

Current Status of Minimally Invasive Surgical Procedures in the Lumbar Spine

a report by

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The last decade has seen an explosion of interest in 'minimally invasive' procedures in all areas of medicine. This is particularly true for spinal disorders. Some of these techniques represent significant advances in spine care, and have assumed major roles in the care of patients with back-related symptoms. Others appear to offer no benefit, and in some cases may actually be less effective than conventional treatments.

Percutaneous lumbar discectomy techniques hold significant promise; however, at the present time, lumbar microdiscectomy remains the gold standard for the surgical treatment of lumbar disc protrusion with radiculopathy.

Intradiscal electrothermal therapy (IDET) is emerging as a useful option for selected patients with intractable mechanical back pain, whose only other option has historically been a spinal fusion. Percutaneous fusion techniques are in their infancy, and may also prove to be of benefit for these patients. Although not a minimally invasive procedure, disc arthroplasty ('artificial disc') was approved by the US Food and Drug Administration (FDA) in 2004, and may be appropriate for selected patients with mechanical back pain.

Percutaneous vertebral augmentation, including vertebroplasty and kyphoplasty, has become the treatment of choice for many patients with intractable back pain secondary to vertebral insufficiency fractures in the elderly. This article chronicles the evolution and current status of several minimally invasive spinal procedures and provides a comparison with conventional treatments.

Percutaneous Discectomy

Over the last 40 years, numerous percutaneous techniques have been developed for the treatment of

radiculopathy secondary to lumbar disc herniation. The effectiveness of these methods must be considered in the context of the conventional procedure – lumbar microdiscectomy.

Lumbar Microdiscectomy

Lumbar discectomy as a treatment for herniated lumbar intervertebral discs was first reported by Dandy in 1929,¹ and subsequently described in greater detail by Mixter and Barr in 1934.² After initial modifications, the procedure was basically unchanged until the operating microscope was introduced as a technical adjunct in 1978. This resulted in better illumination and magnification of the operative field. The operation came to be known as lumbar microdiscectomy or microsurgical discectomy, which is carried out through a smaller incision with less dissection than a standard discectomy. Microdiscectomy is generally regarded as a technical modification of standard discectomy, rather than a distinctly different procedure.

Currently, the procedure is carried out through a small posterior incision, which is centered over the disc space. Most surgeons use some form of magnified vision, either loupes or an operating microscope. Variable amounts of lamina bone, ligamentum flavum, and medial facet are removed as needed to provide access to the disc herniation, which is then removed. The remaining disc nucleus is removed to varying degrees based on surgeon preference. The open surgical approach permits exploration for sequestered disc fragments and decompression of bony foraminal stenosis. In some centers, the procedure is now carried out through tube retractors of various sizes to limit dissection of paraspinal tissues.

Surgical outcomes are generally excellent. Success rates as high as 95% have been reported in single surgeon

1. Dandy W E, "Loose cartilage from intervertebral disk simulating tumor of spinal cord", *Arch. Surg.* (1929);19: pp. 660–672.
2. Mixter W J, Barr J S, "Rupture of intervertebral disc with involvement of spinal canal", *N. Engl. J. Med.* (1934);211: pp. 210–215.
3. Atlas S J, Deyo R A, Keller R B et al., "The Maine Lumbar Spine Study, Part II: 1-year outcomes of surgical and nonsurgical management of sciatica", *Spine* (1996);21: pp. 1,777–1,786.

series. Results obtained in routine clinical practice are not as robust, but are still excellent. In a prospective study of 219 patients undergoing lumbar discectomy performed by multiple surgeons in community hospitals, with one-year minimum follow-up, Atlas reported that sciatica was improved in 81.3% of patients, and that 86.5% of patients would choose surgery again.³

These results serve as an important benchmark when analyzing outcomes with percutaneous approaches.

Chemonucleolysis

The first percutaneous therapy for lumbar disc herniation was chemonucleolysis with chymopapain, a procedure that was initially reported in 1964. Chemonucleolysis was followed by automated percutaneous discectomy, and later by laser-assisted percutaneous discectomy. Each of

US as a result of anaphylactic reactions and neurologic complications associated with inadvertent injection of chymopapain into the subarachnoid space.

Automated percutaneous discectomy was developed by Onik and Maroon,⁴ as an alternative to microdiscectomy. After enjoying a brief period of popularity in the 1980s, interest in this procedure waned after it was found to be less effective than microdiscectomy.⁵

Laser-assisted discectomy also dates to the 1980s. Although there have been some encouraging clinical reports of this procedure, critical assessment of laser-assisted discectomy has been hampered by the fact that the technique has never been directly compared with microdiscectomy.⁶

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these procedures has the same goal – to relieve nerve root compression by removing a portion of the central nucleus pulposus. Chemonucleolysis accomplishes this by means of a chemical reaction, automated percutaneous discectomy by means of mechanical removal, and laser-assisted discectomy by means of laser energy.

These techniques permit only a central nucleotomy; they cannot be targeted at localized areas of disc pathology. They are limited to patients with contained disc herniations with an intact annulus. Unlike microdiscectomy, these procedures cannot be used in patients with extruded disc fragments that have broken through the annulus and posterior longitudinal ligament.

Chemonucleolysis clearly has some clinical benefit; however, it has been found to be less effective than surgery in randomized, controlled trials. Chemonucleolysis has largely been abandoned in the

experienced hands, but are generally regarded as being less effective than microdiscectomy. Neither has gained widespread acceptance.

Endoscopic discectomy techniques have been described by several investigators. The term endoscopic discectomy actually encompasses several different, but related procedures. This lack of procedural uniformity has made it difficult to assess the usefulness of the technique. No single endoscopic technique has emerged as being superior to the others or as superior to microdiscectomy.

Electrothermal disc decompression is a novel procedure that involves the targeted disc ablation using heat energy applied via thermal catheters placed within the disc. This is a variant of intradiscal electrothermal therapy, which will be discussed in the following section. Preliminary clinical data indicate that the procedure may be of benefit in small, contained disc protrusions.⁷

4. Onik G, Mooney V, Maroon J C et al., "Automated percutaneous discectomy: a prospective multi-institutional study", *Neurosurg.* (1990);26: pp. 228–232.
5. Kahanovitz N, Viola K, Goldstein T, Dawson E, "A multicenter analysis of percutaneous discectomy", *Spine* (1990);15: pp. 713–715.
6. Choy D S, Ascher P W, Ranu H S et al., "Percutaneous laser disc decompression: a new therapeutic modality", (published correction appears in *Spine* (1993);18: p. 939), *Spine* (1992);17: pp. 949–956.

Numerous minimally invasive procedures have been proposed for lumbar disc herniation over the last 40 years. Some have shown clinical benefit, but none has been demonstrated to be superior to microdiscectomy. Lumbar microdiscectomy therefore remains the gold standard for surgical treatment of lumbar radiculopathy secondary to disc herniation.

Intradiscal Electrothermal Therapy

Among patients with persistent mechanical back pain, one potential pain generator is the intervertebral disc. The diagnosis of discogenic pain has been the subject of much controversy. Discography is performed to evaluate for intrinsic disc pathology and reproduction of the patient's usual pain. In the past, the treatment of discogenic pain consisted of medical therapy (rest, physical therapy, bracing and injections) and, if necessary, spinal fusion. Recently, a new minimally invasive out-patient procedure called IDET has been offered as an alternative to spinal fusion in selected patients.

One-year⁸ and two-year⁹ outcome data on IDET-treated patients demonstrate statistically significant improvement in their back pain when compared with their pre-procedure pain. A recent double-blinded, placebo-controlled study also confirms a statistically significant reduction in the treatment group's back pain when compared with a control group.¹⁰

Percutaneous Fusion

Conventional techniques for spinal fusion often involve lengthy incisions and extensive muscle dissection. It would be desirable to have less invasive approaches that achieve equivalent or better outcome with less approach-related morbidity.

Percutaneous techniques for posterior lumbar interbody fusion and pedicle screw fixation of the lumbar spine have recently been described in cadaveric and clinical studies. These procedures can also be linked to sophisticated image guidance systems to enhance accuracy of implant placement.

Endoscopic techniques have been adapted for anterior approaches to the lumbar spine. An example of this is laparoscopic anterior lumbar interbody fusion. Although this approach is promising, significant limitations have been identified. In a recent analysis of anterior lumbar interbody fusion comparing laparoscopic and open techniques, the laparoscopic approach resulted in longer operative times and a much higher rate of sexual dysfunction in males, while the open approach provided better visualization and was technically less demanding. The laparoscopic anterior approach to the lumbar spine appears to be an example of 'technology overshoot', and most surgeons now favor open approaches for anterior lumbar fusion.

Another promising area has been the development of bone graft substitutes, such as bone morphogenetic proteins (BMP), which are designed to enhance bony fusion while at the same time obviating the need for bone graft harvest, which is often associated with donor site pain. Recombinant human bone morphogenetic protein-2 (rhBMP-2) was recently approved by the FDA for clinical use in anterior lumbar interbody fusions.¹¹ Bone morphogenetic proteins and other bone graft substitutes are assuming a more prominent role in spinal fusion procedures.

Minimally invasive spinal fusion techniques are in their infancy and are evolving quickly. Currently, the majority of lumbar fusion procedures are carried out via open approaches, with percutaneous approaches being utilized at selected centers, based on surgeon preference.

Disc Arthroplasty

One of the problems with spinal fusion is accelerated adjacent segment degeneration. Disc arthroplasty ('artificial disc') was conceived in an effort to treat a painful disc while at the same time preserving motion and decreasing the risk of adjacent segment degeneration. Pioneering work on the artificial disc dates back to the 1950s; and the first device to receive regulatory approval in the US was the DePuy Charité disc, which was approved by the FDA in October 2004. Several other disc

7. Deen H G, Fenton D S, "Electrothermal disc decompression: preliminary experience", *International Intradiscal Therapy Society, Scientific Program annual meeting, Munich, Germany (2004)*.
8. Karasek M, Bogduk N, "Twelve-month follow-up of a controlled trial of intradiscal thermal anuoplasty for back pain due to internal disc disruption", *Spine (2000);25: pp. 2,601-2,607*.
9. Saal J A, Saal J S, "Intradiscal electrothermal treatment for chronic discogenic low back pain: prospective outcome study with a minimum 2-year follow-up", *Spine (2002);27: pp. 966-973*.
10. Pauza K, Howell S, Dreyfuss P et al., "A randomized, double-blinded, placebo controlled trial evaluating the efficacy of intradiscal electrothermal anuoplasty (IDET) for the treatment of chronic discogenic low back pain: 6-month outcomes", presented at: *10th Annual Meeting of the International Spinal Injection Society; Austin, Texas (7 September 2002)*.
11. McKay B, Sandhu H S, "Use of recombinant human bone morphogenetic protein-2 in spinal fusion applications", *Spine (2002);27(16, suppl. 1):S66-S85*.

protheses are currently undergoing clinical trials. It is important to note that disc arthroplasty is not a minimally invasive procedure, but rather involves an open anterior operation on the lumbar spine.

Disc arthroplasty is controversial. Proponents believe this procedure represents a major leap forward in the treatment of mechanical back pain, while others believe that more information is needed on safety and efficacy before these devices can be recommended for routine clinical use.

Vertebral Augmentation Procedures

Osteoporosis is a major health problem in postmenopausal women and elderly patients of both sexes. The morbid event in osteoporosis is often a spinal compression fracture. To illustrate the scope of the problem, there are an estimated 700,000 new vertebral compression fractures each year in the US.

Spinal compression fractures are associated with considerable morbidity and suffering. Traditional treatments are often not satisfactory. Conservative management with analgesics, bedrest, and bracing is often not effective. Extensive reconstructive spinal surgery is poorly tolerated by elderly, debilitated patients. Recently, percutaneous techniques to augment the collapsed vertebral body have been described. These include vertebroplasty and kyphoplasty.¹²

Vertebroplasty

Vertebroplasty involves the injection of methylmethacrylate into the injured vertebral body via a needle that is percutaneously placed using a transpedicular or extrapedicular approach. Vertebroplasty provides pain relief by reinforcing the damaged vertebral body. Due to the fact that the methylmethacrylate must be forced into the cancellous bone matrix, high injection pressures and a very liquid injectate are required, with potential for extravasation.

Kyphoplasty

Kyphoplasty is a newer method of vertebral augmentation. In this procedure, a balloon placed inside the vertebral body is inflated to create a cavity, which is filled with methylmethacrylate using a low-pressure injection. Similar to vertebroplasty, the procedure provides pain relief by restoring the load-bearing capacity and stiffness of the injured vertebral body. In addition, the balloon inflation has the capacity to reduce the fracture by restoring vertebral body height.

Both kyphoplasty and vertebroplasty are effective treatments of vertebral compression fractures. A 95% improvement in pain and significant improvement in function has been reported with both techniques. In addition, kyphoplasty was found to increase the height of the fractured vertebral body and decrease kyphosis by 50%, if performed within three months of the injury.

Kyphoplasty may have a slight advantage through its potential to restore height of the vertebral body and to correct the kyphosis caused by the fracture. Kyphoplasty also appears to have a lower risk of extravasation, since the methylmethacrylate can be placed in a more viscous form, via a low-pressure injection, in contrast to vertebroplasty, which requires a more liquid injectate placed via high-pressure injection.

These procedures are safe, but not completely risk-free. There is a potential for spinal cord or nerve root compression due to extravasation of methylmethacrylate, pulmonary embolism from methylmethacrylate, and infection. The risk of re-fracture of a treated level appears to be quite low; however, the patient is still at risk for future vertebral compression fractures at other levels. The most common indication for vertebral augmentation is a benign osteoporotic compression fracture, but these techniques can also be used in selected patients with painful compression fractures secondary to multiple myeloma and metastatic tumors.

Conclusion

Interest in percutaneous treatment of spinal disorders dates back to the 1960s, and has accelerated in the last decade. Percutaneous discectomy has the most extensive history of any percutaneous spinal procedure but, to date, none of these procedures has been shown to be superior to open microdiscectomy, which remains the 'gold standard' for surgical treatment of lumbar disc herniation with radiculopathy.

Mechanical back pain is a difficult clinical problem, and outcomes after spinal fusion have been less than ideal. IDET, disc arthroplasty, and percutaneous fusion are new techniques that may prove beneficial for selected patients.

Percutaneous vertebral augmentation is now the treatment of choice for many patients with spinal compression fractures. Kyphoplasty and vertebroplasty have both been shown to be much more effective and safer than conventional therapies. Kyphoplasty has the potential advantage of fracture reduction and improved spinal alignment in some patients and theoretically is slightly lower risk than vertebroplasty. ■

12. Lane J M, Johnson C E, Khan S N, Girardi F P, Cammisia F P Jr "Minimally invasive options for the treatment of osteoporotic vertebral compression fractures", *Orthop. Clin. North Am.* (2002);33: pp. 431-438.