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Emerging Directions in Motion Preservation Spinal Surgery

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Minimally invasive surgical approaches, facet arthroplasty, and posterior tension band devices may be the future of motion preservation spinal surgery. Novel surgical techniques and spinal arthroplasty systems in active development, including minimally invasive approaches to the lumbar disc space that offer the potential for a minimally invasive lumbar arthroplasty system are discussed. Novel facet replacement technology and dynamic neutralization of the lumbar spine with an artificial posterior tension band device are also discussed. This allows for a certain degree of immobilization without fusion.

Lateral transpsoas approach for lumbar disc arthroplasty

Minimally invasive lateral approaches for lumbar interbody fusion (extreme lateral interbody fusion [XLIF]), pioneered by Pimenta [1] have been used for the treatment of degenerative lumbar scoliosis. This same type of lateral transpsoas approach also holds promise as a minimally invasive surgical technique for the insertion of artificial lumbar discs, obviating the need for a general surgeon to provide traditional access to the anterior lumbar spine and significantly reducing postoperative morbidity and length of hospital stay. In this section, we provide a brief overview of the surgical technique of the lateral transpsoas approach using the Nuvasive MaXcess Retractor system (Nuvasive, San Diego, California). Current work is focusing on developing novel lumbar artificial disc designs compatible with this system.

Positioning and approach

The lateral transpsoas approach is performed with the patient in a right lateral decubitus position, approaching the anterior spine from a direct angle of 90° from the midline, with the table flexed to open the approach to the intervertebral disc space. Lateral fluoroscopy is used to identify the desired disc level, and the retroperitoneal space is entered after making a posterolateral incision and passing through the three layers of the lateral abdominal wall with blunt finger dissection (Fig. 1). Lateral fluoroscopy is then used to identify the appropriate location for the spinal instrumentation incision directly over the involved disc space (Fig. 2).

Incision for spinal instrumentation and psoas muscle dissection

The surgeon's finger is brought back to the inner aspect of the lateral abdominal wall, and the skin incision for the spinal instrumentation is made. The initial dilator is brought through the abdominal wall to meet the surgeon's finger at the inner aspect of the transversalis muscle. This

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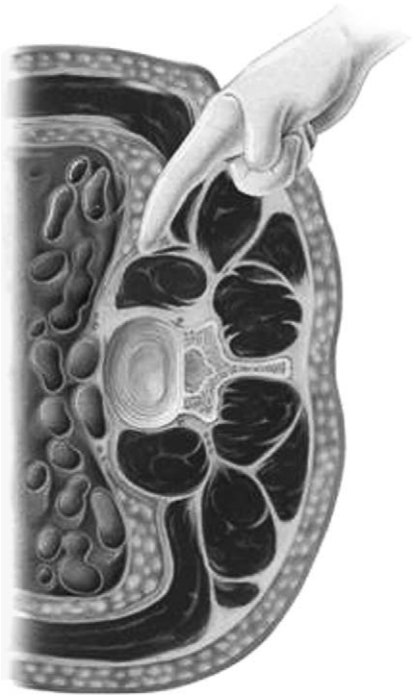

Fig. 1. Blunt retroperitoneal fingertip dissection.

dilator is the guided to the lateral aspect of the psoas muscle by the surgeon's finger (Fig. 3). Using lateral fluoroscopy, the initial dilator is positioned over the middle of the disc space of interest. An anteroposterior (AP) fluoroscopic image is also obtained to confirm the positioning in the center of the disc.

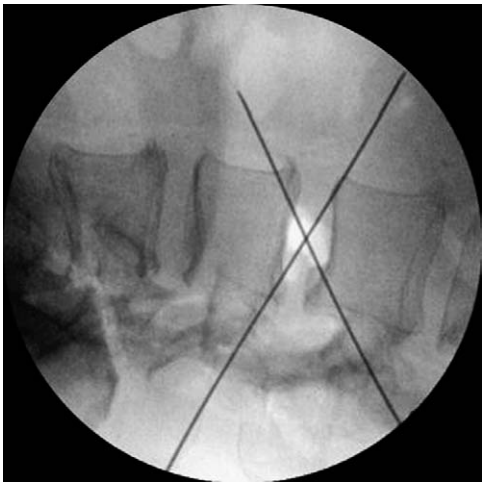

Fig. 2. Lateral fluoroscopic localization of the involved disc space.

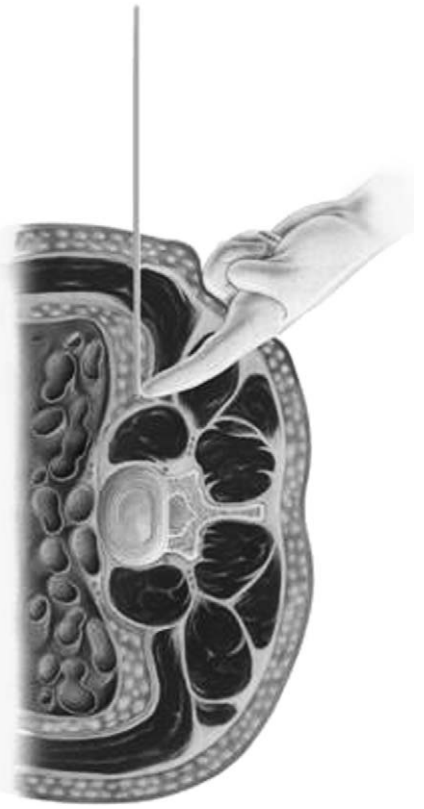

Fig. 3. The initial dilator is guided to the disc space by the surgeon's finger.

After confirmation of accurate placement of the initial dilator on both fluoroscopic images, a K-wire is passed into the involved disc space. Sequential dilation is performed, and the MaXcess Retractor is inserted into the final dilator and attached to the table-mounted arm (Fig. 4). Specialized instruments are used to perform a discectomy (Fig. 5). In the traditional XLIF procedure, an interbody graft is then inserted into the intervertebral space for fusion; however, the ultimate goal is to develop novel artificial discs compatible with the MaXcess Retractor to permit minimally invasive lumbar spinal arthroplasty.

Posterior presacral access route

The AxiaLIF System (TranS1, Wilmington, North Carolina) is currently the least invasive system for anterior fusion and fixation at L5 to S1. The AxiaLIF System's instrumentation provides access to the L5 through S1 disc space through a small presacral axial track. The AxiaLIF

Fig. 4. The MaXcess Retractor is inserted through the psoas muscle. (Courtesy of Nuvasive, with permission.)

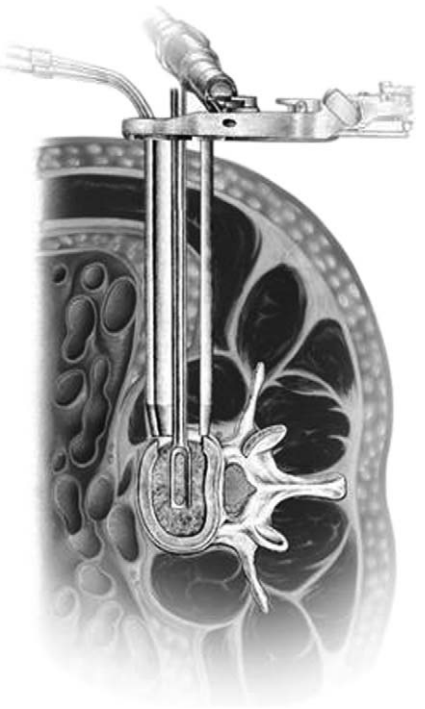

Fig. 5. A specialized disc cutter is used to perform the discectomy.

System's implantable threaded titanium distraction/fixation rod is then inserted via the presacral axial track and positioned to stabilize and fixate the L5 through S1 vertebral bodies. This approach preserves the integrity of the annulus and avoids disruption to surrounding structures and tissue while providing stability to packed bone graft, resulting in the desired L5 to S1 fusion. The technique is easily learned and addresses many of the perceived disadvantages of earlier minimally invasive techniques. Currently, it is used for fusion at the L5 to S1 interspace; however active research is focusing on developing compressible nucleus implants and disc reconstruction devices that can be delivered via the presacral route for arthroplasty at the L5 to S1 level (Fig. 6).

Oblique approach

The oblique approach to the lumber interbody space allows for minimally invasive surgical access with minimal need for vessel retraction compared with traditional anterior approaches. The Oblique-Maverick (O-MAV) Artificial Disc (Medtronic Sofamor Danek, Memphis, Tennessee) is a two-piece metal-on-metal artificial lumbar disc designed for insertion via the oblique approach. The O-MAV keel is cut at an angle approximately 35° of midline. The cutting reference guide shown helps the surgeon to have a posterior reference so that the correct angle for insertion is ensured by lining up the dots on intraoperative fluoroscopy.

Facet replacement technologies

Archus Orthopedics Total Facet Arthroplasty System

The Total Facet Arthroplasty System (TFAS) was designed by Mark Reiley, founder of Kyphon, as a facet replacement system designed to treat degenerative facet joints by preventing fusion of the treated spinal segment. The system is designed to replace degenerative facets with an articulating prosthesis that enables the facet joints to function in a painless manner. By confining motion to the proper surfaces of the facet joint, facet-related pain is theoretically reduced or eliminated. The system enables replacement of the bilateral or unilateral superior or inferior facets at a given level. Because of the pending

Fig. 6. The compressible nucleus replacement device for use with the AxiaLIF System. (Courtesy of TranS1, with permission.)

application for a patent for this product, images of the TFAS are not available.

The superior facet replacement component is driven through the pedicle into the vertebral body. The inferior facet component is attached with bilateral pedicle screws to the pedicle above the level being replaced. The base plate for the inferior component of the system may also be attached to the spinous process via a transspinous process screw to provide additional stability [2].

The TFAS raises two important issues: the ability to revise the facet replacement procedure if necessary and whether the segment treated with TFAS requires a revision to 360° of fusion or an extension of previous fusion from the level above or below. With regard to the first issue, revision procedures after insertion of the TFAS may be problematic, because the prosthesis requires removal of a significant amount of stabilizing bony elements of the posterior column. In addition, the adjacent level pedicles for the superior elements of the system are used to provide anchorage. With regard to the second issue, if a complete facet replacement is performed in the initial procedure, the pedicles at the level above and below are used by the facet replacement system. In addition, the plate spanning the segment as part of the inferior facet component may potentially block the spine surgeon's access to the disc space via a midline approach for replacement of fusion cages, for example. It is important to note that these concerns were derived from the cited patent application's claims and art and may have been addressed in the company's revised design.

The TFAS received investigational device exemption (IDE) from the US Food and Drug Administration, allowing the company to begin important clinical trials comparing the TFAS with conventional pedicle screw fusion procedures.

Other facet replacement technologies

Other companies that are in the process of developing facet replacement technologies include Facet Solutions, Gerra Spine Group, and Quantum Orthopedics [3].

Dynamic neutralization with an artifical posterior tension band

The goal of dynamic neutralization is to realign and stabilize (without fusion) adjacent vertebral segments in an anatomic position to preserve normal intervertebral motion and biomechanics. The Dynesys Spinal System (Zimmer Spine, Warsaw, Indiana) consists of titanium alloy (Protasul 100), pedicle screws, polyester (Sulene-PET) cords, and semistiff polycarbonate-urethane (Sulene-PCU) spacers that are implanted via a classic midline posterior approach. The semistiff spacers are held in place by a central cord and fixed in the heads of the pedicle screws. The polyester cords limit flexion motion, whereas the spacers limit extension. Together, the system acts as an artificial posterior tension band. Thus, intervertebral mobility is limited but preserved, potentially lowering the rates of adjacent segment degeneration while allowing for healing of diseased intervertebral discs or facets.

Summary

Minimally invasive techniques for lumbar disc arthroplasty should shortly be realized and may represent the future of motion preservation spinal surgery. The importance of the role of facet joint replacement should be better understood as long-term data become available on total disc arthroplasty patients. As the indications for constrained and unconstrained disc replacements are better defined, the market potential of facet replacement should evolve. Moreover, because advanced facet

degeneration is a primary contraindication for total disc arthroplasty, facet joint replacement may be an important modality in the surgical treatment of back pain related to facet arthropathy and degenerative disc disease. Posterior tension band devices permitting dynamic neutralization may be useful in slowing the rate of degeneration of the three-joint spinal motion segment while preserving a certain amount of motion and preventing adjacent segment disease.

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