Advances in Minimally Invasive Lumbar Spinal Surgery

a report by

Mark R Foster, PhD, MD, FACS
Orthopaedic Spine Specialist, Western Pennsylvania

Spiral instrumentation seems to have matured, with many improvements being made to familiar methods and, most recently, the emergence of minimally invasive surgery (MIS). The development of spinal MIS has taken place over a longer period of time, from orthopaedics—the now obsolete open meniscectomy—to arthroscopy, then to modern techniques, and general surgery (laparoscopic cholecystectomy). As the use of MIS in the spine expands, it must be remembered that the surgical objective—whether decompression or stabilization—must be fully achieved, otherwise the procedure should be considered a failure. In this article, the history of MIS is presented as a background to its diverse application in the lumbar spine today.

Disc Surgery
MIS is really an extension of basic surgical principles such as gentle tissue handling, hemostasis, and so on; however, there is a risk that a less invasive procedure may fail to achieve the objective of surgery. The initial minimally invasive procedures for the treatment of lumbar disc disease include: chemonucleolysis, introduced by Lyman Smith in 1964; percutaneous manual nucleotomy, introduced by Hijikata in 1975; microdiscectomy, first performed by Yasargil in 1968; automated percutaneous lumbar discectomy—the Nucleotome—described by Onik in 1984; laser discectomy, first performed by Ascher and Choy in 1987; endoscopic discectomy, first used by Schreiber and Suezawa in 1986 and improved by Mayer, Brock, and Matthews in 1996; microendoscopic discectomy, introduced by Smith and Foley in 1995; and intradiscal electrothermy (IDET), first reported by Saal and Saal in 2000. These procedures are used for neural compression and radiculopathy; minimally invasive techniques for fusion came later.

Microdiscectomy is well established for herniated nucleus pulposus (HNP) using either a small incision or a tube such as Atavi™ (Endius, now Zimmer) that is inserted through dilators to the working area. In combination with lighting from optical fibers or the use of a microscope, this method provides excellent visualization and achieves comparable results to the use of a wider, open procedure. Percutaneous discectomy is basically a variation of nuclear ablation or decompression. Chymopapain—which does not require an incision—used to be popular, but results were less satisfactory than those achieved with microdiscectomy; unfortunately, infrequent but severe allergic complications occurred, sometimes leading to transverse myelitis or even death. Percutaneous aspiration of the disc with a Nucleotome and nuclear ablation techniques with lasers have been shown to have comparable results to those achieved with placebo. Arthroscopic microdiscectomy (AMD) is a directed fragmentectomy where the working channel has a pituitary rongeur that can be angled up toward the herniation within the disc to remove a fragment, effectively performing the same operation as a microdiscectomy. Anecdotally, in 1985 one of my patients returned to full manual labor three weeks after AMD; however, ideal candidates for this procedure are rare.

Complications
The development of AMD included anatomical studies to examine the so-called ‘safe zone of Kambin’ through which the discectomy is performed, with the intradiscal procedure visualized arthroscopically through a second portal. All percutaneous techniques have been recorded to yield high success rates, but no studies to date have demonstrated any of the minimally invasive procedures listed above to be superior to microsurgical discectomy, which continues to be the standard with which all other techniques must be compared. Some risks are inherent to all surgery, such as dural tear or infection, but there are also risks that are specific to this procedure, such as psoas hematoma, which occurred in one of the original 100 patients to be operated on using microsurgical discectomy. There is also a risk of irritation of the dorsal root ganglion and a causalgia-type pain in the lateral zone, which can be symptomatic.

Integral Dissection
A discectomy may include a laminotomy, which removes the ligamentum flavum and sometimes some of the lamina, but usually leaves the posterior elements, spinous processes, and ligaments intact. Wider decompression—e.g. for central stenosis, lateral recess stenosis, and foramenotomy—would sacrifice more of the posterior elements. It seems that the stability afforded by the interspinous ligament is diminished due to the loss of tension that occurs with spondylolisthesis and loss of disc height; as a result, the ligament is no longer structurally relevant except as a limit of flexion. However, many surgeons seek to preserve these ligaments. While treatment of radiculopathy resulting from neural compression requires removal of disc material or facets, axial pain associated with instability—whether objective or clinical—may be a sign of further progression of the disc deterioration and loss of supporting structures, and in some cases may require treatment with stabilization or fusion. This fusion may be posterolateral—intratransverse process with or without facet fusions—or interbody—anterior, posterior, lateral, or transfornaminal lumbar interbody fusion (ALIF, PLIF, XLIF, and TLIF, respectively).

The mid-line exposure of a laminectomy may be necessary or even preferred in some patients, and is customary in patients in whom a PLIF cage is being placed. When a mid-line incision is used, dissection and lateral retraction of the muscles is performed for the primary procedure (a decompressive form of laminectomy). A percutaneous microendoscopic bilateral decompression of the lumbar stenosis can be performed to decompress the spinal canal and may be as effective as an open laminectomy, despite the minimally invasive...
techniques and visualization with a microscope. However, results for this technique are closely related to careful patient selection.29

Extension to Fusion
Posterolateral fusion has been performed with both stripping and retraction of the muscles from the mid-line or bilateral paramedian incisions; the latter is known as the Wiltse approach, which splits the multifidus, iliocostalis, and longissimus. Alternatively, a long mid-line incision can be made laterally to allow deeper paramedian exposures; this disguises the procedure, but stresses the skin. Posterolateral fusion requires dissection out past the facet joint to decorticate the transverse process and place a pedicle screw. This denervates the muscles, as they are detached from the segmental innervation, and segmental blood supply is locally reduced. The effect of this dissection is accepted, but not well understood. Special care is required when placing the cephalad pedicle screw as it will be in the vicinity of the facet joint of the next segment up, and injury to that joint—even without diffusion—could cause deterioration at the adjacent level. Minimally invasive techniques should limit this dissection, reduce or eliminate the denervation, and preserve facet joint integrity and motion; these potential advantages are attractive, but they have not yet been documented or rigorously investigated.

TLIF has been performed on a minimally invasive basis.24 Structural support can be provided by allograft bone or interbody cages, and placement of the pedicle screws can be performed in conjunction with posterolateral fusion using a tubular retractor and a muscle-sparing approach. Minimally invasive techniques have also been extended to fusion. For example, anterior interbody fusion can be performed by placing bone graft into the disc space after removal of the disc material, if the bone graft is small enough to be inserted percutaneously, while structural bone grafts or cages can be inserted laparoscopically.25 Minimally invasive techniques have been popularized for inserting pedicle screws using image guidance,26 for example Pathfinder™ (Abbott) or Viper™ (DePuy); this is used as an adjunct to spinal fusion due to the increased success and achievement of fusion, but may also be used as a supplement to ALIF or other techniques without posterolateral fusion (Sextant™, Medtronic). Several minimally invasive techniques have been used to perform laparoscopic ALIF, PLIF, posterolateral only fusion, and internal fixation fusion.27 Cages can be inserted using minimally invasive techniques, for example PLIF cages, TLIF, and intratransverse process bone grafts.28 Some procedures include an endoscopic-type interbody fusion with posterior translaminar fixation or, alternatively, posterolateral fusion via a small incision.29 With stabilization, and especially with cages, pedicle screws may be used as “back-up” without the usual posterolateral intertransverse fusion—the technique for which they were developed and are most commonly used.

Significance
In MIS, with its careful tissue handling, minimal tissue dissection, and good surgical technique, the expectation is that there should be less infection, pain, bleeding, and scarring, and reduced time in hospital, thus facilitating post-operative recovery and return to function. Patients who undergo lumbar fusion are often those who have been injured at work or those who are unable to continue working because of their spinal problem. As a consequence, return to work is an economic issue, both for the patients—who may be financially compromised—and for their employers—who will be paying wages that are usually higher than medical costs; this is in addition to the pain and impairment suffered by patients. Prompt resolution would address the economic concerns, particularly the short-term issues of time in hospital, pain, bleeding, and muscle damage. Long-term outcomes would be to evaluate function and extent of recovery, as well as return to work or function; however, these are not yet documented. Minimally invasive pedicle screw implantation may or may not include posterior or posterolateral fusion; it is therefore important that comparisons are made only with like procedures. The effects of customary lateral muscle retraction with a decrease in local blood flow from segmental vessel interruption, denervation of the retracted muscle, and—in some patients—the retention of the lamina and spinous process seem different, but rigorous examination is still required.