Percutaneous Lumbar Diskectomy

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Abstract

The development of an approach for percutaneous lumbar diskectomy (PLD) began over 20 years ago. Since then, clinical investigations of manual and automated PLD techniques have recorded an average success rate of 50% to 70%. Currently, the indications for PLD include (1) a major complaint of acute unilateral leg pain localized to a single dermatome associated with a single-disk herniation; (2) neurologic signs or symptoms appropriate to a single-disk herniation; (3) magnetic resonance imaging, computed tomographic, or diskographic evidence of a single herniation contained within the annulus of the lumbar disk; and (4) failure of a well-managed course of conservative treatment to relieve the pain and symptoms. Conventional laminotomy/laminectomy, with or without the use of a microscope or surgical loupes, remains the usual method of surgical care for symptomatic lumbar disk disease. The role of PLD awaits further prospective randomized controlled studies.

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Surgical procedures traditionally used to treat herniated lumbar disks include laminectomy and diskectomy, laminotomy and diskectomy, and microsurgical diskectomy. In 1975 Hijikata described the possible alternative of percutaneous lumbar diskectomy (PLD) using a modified pituitary forceps inserted through a 5-mm cannula.[1] He reported an overall success rate of 72% in patients treated by this method. Kambin began to use a similar approach in the United States in 1973. Later, Onik and colleagues developed instrumentation that has been widely used since 1988 for the percutaneous aspiration of herniated nuclear material. In the past 5 years, a number of systems have been evaluated for their effectiveness in removing disk tissue in the laboratory, but technical problems have limited their widespread clinical use.

Four major advantages are cited to support PLD as a treatment method in selected patients with lumbar herniated nucleus pulposus: (1) The technique requires only a small incision for introduction of the probe, which is thought to reduce epidural fibrosis at the operative site. (2) The technique can be performed with the use of local anesthesia on an outpatient basis, which theoretically contributes to a faster return to normal levels of activity and lower health costs. (3) The use of PLD does not preclude the patient from undergoing any of the alternative procedures if the operation fails. (4) The risk of major or life-threatening complications accompanying another less invasive procedure, chemonucleolysis, is believed to be nonexistent.

Preoperative Evaluation

The key to a successful outcome is appropriate preoperative evaluation, including history, physical examination, and imaging studies, combined with proper surgical technique. Before surgical intervention is considered, the patient should have completed at least 6 weeks of conservative therapy without success. A conservative program may include education, limited bed rest, antiinflammatory drugs, and physical therapy. The ideal candidate has unilateral leg pain that is more severe than the back pain. Some patients with central disk herniation that produces bilateral leg pain may also be selected for this technique. If the patient complains of constant pain, unrelieved by any postural change, it is unlikely that he or she is a candidate for a percutaneous procedure.

The physical examination must demonstrate nerve-root irritation accompanied by a positive straight leg-raising test that reproduces sciatica. A patient with a positive cross-straight leg-raising test, indicative of a large lesion or extruded fragment, is unlikely to be a candidate for the percutaneous technique. Neurologic evaluation should confirm motor weakness or sensory and reflex changes indicative of single-nerve-root radiculopathy.

Imaging is critical to confirm the presence of a lesion amenable to PLD (Fig. l). Magnetic resonance (MR) imaging is the most appropriate imaging technique and should demonstrate an asymmetric protrusion or herniation of the lumbar intervertebral disk

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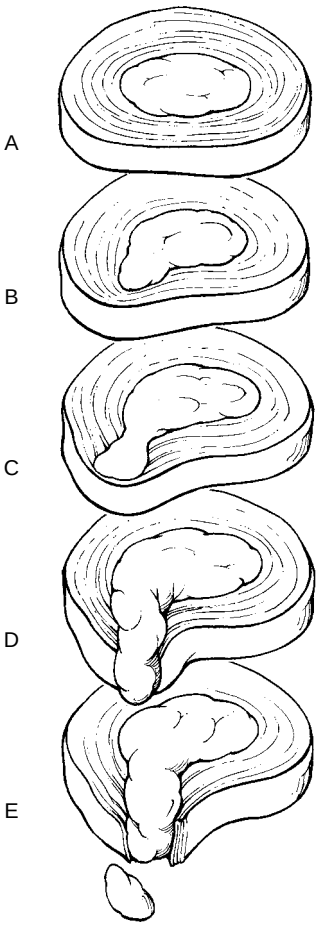

Fig. 1 **A,** Normal. **B,** Initial distention of the annulus occurs with posterior displacement of the nucleus, causing protrusion of the intervertebral disk. **C,** Subsequent radial tear of the annulus allows the nucleus to completely protrude posteriorly through the annulus and rest underneath the longitudinal ligament. Shown here is a contained disk herniation (prolapse), which is an indication for PLD. **D,** Subsequent protrusion through the posterior longitudinal ligament results in an extruded or uncontained disk herniation. **E**, Finally, a piece of the nucleus separates and migrates to form a sequestered herniation. The latter two situations are not amenable to use of PLD.

with displacement of the nerve root[2] (Fig. 2). Visualization of the solid black line representing the posterior longitudinal ligament–posterior annulus complex confirms containment of the nuclear material in both the sagittal and the axial planes. If MR imaging is not available, diskography can be used to confirm containment of the nuclear material by the posterior longitudinal ligament. The size of the protrusion is important. If the herniation is 50% of the anteroposterior diameter of the potential thecal sac space or more, it is likely that an extruded fragment is present, rendering the patient not a good candidate for PLD. Other patients who are not candidates include those whose imaging studies show extreme disk-space narrowing, lateral recess stenosis, or significant lumbar spondylosis.

In a small but important number of patients, the colon is posterior to the psoas muscle (Fig. 3). Because PLD requires that instruments be placed from the posterolateral position into the disk space, a planning computed tomographic (CT) scan of the entire abdomen through the disk space of interest should be obtained with the patient in the prone position, even if use of the lateral decubitus position is planned (Fig. 4).

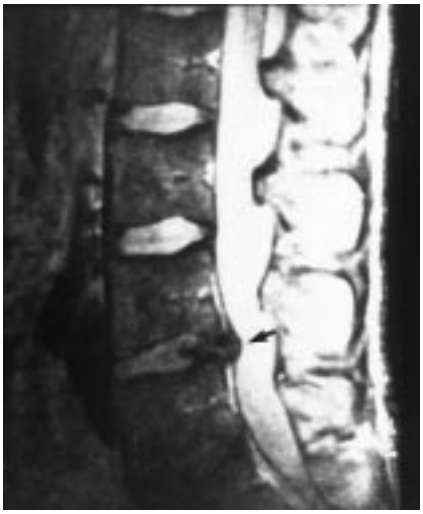

Fig. 2 T1-weighted sagittal MR image confirming a contained herniated nucleus pulposus at L4-5. Arrow indicates intact posterior longitudinal ligament. (Reproduced with permission from Gill K, Blumenthal SL: Clinical experience with automated percutaneous discectomy: The Nucleotome® system. *Orthopedics* 1991; 14:757-760.)

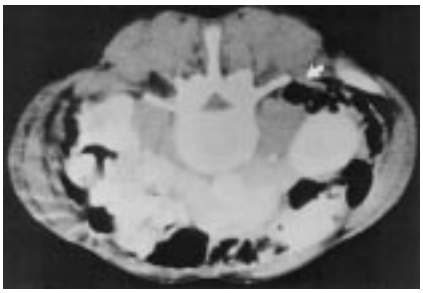

Fig. 3 Abdominal computed tomographic scan. Arrow indicates markedly displaced colon insinuating itself behind the psoas muscle; clearly, a posterolateral approach could perforate the bowel. (Reproduced with permission from Onik G, Helms C (eds): *Automated Percutaneous Lumbar Discectomy*. San Francisco, Radiology Research and Education Foundation, 1988, p 78.)

Manual PLD Procedure

Kambin prefers the prone position to avoid lateral collapse of the spine. He also recommends intravenous administration of 1 g of a first-generation cephalosporin as antibiotic prophylaxis. To begin his procedure, he inserts a long 18-gauge needle into

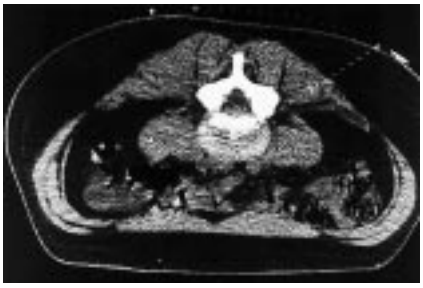

Fig. 4 Unmagnified abdominal CT scan through the disk space. Computer-generated lines, available with all CT scanners, can be used to calculate the distance of the entry point from the midline and a path to the center of the disk. (Reproduced with permission from Onik G, Helms C (eds): *Automated Percutaneous Lumbar Discectomy*. San Francisco, Radiology Research and Education Foundation, 1988, p 81.)

the annulus. Anteroposterior and lateral fluoroscopy is used to obtain a lateral view of the endplates and to confirm central positioning of the needle (Figs. 5 and 6) or Kirschner wire. Following this, a small-diameter Kirschner wire is introduced through the needle, followed by placement of a cannulated blunt trocar and then successively larger sheaths up to 6.9 mm in outer diameter. Through the 6.9-mm sheath, with an internal diameter of 4.9 mm, is placed a 2.5-mm cutting device, which performs the initial annular fenestration. This hole is then enlarged to 4 mm. Straight and curved forceps are introduced through the sheath into the disk space to remove nuclear material (Fig. 7). The length of the forceps permits only a 2-cm penetration beyond the tip of the sheath. Additional material is aspirated with a 50-cm^3 Luer-Lok syringe fitted into the cutting device.[3]

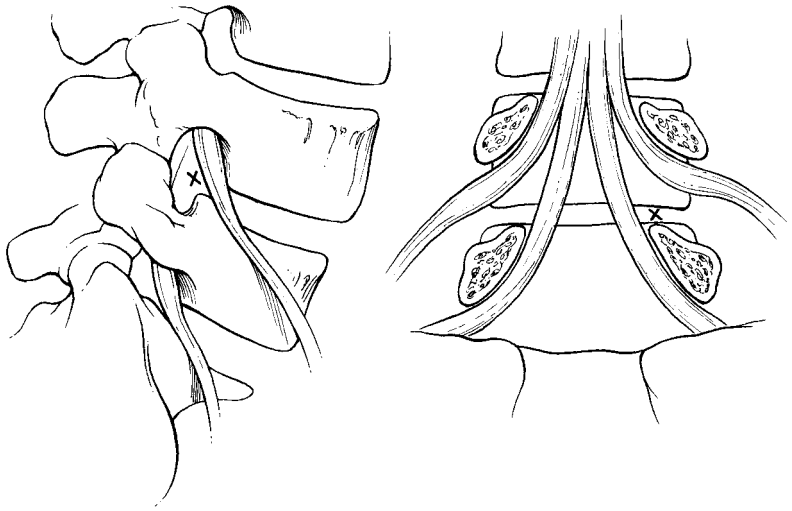

Fig. 5 Lateral **(left)** and anteroposterior **(right)** views of radiographic outline showing position of exiting nerve root. The image-intensifier tube must be tilted to produce perpendicular projections in both planes. On the anteroposterior view, the target for disk entry should be the lower half of the disk in line with the pedicle; on the lateral view, the posterior vertebral body at X for L4-5.

Automated PLD Procedure

The lateral decubitus position is used, with a beanbag placed under the flank to prevent lateral spinal collapse. An 18-gauge diamond-tipped trocar is inserted and directed to the posterolateral corner of the annulus. This position is confirmed with fluoroscopy before penetrating the annulus, similar to the Kambin technique. This avoids the potential of neural injury or incidental dural puncture. Next, a 2.5-mm cannula is inserted against the annulus, and an end-cutting trocar is used to perform the annulotomy. At the L5-S1 level, the pelvic anatomy may require the use of a curved trocar.

An aspiration probe is then inserted into the disk space, and the position is confirmed by fluoroscopy. The probe has an 8-inch-long, 2-mm-diameter needle with a blunt, rounded, closed end and a single side port near the distal tip. The aspiration probe, which can be turned 180 degrees, works a sharpened surgical blade in a reciprocal cutting action at up to 180 cycles per minute (Fig. 8). Suction is applied

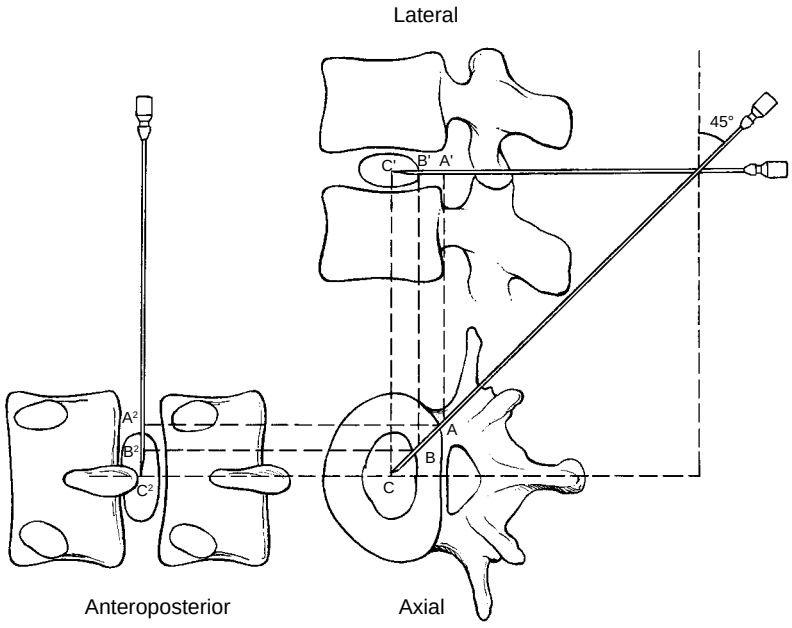

Fig. 6 Anteroposterior, lateral, and axial views showing perfect needle placement in the center of the disk. On the lateral view, the needle is midway between and parallel to the endplates.

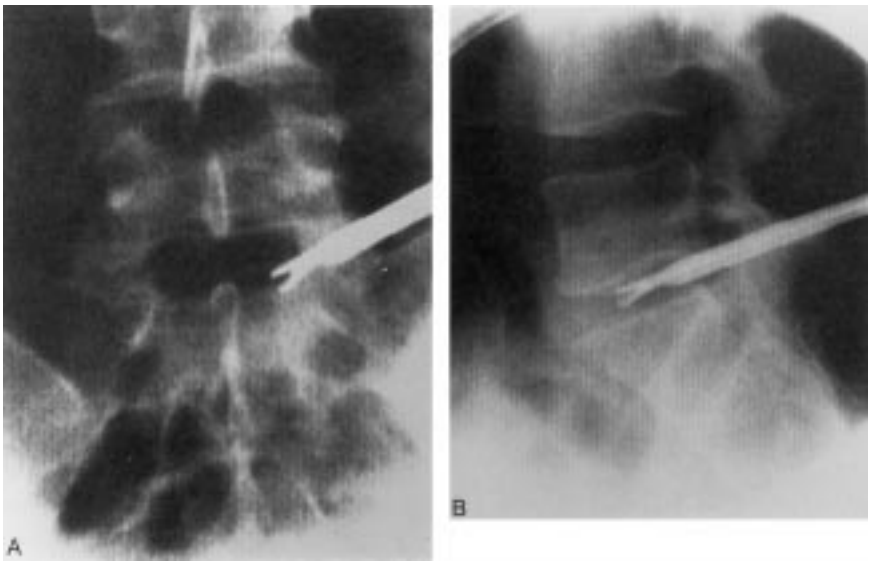

Fig. 7 **A,** Anteroposterior intraoperative study showing forceps at L5-S1 disk space. **B,** Lateral intraoperative study showing forceps at L5-S1 space. (Reproduced with permission from Kambin P, Schaffer JL: Percutaneous lumbar discectomy: Review of 100 patients and current practice. *Clin Orthop* 1989;238:24-34.)

through the inner cannula, aspirating the nucleus pulposus into the port of the needle. The nuclear material, suspended in saline, is then evacuated into a collection bottle.

Recent improvements in instrumentation allow movement of the tip of the device during the procedure. By rotation of a dial, the tip can be pulled 90 degrees from the normal extended position to cover more disk area (Fig. 9).

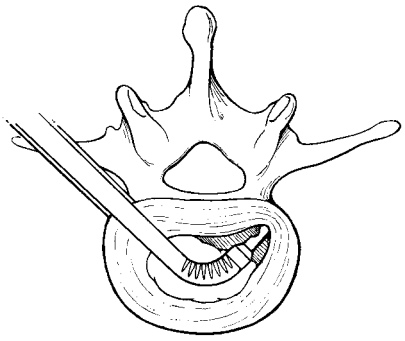

Fig. 9 Angled (90-degree) position of newer surgical instrumentation.

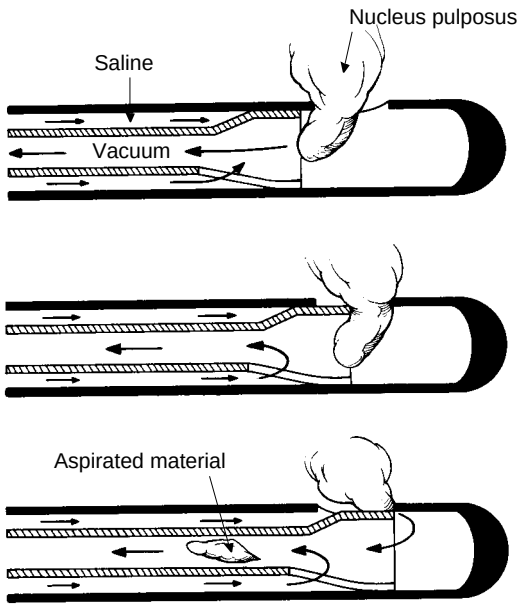

Fig. 8 Views of proximal end of aspiration probe. **Top,** Vacuum draws nuclear material into cutting port. **Center,** Reciprocating guillotine cutting action ensures maximal safety with optimal cutting. **Bottom,** Nuclear material, suspended in irrigation fluid, is aspirated from probe.

Laser Diskectomy

The Nd:YAG laser system has been used for percutaneous disk removal. Because of the proximity of neural tissue, precise aiming and delivery of the laser beam is crucial. The laser is pulsed in tiny microsecond bursts, thus limiting the amount of thermal damage. The time required to vaporize the nuclear material is 1 to 2 minutes, compared with the 10 to 30 minutes it takes to remove the material with the mechanical or automated PLD method. New developments in laser technology may allow other laser systems (super-pulse CO_2, Ho:YAG, and Pr:YAG excimer) to be used clinically in automated or manual PLD procedures.[4] Some experts recommend combination of the manual PLD technique and laser technology.[5]

Published Results

The first extensive reviews of PLD, both automated and manual, appeared during 1987. At that time both procedures were considered investigational. The seven studies included a total of 173 subjects: 117

who underwent manual PLD and 56 who underwent automated PLD. Success rates ranged from 50% to 80%. However, all studies contained serious methodologic flaws. None compared the outcome of PLD with that of the available alternatives, nor did these investigations use objective outcome measures to compare the patient's condition before and after treatment. All outcomes described were qualitative and based on subjective judgment. None of the studies reported using control measures to prevent biasing of results. Patient selection criteria were not clearly defined and reported. Typically, the person assessing outcome was the surgeon who had performed the procedure. In only one study were patients followed up for longer than a 6-month period.

From 1987 to 1989, 22 new PLD studies were reported. The total patient population of these studies was 938 subjects, of whom 611 underwent automated PLD and 327 underwent manual PLD. The overall clinical success rate for all studies was 75%, but the quality of the new evidence remained weak.

In January 1989 the American Medical Association's Diagnostic and Therapeutic Technology Assessment program published an assessment of PLD based on a survey of neurosurgeons and orthopaedic surgeons and a review of the literature.[6] Only 24% of the physicians surveyed believed that the effectiveness of PLD had been established, and 60% considered the procedure still investigational. The overriding concern was the limited nature of the results reported. In a subsequent assessment of automated PLD,[7] only 13% of the panelists believed that the effectiveness of PLD had been established, and 40% considered the procedure still investigational. The panelists recognized a need for more prospective, controlled, randomized clinical trials comparing automated PLD with microsurgical diskectomy to resolve these issues.

Since 1989, 25 additional studies have been published. The patient population totaled 3,500 subjects (3,400 underwent automated PLD and 100 underwent manual PLD). Included in this body of literature are the only multi-institutional studies of PLD. One of these was conducted in the United States by Onik et al.[8] The success rate of all these studies was approximately 75%, with an average follow-up period of 9 months (range, 1 to 144 months).

The multi-institutional study of Onik et al[8] was coordinated by the developers and manufacturers of the automated PLD system. The protocol for inclusion in the study required positive MR and CT studies, completion of 6 weeks of conservative care, and any two of the following four clinical features: (1) major complaint of sciatica, (2) paresthetic discomfort in a specific dermatome, (3) positive straight leg-raising test, and (4) two of four possible neurologic findings (wasting, weakness, sensory alteration, and reflex alteration). The study included 506 patients, 66% of whom met the protocol study criteria and 34% of whom were treated outside the protocol. Overall, 66% of the patients in the study were reported to have a successful outcome. The success rates were 75% for in-protocol patients and 49% for out-of-protocol patients. Of the 81 treatment failures in the in-protocol group, 41 (51%) were in patients who underwent subsequent laminectomy, microdiskectomy, or fusion. In 30 cases these surgical procedures revealed free fragments not identified by the preoperative radiologic examination. Most of these were in patients who had undergone CT or myelography prior to the use of high-resolution MR imaging. With an overall complication rate of 1%, the authors considered the procedure safe.

To date, Davis and colleagues[9] have the largest personal experience with the procedure, having reported on 518 consecutive non-worker's-compensation patients, with an 85% success rate defined at 6-month follow-up. Older patients fared more poorly in this series. The duration of nonsurgical care was not specified. They also treated 44 patients with previous laminectomies who had pain-free intervals before the recurrence of pain; the success rate in this group was 91%.

Schweigel[10] reported a 14-year experience with 3,000 cases in which chymopapain was used and a 2½-year experience with 300 cases of automated PLD. The success rate was 78% for the percutaneous procedure, which is comparable with that for chymopapain therapy.

Maroon and Allen[11] reported a retrospective review of automated PLD procedures performed by 35 private neurosurgeons or orthopaedic surgeons. A successful outcome was reported in 82.1% of 1,054 cases. Two disk-space infections and one hematoma were reported. In all cases, the treating surgeon reported and reviewed his own results.

Swiecicki[12] compared the outcome of automated or manual PLD, chymopapain therapy, and laminectomy. Each treatment group contained 100 consecutive patients. The same surgeon performed all procedures. The results after PLD were superior to those after chymopapain therapy and laminectomy by all measures of outcome. The percentage of patients who returned to work after PLD was 83%, compared with 75% after laminectomy and 58% after chymopapain therapy. Postoperative physical therapy was

required by 15% of PLD patients, compared with 37% of laminectomy and chymopapain patients.

The results of the prospective studies of automated and manual PLD for 2,065 patients showed an average success rate of approximately 77%. The average success rate with the manual technique was 83%, slightly better than the 75% average success rate reported in prospective series of automated PLD.

In a prospective series, Davis and Onik[13] reported the results in 200 consecutive patients who underwent automated PLD. Selecting patients consecutively for a clinical series study reduces the probability of selection bias. Unlike most other studies, worker's-compensation cases were not excluded from this patient review. Overall, 155 cases (77.5%) were reported as treatment successes, and 45 (22.5%) were reported as failures.

Kambin and Schaffer[14] reported their results in a prospective series of 100 patients, all followed up for more than 1 year and some for up to 6 years. Using the modified MacNab criteria, they noted 87% successful results with no major complications. They stated that the key to their success was meticulous selection for PLD. Their minor complications included a psoas hematoma and one transient sensory and distal motor deficit; all of these complications resolved.[15]

The outcome of PLD in the retrospective studies was very similar to that in the prospective studies. The overall average success rate was approximately 74%. The best success rate for individual studies was 90% for automated PLD and 86% for manual PLD.[16] The average follow-up was longer in the manual PLD studies (25 months) compared with the automated PLD studies (9 months). The most commonly documented cause of failure was the presence of free disk fragments not identified during the preoperative radiologic studies (32 cases).

I have reported my clinical experience with the automated PLD system in retrospective reviews.[17,18] The outcomes were based on the MacNab criteria for pain relief, performance status, and medication dependence. In 109 patients with an average follow-up period of 4.2 years, the overall success rate was 79% (85% in private-pay cases and 70% in worker's-compensation cases). Twenty-three patients (21%) underwent additional surgery and were classified as treatment failures. No infections or nerve or blood vessel injuries occurred; however, there was one symptomatic psoas hematoma, which resolved in 10 days with nonsurgical care.[19] Seventy percent of the patients returned to work within 2 weeks of the procedure. The best results in this series were in patients under 30 years of age, in whom the success rate was 90%. Five patients with far lateral disk herniations also had a high success rate (90%). Older patients fared more poorly in this series.

To date, the only prospective, randomized, controlled study, that by Revel et al,[20] has shown the most disappointing results. In this multicenter trial, automated PLD was compared with chemonucleolysis. The study included a total of 141 patients followed up for a minimum of 1 year. Seventy-two patients were randomized to chymopapain, and 69 patients were allocated to automated PLD. Excellent or good results were obtained in 37% of the patients who underwent automated PLD, compared with 66% in the chymopapain group. Twenty-three automated PLD patients (33%) underwent surgical revision, compared with five chymopapain patients (7%). There are several concerns with the study by Revel et al, including the possibility that free fragments were not excluded and the fact that there was no requirement that leg pain be greater than back pain. Sixteen percent of patients had severe degenerative disk disease, and 9% had significant disk-space narrowing, which is a contraindication for automated PLD.

Other poor results with automated PLD have been reported by Kahanovitz et al,[21] who noted that only 21 of 39 patients (54%) were able to return to work 17 months after the procedure. In 13 cases of treatment failure, the patients subsequently underwent microsurgical diskectomy with good results.

Complications

With PLD becoming an alternative to conventional disk surgery and chemonucleolysis, there is a concern about the complications that may occur when less experienced persons perform the procedure or when proper indications for its use are not followed. Disk-space infections and hematomas have been reported. It is estimated that the incidence of infection is the same as that for diskography, probably 1 in 1,000 cases. Only six cases with major complications have been reported: two cauda equina injuries, one nerve-root injury, and three cases in which a small part of the automated PLD instrument broke off in the patient and was left in place with no ill effects.[22,23] There have been no major blood vessel injuries and no permanent damage to the disk or supporting structures resulting in significant disk-space narrowing or spinal instability.

Discussion

Minimally invasive lumbar disk surgery can now be considered an option for the treatment of symptomatic contained herniated nu-

cleus pulposus. The outcomes of more than 4,000 automated and manual PLD procedures have now been published. The outcomes reported are variable, but overall the success rate approximates 75%. Complications are reported to be minimal and occur in fewer than 1% of patients. The large number of patients, the large volume of literature, and the consistency of results reported in the literature support the conclusion that PLD may have efficacy in appropriately selected patients.

It must be recognized, however, that the evidence reported in the available studies is limited. The literature consists almost entirely of uncontrolled clinical studies. Further, it has been of major concern that objective outcome measures have been lacking. The studies do not clearly document the condition of all patients before and after treatment. In general, uncontrolled studies that use subjective outcome measures are likely to overestimate the effectiveness of a treatment. Another major concern is patient selection. Without a defined protocol for conservative treatment and documentation of patient compliance, it is likely that some patients treated with PLD have not really experienced treatment failure with so-called conservative therapy. In addition, some patients would have improved regardless, since the natural history of disk problems is for the pain to diminish and disappear with time, and therefore may have been incorrectly counted as PLD treatment successes.

On the basis of these studies, all the following must be present for the patient to be considered appropriate for PLD: (1) A major complaint of acute unilateral leg pain localized to a single dermatome or a major complaint of acute back and leg pain consistent with a single herniation contained within the annulus of the disk. (2) Neurologic signs or symptoms that are consistent with a single herniation contained within the annulus of the disk (e.g., sensory abnormalities, reflex alterations, positive straight leg-raising test, weakness). (3) Magnetic resonance imaging, CT, or diskographic evidence of a single herniation that is contained within the annulus of the lumbar disk (L1-2 through L5-S1) and is consistent with the signs and symptoms. (4) Failure of a well-managed course of conservative therapy to relieve pain and other signs and symptoms.[24]

Percutaneous lumbar diskectomy is not appropriate in patients with physical or diagnostic imaging evidence of disease other than an uncomplicated single herniation contained within the annulus. Although surgical treatment may speed the disappearance of pain, it is costly, and long-term results do not differ from those obtained with nonsurgical care, with the exception of surgical failures. Therefore, PLD is not considered an option in patients who have (1) a history of previous chymopapain or surgical treatment of the disk, (2) progressive neurologic deficit, (3) impairment of bowel or bladder function, (4) evidence of a sequestered disk or free disk fragment, or (5) evidence of vertebral disease, such as degenerative spinal stenosis or spondylolisthesis.

Conventional laminotomy or laminectomy, with or without the use of a microscope or surgical loupes, will remain the traditional method of surgical care for symptomatic lumbar disk disease. The role of PLD remains investigational until reliable validated outcomes from prospective randomized controlled studies can be obtained. In the future, research will explore the possibility of using small fiberoptic technology (spinal endoscopy) to visualize the area of nucleotomy. Percutaneous lumbar diskectomy may also be used for instillation of therapeutic agents within the disk for the purpose of chemical disk removal or percutaneous interbody fusion.

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