Endoscopic Automated Percutaneous Lumbar Diskectomy

ARTICLE BY STEPHEN DE SISTO, CST

One of the primary goals of surgery always has been to achieve the best result while introducing the least iatrogenic disorder. Surgeons are attaining this goal increasingly in the more recent application of percutaneous surgery for the treatment of lumbar disk disease. Percutaneous lumbar diskectomy, when used in association with modern imaging techniques (CT, MRI), delineates a new concept for the surgical treatment of prolapsed, symptom-producing disks. Its unique distinction, when compared with traditional laminectomy or microlumbar diskectomy, is that the surgeon leaves the spinal canal and its contents untouched during the procedure. Additionally, hospital time shortens, and the patient can return to a productive lifestyle sooner. Also, the patient experiences less discomfort and the muscle and bone remain intact.

History

Several researchers simultaneously pursued the first experimental work with percutaneous diskectomy in differing locations without collaboration. In 1973, while Kambin et al introduced Craig cannulas to decompress an L4-L5 disk at the Graduate Hospital, University of Pennsylvania, Hijikata also was working on a method of percutaneous nuclear extraction at the Toden Hospital in Japan.[1,2] The Journal of Toden Hospital later published Hijikata's observations and method in 1975. Finally, Onik et al introduced the automated nucleotome in 1985.[3]

Great tribute should be paid to Valls, Ottolenghi, and Craig for their work and publications on the posterolateral approach to the spine.[4-6] Although this procedure was originally described for biopsy purposes, the approach was later utilized for diskography, chemonucleotherapy and subsequently for percutaneous lumbar diskectomy. Ottolenghi's schematic drawing demonstrating the proper positioning of the needle via the posterolateral approach has remained unchallenged.[7]

McCulloch further refined this approach to the spine with his dissertation on windows of opportunity to the disk space.[8]

Anatomy and Physiology

Minimally invasive encroachment surgery requires an in-depth knowledge of the anatomy for the sake of safety and efficacy. Otherwise, between the skin the surgeon sees and the bones on the fluoroscopy screen, the rest is left to chance. Within the relevant anatomy are numerous at-risk structures, such as (1) the nerve root, (2) the thecal sac, (3) iliolumbar vasculature, particularly the venous drainage, and (4) the viscera within the retroperitoneal space. The posterolateral approach can damage all the aforementioned structures.

Although 24 of the 33* vertebrae in the spinal column are moveable, allowing for considerable flexibility in the spine, the lumbar region is a common site of injury.

This is mainly because it is one of the most mobile parts of the vertebral column. The shape and strength of the vertebrae, in relation to the intervertebral disks, ligament, and musculature, provide the stability of the vertebral column. Specifically, paired facet (zygapophyseal) joints between articular processes connect the lumbar vertebrae to each other. A resilient fibrocartilaginous layer of intervertebral disk, whose major role is absorbing shock sent through the spinal column, separates each joint. A stout external annulus fibrosus that surrounds an internal plastic nucleus pulposus composes each disk. Annulus fibrosus consists of concentric lamellae of fibrocartilage running obliquely between the superior and inferior vertebrae. The nucleus pulposus, the core of the intervertebral disk, is more cartilaginous than fibrous and has a significant water content before old age or injury. In addition to absorbing shock, the nucleus pulposus also functions as a semi-fluid ball joint during movement of the vertebral column.

There are also strong anterior and posterior longitudinal ligaments that transverse the length of the vertebral column, attaching to both the vertebrae and the intervertebral disks (Figure 1). These ligaments prevent hyperflexion and hyperextension. Several factors limit the normal range of movement in the vertebral

* Not everyone has 33 vertebrae, but the cervical vertebrae always number seven. Variations occur in the number of thoracic, lumbar, and sacral vertebrae in approximately 5% of the population[9] This congenital anomaly evidences itself by a plus or minus change in the number of vertebrae in one region at the expense of another, or without a corresponding change in other regions. Hence, when initially counting vertebrae, it is imperative to begin at C-7, because what may appear to be an extra lumbar vertebra on x-ray film may be an extra thoracic or sacral vertebra.

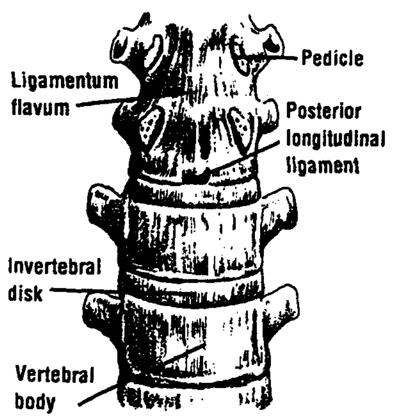

Figure 1. Anterior view of T12-L2.

column. These include tension of the facet joints, thickness and compressibility of the intervertebral disk, and resistance of the muscles and ligaments. In the lumbar region, the most noticeable factors are lateral flexion and extension. Flexion is slightly less marked, in that during hyperflexion of the lumbar region, the nucleus pulposus

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moves posteriorly. This significantly directs pressure against the posterior aspect of the annulus fibrosus. These extreme pressures generated in flexion are just one reason that posterolateral herniations occur frequently in the lower lumbar and lumbosacral regions (Figure 2). Additionally, the posterior aspect of the annulus fibrosus and the posterior longitudinal ligament are the weakest in this area.

On examination of a transverse section of the abdominal lumbar region, it is apparent immediately that the lumbar vertebrae have the largest bodies of all moveable vertebrae. The lumbar vertebrae and their related anatomy make up much of the lumbar mass. The structural differences in this region correlate to the fact that the lumbar vertebrae carry more weight than both the cervical and thoracic vertebrae.

A large, solid, cylindrical mass, called the body, forms each vertebra. The vertebral bodies increase in size as the surgeon progresses downward in the lumbar region. The superior and inferior surfaces of each body are flat except for rounding of the edges along the circumferential borders. A nutrient foramen is on the anterior surface of the body, while a larger foramen is on the posterior side where the basivertebral vein exits. Additionally, a vertebral arch with the body forms an enclosed space called the vertebral foramen which protects the neural tissues (ie, spinal cord, nerve roots) from injury. Anatomically, the joining of two opposing pedicles form the arch.

These two pedicles protrude posteriorly, meet with two opposing laminae, and finally culminate to form the spinous process. The pedicles are short, strong processes that attach superiorly on opposite sides of the vertebral body. The laminae are broad flat plates that extend posteriomedially and slightly inferior from the pedicles to overlap the laminae of the vertebra below only partially. There are also four articular processes from the vertebral arch, two transverse processes, and one spinous process, which combine to make a total of seven vertebral processes.

Ligamentum flavum, usually removed during traditional laminectomy or microlumbar diskectomy, attaches to the superior and inferior borders of the laminae. Numerous intraspinous and supraspinous ligaments, as well as many muscles, attach along the spinous process. Ligaments also straighten the spinal column after flexion. In a more passive way, they help preserve the normal curvature of the spine.

The deep back muscles, which use the lever-like protrusions to position the vertebral column, act

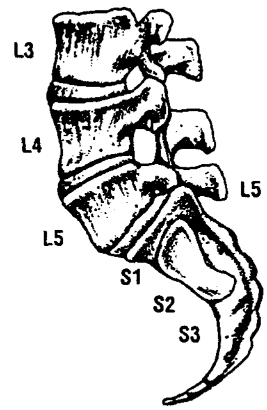

Figure 2. Left lateral view of L3-S1 vertebrae.

upon the transverse processes. In contrast, the articular processes aid in preventing anterior movement of the superior vertebra during flexion, extension, and rotation.

It should be noted here the L5 vertebra can consist of two parts in a limited percentage of the population. Typically, the posterior segment remains, within normal limits, in relation to the lumbosacral arch. However, the anterior portion and the superimposed vertebra may move anteriorly. This condition,

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often noted on radiologic consults, is called spondylolisthesis. If displacement does not occur, it is called spondylolysis.

The principal muscle groups involved in moving the lumbar spine are the rectus abdominis, psoas major, and iliacus, which work together with the psoas, sometimes called the iliopsoas muscle. These muscles all have a role in con-

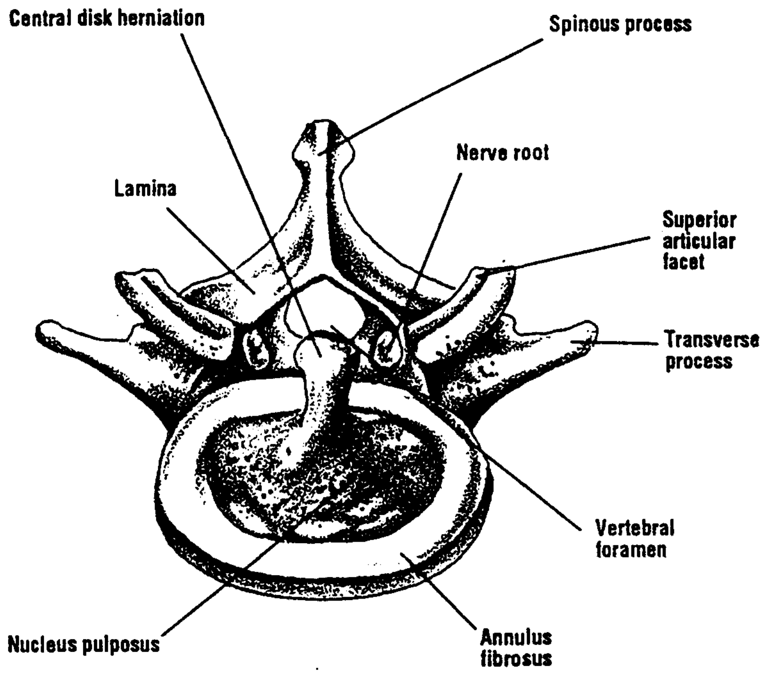

Figure 3. Superior view of a lumbar vertebra with central disk herniation causing cauda equina compression.

trolling flexion. The quadratus lumborum and unilateral action of the iliocostalis lumborum mediate lateral flexion, while bilateral action of the erector spinae and multifidus produces extension. The major muscles involved in rotating the trunk are the rotatores, multifidus, and the external oblique, functioning simultaneously with the opposite internal oblique.

Pathophysiology
According to Jennett and Lindsay,

> Some 90% to 95% of prolapsed lumbar intervertebral disks occur at the L4/5 or L5/S1 levels. Only rarely do disks at two levels prolapse at the same time. Most lesions are lateral and affect either the L5 or S1 nerve root; but the few central protrusions that occur are important because they can produce paraplegia with sphincter involvement.[10]

The nucleus pulposus is located more posteriorly than centrally. Flexion of the lumbar spine pushes the nucleus pulposus even further posteriorly. If degeneration of the annulus fibrosus has resulted from strain in flexion, caused by either a severe stretching or multiple lesser strains, the nucleus pulposus may rupture and prolapse or extrude (Figure 3). The disk material then presses against the thecal sac (cauda equina) of one or more of the spinal nerves. This compression is the underlying cause for the severe lower back pain and leg pain.

Alternatives
The most often recommended initial treatment for symptomatic herniated lumbar disks is a course of conservative treatment. However, a large percentage of patients do not respond to conservative treatment and require surgical intervention. As an alternative to the more traditional lumbar laminectomy or microlumbar diskectomy, researchers now are pioneering less invasive techniques. However, some of these techniques carry with them serious complications. Surgeons have all but abandoned chymopapain and chemonucleolysis due to complications that range from paraplegia to subarachnoid hemorrhage and anaphylaxis.

Physicians can use automated percutaneous lumbar diskectomy (APLD) with an endoscopic nucleotome in patients who fit specific criteria. Endoscopic visualization enables surgeons to examine the disk space to determine whether they have removed enough nucleus pulposus. It also saves bone, hence stabilizing the vertebral column, and reduces surgical trauma, thus shortening the time of post surgical recovery and hospitalization. In addition, it carries no inherent risk of anaphylaxis or other similar complications.

Criteria
As with all surgical intervention, the match between the patient and the proper procedure determines in part the success of the operation. APLD is efficacious in treating patients who display evidence both clinically and radiologically of lumbar radiculopathy, which is precipitated by herniation of the nucleus pulposus. Before APLD, the surgeon should rule out pain that originates from a structure other than the disk or is associated with other mitigating factors such as large, free fragments or severe bony stenosis.

CT or MRI studies should be obtained and the impression of the reading physician should correlate with the patient's clinical and radiologic findings. The physician may use either study to rule out free fragments of nucleus pulposus. Further, these studies provide excellent visualization of focal herniation impinging upon the thecal sac.

Patients not considered candidates for this procedure at this time include those who present with radiologic evidence of a diffuse annular bulge extending out from the entire circumference of the vertebral body, severe lateral body stenosis, calcified disk herniation, severe degenerative facet disease, ligamentum flavum hypertrophy, or free or extruded disk fragments within the spinal canal. Existence of other pathologies or conditions, such as cauda equina syndrome, or other progressive neurological deficits, fractures, tumors, pregnancy, or active infection can be considered contraindications to this procedure. Finally, the shape of the extruded disk has a significant effect on the success of the procedure.

Excellent candidates for APLD will present on CT or MRI with a focal bulge type herniation that occupies no more than 50% of the thecal sac. The impression should be that the herniation migrated neither caudal nor cephalad. All studies should be consistent with the patient's symptomatology. Other criteria would include patients who exhibit no improvement after 6 weeks or more of conservative therapy. Unilateral leg pain with paresthetic discomfort in specific dermatomes, positive (straight leg raising) test or bowstring test, and/or reflex or sensory changes, and wasting or weakness or both are further indications for use.

Special Instrumentation

A C-arm with fluoroscopic image intensification should be available throughout the procedure and properly draped to avoid sterile field contamination. The surgical team should test the patient and table for stable positioning and the ability to work effortlessly with the C-arm, as many clear and sharp images are necessary in the anteroposterior, lateral, and oblique views.

Surgical Dynamics provides the only flexible endoscopic automated nucleotome set available at this time. They also have available flexible curettes and pituitary rongeurs that compliment the nucleotome.

Patient Positioning

The surgeon can perform the APLD procedure in both the prone and lateral decubitus positions. After positioning the patient in the prone position with all pressure points padded, the surgical team flexes the table to decrease lumbar lordosis while opening the disk spaces posteriorly. When performing the procedure in the lateral decubitus position, the team should flex the patient to resemble the fetal position. The physician should pay attention to securely stabilizing the patient to avoid shoulder or hip rotation during the procedure. This is extremely important in that movement causes the instruments to change position in the midst of the procedure. On the anteroposterior view, the spinous process is exactly between the pedicles when the physician positions the patient correctly.

Finally, in order for the surgical team to correctly identify the symptomatic disk space while under fluoroscopy, the sacrum must first be distinguished. Then, with the fluoroscope on continuously, the team must scan superiorly until the fluoroscope is centered over the symptomatic disk.

Operative Procedure

Once the surgeon has selected the operative site, the team should prep and drape the field to include the C-arm. The design of the Endoflex is such that it works with all existing models of endoscopic cameras now in use for arthroscopic and laparoscopic surgery. The surgical team should connect the nucleotome to the camera in the recommended manner, assuring that the eye piece locks firmly into the camera and remains free of moisture and foreign objects. They should next adjust the focusing ring until a clear, sharp image appears on the screen.

The nucleotome comes provided with a sterile drape attached to it. The team should pass this drape to the circulator in the typical manner to maintain sterility of the probe, camera, and cables. The team then attaches the draped assembly to the field in a manner to allow ample slack for use of the probe with the outer cannula.

To utilize adequately the viewing feature of the nucleotome, the surgeon must engage a peristaltic fluid pump with a variable speed outflow control simultaneously while viewing. The pump pressure neutralizes the vacuum within the disk space, which causes nucleus pulposus to obstruct the fiberoptic viewing cable, thus allowing for clear visualization of the disk space. To return to aspiration of nucleus pulposus, one need only deactivate the pump.

Next, the surgeon passes the sterile irrigation tubing set, included in the Endoflex kit, from the field to the circulator for connection to a 1000-cc bag of sodium chloride. The team then primes this system before the surgery. The initial setting for the flow rate should range between 10 and 20 ml/min for optimal aspiration of the cavity and visualization.

Surgical Dynamics recommends that the surgeon deactivate the nucleotome during visualization of the disk space, as the mechanical action of the nucleotome creates a vacuum that greatly reduces visualization. Once the team has established the entry point, they inject a local anesthetic into the skin and underlying musculature along the line of entry for the nucleotome. General anesthetics are contraindicated, as the chance exists of causing nerve root injury. Hence, intraoperative communication with the patient is essential.

At the posterolateral entry point, about 10 cm from the midline, as well as parallel and between the endplates of the involved disk, the physician makes a small stab incision and inserts the Flextrocar. Proper Flextrocar positioning is the most significant aspect, which will subsequently affect the outcome of the procedure. "The inserted needle should penetrate the sacrospinalis, quadratus lumborum, and psoas major muscles in its path."[11] Introduction of the Flextrocar lateral to the boundaries of these muscles will increase the likelihood of perforating the retroperitoneum. If it is too close to midline, it will impede sufficient aspiration. The surgeon should ascertain the Flextrocar position by anteroposterior, lateral, and oblique views, while constantly monitoring the patient for radicular pain throughout the procedure. If the patient experiences radicular pain, the surgical team should withdraw and reinsert the Flextrocar. The tip should just touch the exterior circumference of the annulus when the surgeon stops to verify position and confirm that the spinal canal and its contents are not at risk.

When the team achieves the proper position, they should insert the Flextrocar to the central area of the disk in proximity to the herniation. The team obtains fluoroscopic confirmation again and they remove the knob attached to the Flextrocar. Due to the vast amount of radiation emitted, the team should use lead shielding and follow other recommended precautions.

The surgeon then passes the outer cannula and dilator over the Flextrocar to the exterior circumference of the annulus fibrosus. After fluoroscopic confirmation of position, the surgeon removes the dilator. During this phase of the operation, it is imperative that the Flextrocar stay in position. The doctor now passes the trephine and, following fluoroscopic confirmation of proper positioning, rotates it in a clockwise direction using light pressure. When the physician completes the annulotomy, he or she removes the trephine and Flextrocar, leaving the outer cannula in position.

Next, the surgeon passes the nucleotome through the outer cannula and locks it into position. Once more, the team confirms the position by fluoroscopy before activation of the nucleotome. Initially, the nucleotome cut rate should be set at maximum to help the cutting and aspiration of the disk material. After the aspiration of disk material begins to decrease, the surgical team may lower the cut rate as the possibility of clogging the probe has lessened.

Following approximately 10 minutes of aspiration, the team deactivates the nucleotome and activates the peristaltic pump at a setting between 10 and 20 ml/min to facilitate viewing of the disk space. Team members then turn the camera off and, quite often, activate the nucleotome for another 10 to 15 minutes, or until they have removed a significant amount of disk material. At the completion, they activate the endoscopic camera once again to show there has been satisfactory decompression inside the disk space. Finally, the team withdraws the nucleotome and removes the cannula, placing a sterile bandage over the incision. The team puts the patient back onto the gurney and takes him or her to the recovery room where staff test the patient for movement and strength in the lower extremities. The surgeon should always consider the chance, however small, of postoperative hemorrhage in the overall treatment plan. Postoperatively, the doctor advises the patient to restrict activity and places him or her on a conservative rehabilitation program designed to strengthen and stabilize the lumbar region.

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In conclusion, due to the possible complications arising from traditional lumbar laminectomy and microlumbar diskectomy, surgeons have been seeking less invasive ways of decompressing herniated disks and relieving sciatica. As the data continue to accumulate on percutaneous lumbar diskectomy, it is becoming apparent that in selected cases this surgery is a viable alternative. Furthermore, should the procedure not succeed in alleviating the patient's symptoms, the success of traditional lumbar laminectomy or microlumbar diskectomy has not been compromised. Δ

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References

1. Kambin P, Gellman H. Percutaneous lateral discectomy of the lumbar spine: A preliminary report. *Clin Orthop.* 1983; 174:127.
2. Hijikata SA. A method of percutaneous nuclear extraction. *J Toden Hospital.* 1975; 5:39.
3. Onik G, Helms C, et al. Percutaneous lumbar discectomy using a new aspiration probe. *AJNR.* 1985; 6:290.
4. Valls J, Ottolenghi CE, Schajowicz F. Aspiration biopsy in diagnosis of lesions of vertebral bodies. *JAMA.* 1948; 136:376.
5. Ottolenghi CE. Vertebral body biopsy, aspiration biopsy. *J Bone Joint Surg.* June 1955; 37-A.
6. Craig FS. Vertebral body biopsy. *J Bone Joint Surg.* 1956; 38-A:93.
7. Kambin P. History of surgical treatment of herniated lumbar discs. In: Mayer and Brock, eds. *Percutaneous Lumbar Discectomy.* New York, NY: Springer-Verlag; 1989:4.
8. McCulloch JA, Waddell G. Lateral lumbar discography. *Br J Radiol.* 1978; 51:498-502.
9. Bergman RA, et al. *Compendium of Human Anatomic Variaton: Text, Atlas, and World Literature.* Baltimore, Md: Urban and Schwarzenberg; 1988.
10. Jennett B, Lindsay KW. *An Introduction to Neurosurgery.* 5th ed. 1994:263.
11. Kambin P, Brager M. Percutaneous posterolateral discectomy: Anatomy and mechanism. *Clin Orthop.* 1987:223:145.

Bibliography

Frymorer JW, et al. *The Adult Spine: Principles and Practice.* City, State: Raven Press; 1991.
Lindsay KW, Jennett B. Ruptures of the lumbar intervertebral disc. In: *An Introduction to Neurosurgery.* 5th ed. Boston, Mass: Butterworth and Heinmann; 1994.
Mayer M, Brock M, eds. *Percutaneous Lumbar Discectomy.* New York, NY: Springer-Verlag; 1989.
McCulloch JA. *Principles of Neurosurgery for Lumbar Disc Disease.* New York, NY: Raven Press; 1989.
Moore KL. *Clinically Oriented Anatomy.* 3rd ed. Baltimore, Md: Williams and Wilkins; 1992.

Stephen R. DeSisto, *CST, former education chairperson for AST Chapter 66, is a certified surgical assistant and presently works as an independent first assistant in various hospitals throughout the Denver area.*