, the use of an open technique may be more complicated and overly burdensome compared to the simple and practical methods described above.

5) ASSESSMENT OF THE EVACUATED DISC SPACE

Ideally, the patient's spinal condition and disc space could be fully characterized by the use of imaging prior to surgery. While the use of magnetic resonance imaging (MRI) is integral to this process, the resolution of such systems can be limiting; slice thicknesses are commonly on the order of 4mm. The use of plain film radiographs (anterior-posterior and lateral) can be useful in such analyses, but radiographic images are also prone to a certain margin of error (2.3 to 4.5%). In order to obtain a true assessment of the disc space after nucleus evacuation, it is best to measure the space intra-operatively, with attention given to assessing the disc space in its natural lordotic state. Thus, the introduction of a distractor or other mechanical means to gain access to the disc space must be avoided to eliminate measurement inaccuracies. An appropriate device

should be capable of being inserted through the established annulotomy and provide accurate intradiscal measurements of the central and lateral portions of the disc space. The resulting disc space measurements should be repeatable among different users to ensure accurate sizing and selection of an appropriate nucleus replacement device. The ability to measure the disc space intra-operatively would eliminate the need for the insertion/removal of trial components, thereby reducing potential damage to the endplates that may result in future subsidence of the prosthesis.

REFERENCES

1. Patwardhan AG, Carandang G, Ghanayem AJ, Havey RM, Cunningham B, Voronov LI, Phillips FM. Compressive preload improves the stability of anterior lumbar interbody fusion cage constructs. *J Bone Joint Surg Am.* 2003 Sep; 85-A (9):1749-56.
2. Lu WW, Luk KD, Ruan DK, Fei ZQ, Leong JC. Stability of the whole lumbar spine after multilevel fenestration and discectomy. *Spine.* 1999 Jul 1; 24(13):1277-82.
3. Natarajan RN, Andersson GB, Patwardhan AG, Verma S. Effect of annular incision type on the change in biomechanical properties in a herniated lumbar intervertebral disc. *J Biomech Eng.* 2002 Apr; 124(2):229-36.
4. Smith LJ, Fazzalari NL. Regional variations in the density and arrangement of elastic fibers in the annulus fibrosus of the human lumbar disc. *J Anat.* 2006 Sep; 209(3):359-67.
5. Rao RD, Wang M, Singhal P, McGrady LM, Rao S. Intradiscal pressure and kinematic behavior of the lumbar spine after bilateral laminotomy and laminectomy. *Spine J.* 2002 Sep-Oct; 2(5):320-6.
6. Frobin W, Brinckmann P, Biggemann M, Tillotson M, Burton K. Precision measurement of disc height, vertebral height and sagittal plane displacement from lateral radiographic views of the lumbar spine. *Clin Biomech (Bristol, Avon).* 1997; 12 Supp 1:S1-S63.