Low Back Pain: An Interventional Approach to Diagnosis and Treatment

Evolution of Minimally Invasive Surgical Approaches
Percutaneous Discectomy

Merrill W. Reuter, MD, PhD, FACS - Director
Asya E. Mikulinsky, MD, FACPS - Fellow
Diane Marie Anger, BS - Director of Research

Minimally Invasive Spine Fellowship
Advanced Orthopaedics
Lake Worth Medical Center
Lake Worth, FL

Introduction

The 21st century is not the birthplace of minimally invasive surgery but it certainly is the childhood for minimalists in many fields of medicine. Initially a surgeon's dream, percutaneous instrumentation has traversed the line from general and gynecological surgery to specialties such as pain management, orthopaedics and neurosurgery. Spinal discectomies and decompression are becoming less invasive in recent years, although still relatively few spine surgeons are trained as minimally invasive spine surgeons. The advent of endoscopic instrumentation has allowed many surgical procedures to be cut in time and expense. Percutaneous spine surgery has been no exception. Endoscopic lumbar discectomy has given the patient a quicker recovery and functionality than the conventional, open procedure. These procedures are now being done in outpatient surgery centers. As surgeons in the new millennium we see that our ability to treat patients with lumbar disc disease in this faster, less invasive and less expensive approach had its roots back in the 18th century. While in what took a few hundred years worth of discovery, trial and error, where physicians and scientists went from curiosity, idea and crude operative practices, we are now in the forefront of truly minimally invasive surgical treatment of spinal disease (Table 1).

Early History

Early on physicians realized that they needed access to see the disease process inside a live human being to better understand the disease process itself and to be able to treat diseased anatomy surgically. While early investigations did not include the spinal anatomy, those early experimental procedures gave birth to percutaneous spinal surgery today. In 1795 Bozzini (1) was the first to use an endoscope which used a candle as the endoscopic light source to view and examine the rectum and uterus. As crude as it was, it was the beginning of modern endoscopic

surgery today. Lighting, however, was the real problem for these first medical pioneers and these early physicians found differing ways to overcome this obstacle. Nitze (2) in 1879 used an overheated glowing piece of platinum at the tip of a cystoscope. This technique needed a constant water source for cooling which rendered the procedure impractical. In 1906 Rosenheim (3) incorporated the use of a miniature electric lamp for better lighting. Shortly thereafter he made an improvement with a rigid instrument called Bruening's electroscope.

Modern History

Chemonucleolysis was the first minimally invasive technique to treat a lumber disc herniation in modern medicine. In 1963 Smith (4) utilized intradiscal injections of chymopapain to treat ten patients with sciatica. In the 1970s the technique was widely used but because of associated complications such as transverse myelitis and anaphylactic shock, physicians began looking for other alternatives to treat herniated discs (5).

A significant advancement of the laparoscope was made by a British physicist named Hopkins in 1966 (13). His invention of the rod lens system enabled a light transmitter with air spaces between rod-shaped glass elements to improve resolution and illumination. Laparoscopy was slow to be accepted because many physicians simply could not see well enough to prevent anatomic injury. The advent of practical and sufficient lighting sources helped laparoscopy achieve the status it has today. Kurt Semm (7), a German gynecologist, began using in the late 1960s an automatic insufflator which continuously monitored intra-abdominal pressure and gas flow. He named his technique "operative pelviscopy." Semm developed a myriad of laparoscopic instrumentation to advance the field of laparoscopy into what we see today.

As the evolution of spinal surgery modernized it was apparent that the trend was a minimalist approach to treating disc pathology. In 1983 Kambin (8) published his results of

work he had done in 1973 where he performed percutaneous insertion of a Craig cannula and a small forceps into the disc space during open laminectomy and discectomy. He further developed the technique utilizing modified Craig instrumentation. Kambin, for more than two decades now, has published well over two dozen articles describing his continuing refinement of the percutaneous discectomy technique. In describing the difference between arthroscopic microdiscectomy (endoscopic magnification and illumination) and nucleotomy, Kambin (9) wrote that in arthroscopic microdiscectomy, the emphasis is placed on evacuation of the posterior collagenized fragments, which are responsible for mechanical compression of the nerve root. Nulceotomy, on the other hand, only allows for central evacuation of the nuclear mass. In 1991 he described arthroscopic microdiscectomy through a posterolateral approach (10). Utilizing fluoroscopy allowed visualization of the triangular working zone and safe entry of instrumentation with an external diameter of 7-8 mm into the intervertebral disc. The new technique allowed evacuation and decompression of contained herniated discs, and also the introduction of instrumentation for decortication of the vertebral end plates and bone grafting for percutaneous interbody fusion. He commented that endoscopic laser nucleolysis could be useful in the treatment of herniated discs. He concluded that arthroscopic microdiscectomy was a safe, effective and cost efficient treatment for herniated disc pathology. His own carefully selected patients who underwent the technique had a 85% success rate. Kambin and Savitz (11) published in 2000 a series of 600 arthroscopic microdiscectomy cases. After many years of proactive refinement of his technique, he concluded that advantages of the technique include one hour operative time, negligible blood loss, lack of significant spinal canal scarring, and anterolateral fenestration of the annulus for continuing relief of intradiscal pressure and nerve root decompression. (Figure 1 - The black triangle represents the working zone)

Hijikata (12) in 1975 published his alternative research to open treatment of disc herniations. He described percutaneous nucleotomy under local anesthesia where the disc material was partially resected by a posterolateral approach. Removal of the nucleus pulposus within the central portion of the disc reduced intradiscal pressure which alleviated nerve root irritation and pain receptors around the herniation. Because of this early experimentation only a small amount of disc material was retrieved and anatomic structures of the spinal canal could not be visualized although Evans blue dye was utilized for discography in the disc space. In 1989 (13) Hijikata published his results from his 12 year series and reported that of the 136 cases followed, 72% of the patients were satisfied with their surgery.

In 1983 Friedman (14) described a new technique for lumbar disc removal called "percutaneous discectomy." He concluded that it could be a viable alternative to other discectomy techniques for certain selected cases. Caspi (15), four years later reported successful partial discectomies with a lateral percutaneous approach in eight of ten patients. Brazilian author Magalhaes (16) wrote in 1985 of using automated percutaneous discectomy for the first time in Brazil.

Onik published his study of percutaneous lumbar discectomy in four pigs and three cadavers in 1985 (17). He wrote that 80-100% of the nucleus pulposus was removed in the pigs and 30% of the cadaver disc was removed. Onik believed that his findings had promise in the treatment of herniated discs in patients and could be an alternative to chymopapain and traditional open discectomy. There were also other articles published by Onik and coauthors between 1985 and 1989 describing this technique on patients (18-21). Onik developed a 2mm blunt-tipped suction cutting probe (nucleotome) for automated percutaneous lumbar discectomy at L4-5 or higher levels. The small size of the probe minimized nerve injury. He utilized

radiography for visualization intraoperatively with CT scanning and C-arm fluoroscopy as a guide while cutting and aspirating the nucleus pulposus. The nucleotome was inserted into the proper disc space with specifically designed instrumentation, guided by landmarks similarly utilized for needle placement in chemonucleolysis. In 1996 Onik reported the use of automated percutaneous biopsy in the diagnosis and treatment of infectious discitis (22).

In 1986 a computer chip TV camera attached to a laparoscope enabled participation from other surgeons and allowed video images with better clarity and resolution (23). The surgical video age was conceived and technology has been improving ever since. Reddick (24) was the first to use an endoscopic disposable clip applier in 1988 which allowed the average surgeon to perform laparoscopic surgery requiring vascular manipulation. In the decade that followed, laparoscopic surgery was continually being improved upon with instrumentation and refinement of technique to include laparoscopic lumbar discectomy (25). The ability to visualize the operative field with cameras was the catalyst spine surgeons were waiting for to give birth to the new age of minimally invasive spine surgery. These advances in minimally invasive surgery are responsible for the new type of spine surgery that we perform today. While minimally invasive surgery was not originally intended for use in the spine, we today reap the benefits of these advances, both for ourselves and for our patients.

Not all the clinical studies showed favorable results following minimally invasive surgery. In 1990 Kahanovitz (26) published a multi-center study of single level percutaneous discectomy at L4-5 or L5-S1 after confirming herniated nucleus pulposus (HNP) with either computerized tomography (CT), myelogram or magnetic resonance imaging (MRI). He concluded that percutaneous discectomy was not as successful or predictable as conventional open surgery. In 1990 Yonezawa (27) published results from his study which began in 1986 on

percutaneous intradiscal laser nucleotomy (PILN). The purpose was to develop PILN as an alternative to chemonucleolysis and other percutaneous discectomy techniques. The use of lasers in laparoscopic surgery was first reported by Bruhat (28) in 1979. Laser energy is used to dissect, coagulate and/or ablate (vaporize) the tissues. The continuing effort to incorporate lasers into discectomy was described by Kopchok (29) in 1992. He reported that the advantages of lasers include miniaturized, safe and effective energy delivery for herniated disc removal. Choy (30-31) subsequently published his results of posterior, extrathecal approach to the L5-S1 disc for percutaneous laser disc decompression (PLDD). He concluded it was a safe, simple and without neurologic sequelae alternative to entering the disc with a curved needle. He also reported that it did not preclude subsequent open surgery should that become necessary (32).

Obenchain (33) pioneered laparoscopic lumbar discectomy in 1991. Mack (34) was the first to report use of video assisted thorascopic surgery in 1993. In 1994 Regan (35) presented results on laparoscopic fusion of the lumbar spine using a threaded fusion cage. While the debate on fusion versus discectomy alone continues, the purpose of this chapter is not to discuss fusion versus non-fusion, but we do see a downward trend in the use of fusion cages. From the mid to end of the 1990s a handful of authors have reported their success with laparoscopic lumbar discectomy with and without fusion. In 1995 Zelko (36) reported that a laparoscopic lumbar discectomy series of selected 23 patients was a safe alternative to posterior microdiscectomy. Slotman and Stein (37) in 1996 reported that their series of L5-S1 laparoscopic lumbar discectomy revealed a significant therapeutic improvement over traditional laminotomy for discectomy. Their experience was that it was a safe and cost-effective technique, one in which patients had little postoperative morbidity. Patients who underwent the surgery returned to work at a median of 17 days compared to 79 days with laminotomy.

Although percutaneous discectomy was becoming more utilized by minimalists, many spine surgeons practiced the traditional open approach because they were not convinced the newer treatment was an effective, safe alternative. Kleinpeter (38) in 1995 published his study comparing 313 patients treated with minimally invasive open lumbar disc surgery (OLDS) to 13 patients treated with percutaneous endoscopic lumbar discectomy (PELD). The study revealed that percutaneous discectomy may be appropriate for a few patients, but it was not a substitute or alternative to conventional open discectomy. However in the same year Black (39) reported on his study of automated percutaneous discectomy with KTP and Nd: YAG laser assistance. His conclusion was that PLDD, if selected for appropriate patients, was a viable treatment choice. Thus, the importance of diagnostic imaging as a tool for selecting patients, PLDD began to gain attention. Botsford (40) in 1995 discussed the use of diagnostic radiology for patient selection, intraoperative imaging, postoperative evaluation, and analysis of complications. Gangi (41) reported that with 119 patients who underwent PLDD with CT and fluoroscopic guidance for their lumbar disc herniations, 76.5% had a good or fair result. He concluded that PLDD with appropriate imaging was safe and effective for treating herniated intervertebral discs. Min (42) in 1996 also reported that CT discography was an accurate and useful diagnostic tool in aiding preoperative patient selection and intraoperative guidance on targeted discs.

Teng (43) reported on a large multi-center series of automated percutaneous lumbar discectomy (APLD) performed in China from 1992 to 1994. The success rate measured by Hijikata's criteria was 83% at one year. Nine patients developed discitis, the only reported kind of complication out of the 1,582 discectomies. Teng concluded that APLD with his instrumentation had excellent results and indications for discectomy **may** include back pain alone.

Ditsworth (44) wrote in 1998 of his work employing endoscopy to pass completely through the foramen into the spinal canal (transforaminal). The advantage of this spinal endoscope was its small size and ability to bend up to 90 degrees depending on the guiding cannula. It enabled the spine surgeon to remove free fragments and reconfigure the disc, relieving root and dural displacement at all lumbar levels. Ditsworth further stated that the percutaneous transforaminal endoscopic technique could be an effective, safe approach for disc removal via the foramen, especially in cases where the disc presents itself for direct removal.

In 1998 Slotman (45) published his results comparing traditional laminectomy (LAM) to lumbar discectomy (LLD) based on clinical efficacy and cost effectiveness. Half of the 62 adult patients underwent the LAM and the other half LLD. All had L5-S1 disc herniations. He reported that compared to LAM, LLD is safe and cost effective for treating L5-S1 herniations. Furthermore, LLD reduced operative blood loss, hospital stay, costs and rehabilitation time. Laparoscopic lumbar discectomy also increased long-term pain relief and improved functional outcome. When LLD was performed at an outpatient surgical facility it further decreased costs.

A certain percentage of patients will need to be reoperated on for failed discectomies following either an open or minimally invasive procedure. However, Dangaria (46) in 1998 published his results of 15 patients with failed percutaneous discectomy (PD) who he went on to treat with laser-assisted disc decompression (LADA) at the same level. He concluded that the use of the laser (Neo:Yag), via LADA technique, had a low success rate after a previous failed PD.

Choy (47) in 1999 published his results for treating two patients with erectile dysfunction utilizing PLDD. He cited that along with his own findings of herniated discs being the cause of erectile dysfunction, the literature reported 23 other similarly related cases. His conclusion was

that PLDD was an effective treatment for erectile dysfunction as a result of disc herniation pathology.

As in the evolution of any new medical technology, it can be difficult to ascertain definitive treatment protocols, safety and efficacy of these so called scientific breakthroughs. Literature review can yield conflicting results of similar therapies to like pathology or can depict different approaches to treating the same clinical situations. The advent of minimally invasive spine surgery has been no exception. While chemonucleolysis has been an effective treatment for herniated discs worldwide, it currently has little backing in the United States due to reports of adverse events in this country and many surgeons therefore are reluctant to use it as a primary treatment choice, although literature from outside the United States supports the wide use of chymopapain. Surgical approaches to disc herniation where traditional, open surgery gave way to a more minimalist approach have stagnated under similar scrutiny that chymopapain has.

Gibson in 1999 (48) and 2000 (49) published his Cochrane Review of randomized controlled trials for the surgical management of lumbar disc prolapse and degenerative lumbar spondylosis. In his article he stated that there was strong evidence of the effectiveness of surgical discectomy versus chemonucleolysis versus placebo. He furthermore stated that there was considerable evidence to support the clinical effectiveness of discectomy for carefully selected patients with sciatica caused by lumbar disc prolapse that failed to resolve with conservative treatment. Similarly, Schmid (50) in Switzerland analyzed 69 prospective and retrospective studies in the treatment of lumbar disc herniations. This study compared standard discectomy, microdiscectomy, chemonucleolysis, laser therapy and percutaneous nucleotomy. The results showed that both the standard and microdiscectomy techniques had a higher success rate (4% recurrence rate) than with chemonucleolysis (17% recurrence rate), laser (18%

recurrence rate) or percutaneous nucleotomy (14% recurrence rate) treatment.

Yeung (51) in 2000 published his results from a seven year series of percutaneous spinal endoscopy and discectomy. His patients were treated with the Yeung endoscopic spine system (YESS), which has an endoscope with a 2.8 mm working channel. When indicated by visualized spinal pathology the manual discectomy was supplemented by KTP laser (100 patients), radio frequency with electrothermal probe (400 patients), chymopapain (50 patients), and/or intraoperative steroids (100 patients). Yeung also employed a slotted tube system which allowed for access through the foramen to perform foraminoplasty and removal of osteophytes and extruded fragments. The overall result of this approach was good to excellent in 86.4% of cases. He concluded that the 2.8 mm operating channel scope allowed for clear visualization of annular tears, disc fragments, foraminal osteophytes, and the epidural space. Yeung and the YESS instrumentation, with the use of the adjuvant therapies, laser, radiofrequency, chymopapain and intradiscal steroids along with the slotted tube system, have contributed greatly to the advancement of minimally invasive techniques available for endoscopic discectomy.

A study comparing the results of automated percutaneous discectomy (APD) versus chemonucleolysis was published in 2000 by Krugluger (52). Both groups had similar preoperative Oswestry scores and were quite comparable. Both groups had significant improvement of neurologic deficits and of Oswestry score after their procedures. The APD group had one intraoperative complication and had two revision surgeries at the same level. In the chemonucleolysis group, only one revision was required. Krugluger reported that at two year follow-up the chemonucleolysis patients were significantly better with respect to their Oswestry score, back pain and leg pain recurrence.

The authors of this chapter also published a series of laparoscopic discectomy in 2000 (25). Since 1995 we performed laparoscopic lumbar discectomy on 32 patients. Our patient population was limited to those with back pain who had radicular symptoms and were candidates for surgery. Many had central disc herniations.

Our overall success rate was 84% good or excellent outcome. Fifteen patients were rated excellent, 11 good, three fair, two poor and one patient was lost to follow-up. Of those 31 patients followed four patients required fusion with or without laminectomy.

Twenty-six patients had an L5-S1 discectomy. Nineteen of those patients had a >1 year follow-up. Of those, 17 had a good or excellent outcome (89%). Complications were identified in three patients. One patient with excellent pain relief had persistent retrograde ejaculation, another patient requiring laminectomy and subsequent fusion had persistent neuritic leg pain, and the last patient had a left iliac vein laceration requiring open repair.

Continued evolution of percutaneous discectomy techniques will improve the minimally invasive technique and will make the procedure even easier for both patients and surgeons. During the past ten years the technique has been continually refined to the point that the procedure is now done in outpatient facilities where the patient can go home just hours after the surgery. The posterolateral, endoscopically and laser assisted lumbar discectomy, is depicted in Figure 2. Patients have a high functional ability and go back to work in a matter of days, rather than weeks. The pain from surgical incisions has been significantly minimized due to the usage of small portals rather than larger incisions. Operating through holes the size of needles, fiberoptic cables and miniaturized optical devices will replace present day endoscopes. The reduction in size will further minimize epidural scarring and nerve retraction that has been previously seen with open laminectomy/laminotomy.

From what was hailed as a medical breakthrough just in the early 1990s, minimally invasive endoscopic spine surgery continues to improve, becoming even less invasive. Robots are now being utilized as surgical assistants to aid with procedures that simply require a steady set of hands. From this point further we can only venture to guess what the next decade will achieve in the field of minimally invasive spine surgery. D

This minimally invasive approach is applicable for fusions as has been presented by Zuckerman (53) and others. While the debated question of whether to fuse these herniations has not been answered, many patients have similar outcomes whether fused or not. The added advantage of mechanical stabilization has not been demonstrated to outweigh the risks of longer operative time and hardware failure when compared to non-fusion in all situations. While some patients do report less pain with fusion, the functionality and recovery rates of both fused and non-fused patients remains almost identical. Therefore, as technology and our understanding of what works continues to progress we will be able to do more with less invasiveness.

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Table 1 Historical Evolution of Minimally Invasive Surgical Approaches: Percutaneous Disectomy

Year	Main Author	Contribution
1795	Bozzini	Employed candle endoscope to examine rectum & uterus
1879	Nitze	Utilized over heated glowing piece of platinum at tip of cystoscope
1906	Rosenheim	Used miniature electric lamp for better lighting and Breunig's electroscope
1963	Smith	Utilized intradiscal injections of chymopapain
1966	Hopkins	Incorporated rods lens system to improve resolution and illumination
Late 1960s	Semm	Employed automatic insufflator which continuously monitored intra-abdominal pressure and gas flow called "operative pelviscopy"
1973	Kambin	Performed percutaneous insertion of Craig cannula and a small forceps into disc space during open laminectomy and discectomy
1975	Hijikata	Reported his use of percutaneous nucleotomy
1979	Bruhat	Published his use of lasers in laparoscopic surgery to dissect, coagulate and/or ablate (vaporize) tissues
1983	Friedman	Described his percutaneous discectomy technique
1985-1989	Onik	Reported his findings on the use automated percutaneous lumbar discectomy (APLD)
1986	Way	Described the employment of computer chip TV camera attached to laparoscope which allowed better video images
	Yonezawa	Published his technique on percutaneous intradiscal laser nucleotomy (PILN) he developed as alternative to other techniques
	Choy	Published his results on posterior, extrathecal approach to L5-S1 disc for percutaneous laser disc decompression (PLDD)
1991	Obenchain	Reported his laparoscopic lumbar discectomy technique

1992	Teng	Reported large multi-center series of APLD performed in China with 1 year success rate of 83%
1993	Mack	Published his use of video assisted thorascopy for diseases of the spine
1994	Chiu	Reported on percutaneous microdecompressive endoscopic cervical discectomy
	Regan	Published his findings on the use of laparoscopic fusion of the lumbar spine with threaded cage
1995	Kleinpeter	Published study comparing minimally invasive open lumbar disc surgery (OLDS) to percutaneous endoscopic lumbar discectomy (PELD)
	Black	Reported study of APLD with KTP and Nd: YAG (PLDD) laser assistance
	Botsford	Discussed use of diagnostic radiology for patient selection
	Zuckerman	Reported utilizing minimally invasive instrumented laparoscopic fusion
1996	Gangi	Published results of PLDD with CT and fluoroscopic guidance for lumbar disc herniation with 76.5% success rate
	Min	Reported CT discography was an accurate and useful diagnostic tool in aiding patient selection
	Chiu	Discussed percutaneous arthroscopic thoracic discectomy with or without laser (mid back surgery without stitches)
1998	Ditsworth	Employed endoscopy to pass completely through foramen into spinal canal (transforaminal)
	Slotman	Published results comparing laminectomy to lumbar discectomy based on clinical efficacy and cost effectiveness
	Dangaria	Published results on failed percutaneous discectomies that had low success rate treated later with laser assisted disc decompression (LADA)
1999	Choy	Treated two patients with erectile dysfunction utilizing PLDD with good outcomes
	Gibson	Published Cochrane Review of randomized, controlled trials for surgical mgt. of lumbar disc prolapse and degenerative lumbar spondylosis
2000	Schmid	Reported his analysis that microdiscectomy techniques had higher success rate than standard treatments
	Yeung	Published 7 year series of percutaneous spinal endoscopy and discectomy utilizing his YESS treatment

	Krugluger	Reported his study comparing results of automated percutaneous discectomy vs. chemonucleolysis with better results for the latter
	Reuter	Reported series of 32 patients treated with laparoscopic discectomy with 84% success rate