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A Focused Review

Percutaneous Lumbar Disc Decompression

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Chronic low back pain is a major social, economic, and healthcare issue in the United States. Various techniques are utilized in managing discogenic pain, with or without disc herniation. Percutaneous techniques are rapidly replacing traditional open surgery in operations requiring discectomy, decompression, and fusion. The percutaneous access to the disc was first used in the 1950s to biopsy the disc with needles. Percutaneous access to the disc using endoscopic techniques was developed in the 1970s.

Technical advances in the use of intradiscal therapies led to the development of intradiscal electrothermal annuloplasty (IDET®), DISC Nucleoplasty™, and DeKompressor®, along with laser-assisted, endoscopic, and Nucleotome® disc decompressions. The indications for percutaneous lumbar disc decompression include low back and lower extremity pain caused by a symptomatic disc.

Internal disc disruptions and disc herniations are common causes of low back and/or lower extremity pain which may become chronic, if not diagnosed and treated. Annular tears lead to migration of the nuclear material and deranged internal architecture. In the chronically damaged intervertebral disc, leakage of nuclear material from annular tears can initiate, promote, and continue the inflammatory process and delay or stop recovery of vital remaining intradiscal tissue.

The most often stated goal of central nuclear decompression is to lower the pressure in the nucleus and to allow room for the herniated fragment to implode inward.

Provocative discography prior to percutaneous lumbar disc decompression is recommended. Percutaneous disc decompression may result in a small number of complications but occasionally, these could be serious.

Key Words: Internal disc disruption, disc herniation, discogenic pain, percutaneous lumbar disc decompression, IDET®, nucleoplasty, LASE®, decompressor, nucleotome

Among chronic pain disorders, pain arising from various structures of the spine constitutes the majority of problems (1). The lifetime prevalence of low back pain has been reported as high as 80% (1-6). Studies of the prevalence of low back pain and impact on the general health showed 25% of patients reporting Grade II to IV low back pain (high pain intensity with disability) (4). The studies evaluating chronic low back pain estimated the average age-related prevalence of persistent low back pain as 12% in children and adolescents, 15% in adults, and 27% in the elderly (1-4).

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Duration of pain and its chronicity have been topics of controversy. Conventional beliefs are that most episodes of low back pain will be short-lived, with 80% to 90% of attacks resolving in about six weeks irrespective of the administration or type of treatment, and 5% to 10% of patients developing persistent back pain. However, this concept has been questioned, as the condition tends to relapse, so most patients will experience recurrent episodes. Modern evidence has shown that chronic, persistent low back pain in children and adults is seen in up to 60% of the patients, five years or longer after the initial episode (1, 7-11). Low back pain is also associated with significant economic, societal, and health impact (1, 12-23). Estimates and patterns of direct healthcare expenditures among the individuals with back pain in the United States have reached $90.7 billion for the year 1998 alone (13). On average, individuals with back pain incur healthcare expenditures about 60% higher than individuals without back pain. It was estimated that the cost of healthcare for patients with chronic pain might exceed the combined costs of treating patients with coronary artery disease, cancer, and AIDS (19).

Kuslich et al (24) identified intervertebral discs, facet joints, ligaments, fascia, muscles and nerve root dura as tissues capable of transmitting pain in the low back. Discogenic pain, facet joint pain and sacroiliac joint pain have been proven to be common causes of pain with proven diagnostic techniques (1, 25-28). Clinically, the intervertebral disc, can produce pain in the low back and lower extremities (1, 24-33). Intervertebral disc-related pain can be caused by structural abnormalities, such as disc degeneration or disc herniation; correspondingly, biochemical effects, such as inflammation and neurobiological processes may play a role. First to create widespread interest in the disc as a source of pain in American literature were Mixter and Barr (32) with their 1934 hallmark description of the herniated nucleus pulposus. Subsequently, within one year, in 1935 Mixter and Ayers (33) also demonstrated that radicular pain can occur without disc herniation. Internal disc disruption, or IDD, is a condition in which the internal architecture of the disc is disrupted but its external surface remains essentially normal (34).

Multiple percutaneously administered minimally invasive interventional techniques to achieve disc decompression have been described. Recently, percutaneous techniques are rapidly replacing traditional open surgery with discectomy, decompression, and fusion (35-39).

Evolution and Effectiveness

Although percutaneous access to the disc was first used in the 1950s to biopsy the disc using needles (2, 4), dissolving nuclear proteoglycans by the injection of chymopapain was the first percutaneous technique used to treat radicular pain caused by herniated nucleus pulposus (Table 1). Introduced in the 1960s by Lyman Smith (40), the procedure is still used in many countries. In the United States, however, catastrophic complications following inadvertent injection of chymopapain into the subarachnoid space dampened the early enthusiasm for this procedure.

Percutaneous access to the disc using endoscopic techniques was developed in the 1970s by Hijikata (41) in Japan and Kambin and Sampson (42) in the United States. Using a 7 mm cannulae placed into the center of a disc by a posterior-lateral approach, Hijikata "decompressed" the disc nucleus by manually removing nuclear material. Kambin and Sampson (42) described a similar technique, but gradually perfected the technique and approach to include removing herniated disc nucleus through one portal while viewing through an arthroscope placed from the contra-lateral side. Realizing central nuclear debulking was inadequate, in the 1980s, Kambin (43) developed arthroscopic techniques to access and remove posterior herniated fragments through a scope that included both working and viewing channels. Current techniques and equipment include 30 and 70 degree fiberoptic endoscopes, shavers to decompress the lateral recess and foramen, and specialized suction shavers to quickly remove nucleus. Some surgeons combine manual percutaneous decompression with bipolar radiofrequency to contract collagen fibers and coagulate granulation tissue within annular tears, low dose chymopapain (1000 u) to assist removal of the herniated nucleus, and lasers to remove nucleus and bone (44).

Directly visualizing and removing disc herniations and decompressing the lateral recess and foramen was not appealing to many because of the large cannulae required for the instruments and optics and the added risks of removing tissue outside the relative safety of the disc nucleus. Because no one knew that the benefit of directly removing the herniated disc was better than simply decompressing the nucleus to relieve pain caused by a herniated disc, several methods were developed in the 1980s to remove central nuclear tissue through medium sized cannulae using either a cut and suck technique or nuclear vaporization using the heat generated by laser.

In 1984, Onik et al (45), a radiologist working with engineers from Surgical Dynamics, developed a method of removing nuclear material through a 2 mm probe introduced through a 2.5 mm cannula. The probe removed disc material by suctioning it into the enclosed guillotine-like cutting apparatus (45). Early reports of a 75% success rate lead to its wide-spread use, but its use declined after a randomized trial by Revel et al (46) published in 1993 compared chemonucleolysis with Automat-

Table 1. *Timeline of Developments Minimally Invasive Surgical Techniques*

Year	Primary 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
1973	Kambin	Percutaneous insertion of Craig cannula 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 of automated percutaneous lumbar discetomy (APLD)
1986	Choy	Performed the first human percutaneous laser disc decompression
1991	Obenchain	Reported laparoscopic lumbar discectomy technique
1995	Kleinpeter	Compared minimally invasive open lumbar disc surgery to percutaneous endoscopic lumbar discectomy
1998	Ditsworth	Employed endoscopy to pass completely through foramen into spinal canal (transforaminal)
2001	Singh	Reported the first study on the clinical efficacy of nucleoplasty

ed percutaneous lumbar discectomy (APLD) and showed a 33% success rate. Another randomized controlled trial by Chatterjee et al (47) in 1995 reported a 29% success rate and also stifled the use of this technique.

The use of laser energy to vaporize nuclear material was introduced in 1986 by Peter Ascher and Daniel Choy. Their first device used a Nd-YAG, 1.06-µm laser via a 400-nm fiber through an 18 gauge needle placed percutaneously into the lumbar disc using a posterior lateral approach (48). Although their first series had less than a 30% satisfactory outcome at six months, subsequent studies reported 78.4% fair and good outcomes (49). Since its introduction, a variety of different lasers have been investigated for laser discectomy including YAG, KTP, holmium, argon, and carbon dioxide lasers. These devices use outer cannulae sizes of ~ 3 mm and usually include a fiberoptic channel for viewing. Due to differences in absorption, the energy requirements and the rate of application differ among the lasers, but most use approximately 1200 joules of energy per disc using a pulsating burst of energy. It is unknown how much disc material must be removed to achieve decompression. Therefore, protocols vary according to the length of treatment, but the laser is typically only activated for brief periods.

The real efficacy of the procedure is unknown because the literature is predominantly enthusiastic retrospective case series reports by the operating surgeon. For example, Ahn et al (50) reported symptomatic improvement in 88% of his 111 case series, Gronemeyer et al (51) reported a 73% success rate for eliminating or reducing back pain, and Choy et al (52) reported a 78% success rate at two to four year follow-up following laser decompression in 333 patients with contained herniated discs. However, Gibson et al (53) published a Cochrane review of surgery for lumbar disc prolapse, which included a review of laser discectomy. The review aimed to determine the relative treatment effectiveness of laser discectomy compared to either no treatment, discectomy, or automated percutaneous discectomy. The reviewers identified 27 randomized controlled clinical trials pertaining to all surgeries, but none addressed laser discectomy. This review concluded that unless or until better scientific evidence is available, laser discectomy should be regarded as a research technique.

Technical advances in the use of the mid-sized cannulae approach to decompressing the nucleus have evolved to include newer techniques using even smaller cannulae. The early success of IDET in the late 1990s encouraged others to investigate disc decompression methods using smaller cannulae as well as devices that would be more acceptable to non-surgeons and not require expensive instrumentation.

The disc nucleoplasty procedure uses bipolar radiofrequency energy in a process referred to as coblation technology. The technique consists of multiple small electrodes that emit a fraction of the energy required by traditional radiofrequency energy systems. The result is that a portion of nucleus tissue is ablated with a low-temperature plasma field of ionized particles. These particles have sufficient energy to break organic molecular bonds within tissue, creating small channels in the disc. The proposed advantage of this coblation technology is that the procedure provides for a controlled and highly localized ablation, resulting in minimal therapy damage to surrounding tissue.

Disc nucleoplasty is a relatively new technology and there is minimal published literature and no controlled trials. The advantage is that the probe can be introduced through a relatively small 17-gauge introducer needle. However, the amount of tissue that can be vaporized is probably less than other techniques. Unpublished animal studies showed vaporization of a small amount of disc tissue and, although advertised as a device that vaporized tissue without excessive rises in temperatures, one animal study concluded that destructive temperatures could be achieved (54). Similar to other optimistic early outcome series, case series outcomes report ~75 to 80% success rates with little or no morbidity in the treatment of radicular pain caused by lumbar disc protrusions (55). The clinical efficacy of nucleoplasty was first presented by Singh et al (56) at the Annual Meeting of the Florida Pain Society in 2001. Singh et al (57) later reported clinical outcome data from an uncontrolled case series of 80 patients with contained lumbar disc herniation who underwent DISC nucleoplasty. Overall, 75% of patients indicated a decrease in their pain scores 12 months after the procedure. Alexandre et al (58) retrospectively reported favorable results in 1,390 patients who underwent DISC nucleoplasty between 2001 and 2003. Cohen et al (59) reported on 16 patients with extremity and back pain undergoing either nucleoplasty alone or combined with IDET. The average decrease in VA score was less than 2 and only one of six patients who had only nucleoplasty had 50% or more pain relief. The authors concluded that neither procedure alone or in combination was ineffective.

Finally, the DeKompressor® Percutaneous Discectomy Probe was recently introduced for the intended use for aspiration of disc material during percutaneous discectomies in the lumbar, thoracic, and cervical regions of the spine. A 1.5 mm (17G) or 1.0 mm (19G) outer diameter cannula provides access to the disc space and serves as a channel for tissue removal. When activated, the probe rotates to create suction and removes nucleus pulposus through the cannula using early anecdotal and case series reviews report outcomes comparable to or better than nu-

Table 2. *Contraindications for percutaneous disc decompression*

- Large, non-contained disc herniation, sequestration or extrusion.
- Equivocal results of provocative and analgesic discogram.
- Infection.
- Cauda Equina syndrome or newly developed signs of neurological deficit.
- Patients unable to understand informed consent protocol.
- Uncontrolled coagulopathy and bleeding disorders

cleoplasty.

Indications and Contraindications

The purpose of lumbar disc decompression is to relieve leg pain, low back pain, or a combination of leg and low back pain caused by a symptomatic painful disc with reduction of intradiscal pressure. Contraindications are listed in Table 2.

Pathophysiologic Considerations

Spinal pain is the result of a complex interplay of biochemical and biomechanical processes. Internal disc disruption and disc herniations are common causes of low back and/or lower extremity pain which may become chronic if not diagnosed and treated. Annular tears lead to migration of the nuclear material and derange internal architecture. In the chronically damaged intervertebral disc, leakage of nuclear material from annular tears can initiate, promote, and continue the inflammatory process and delay or stop recovery of vital remaining intradiscal tissue. Inflammatory chemicals from the response to a damaged disc may activate or injure the dorsal root ganglion. These prominent mediators include matrix metalloproteinases (MMP), phospholipase A2 (PLA2), cyclooxygenase (COX), prostaglandins, nitric oxide (NO), cytokines, and interleukins. Infiltration of macrophages and other inflammatory cells may promote neovascularization in the outer regions of the annulus allowing infiltration by inflammatory cell populations bringing additional cellular inflammatory initiators. Sensitization of the central nervous system has also been suggested to be a possible causative factor of chronicity in some spinal pain conditions. Disc herniation has been defined as displacement of the nucleus pulposus. The most uniformly accepted terminologies are as follows (Fig. 1):

- Disc protrusion—herniation in which the annulus bulges noticeably but is not ruptured, thus allowing no contact between the nucleus and the extra-discal space.
- Extrusion or incomplete prolapse—the annulus is ruptured but any expelled nucleus is still attached to the rest of the disc.
- Sequestered disc or complete prolapse—disc tissue is expelled from the disc and is no longer attached to it. Increased pressure from a displaced matrix stimulates nociceptors in the outer annulus. Because of the arrangement of the disc lamellae, the posterolateral portion of the disc is the most vulnerable for injury and herniations. The severity of symptoms does not always correlate with the extent of the herniation (60).

Clinical Applications

Traditionally, decompression procedures, whether open or percutaneous, have been used to remove a herniated disc that is compressing neural structures and causing radicular pain and radiculopathy. Herniated discs, however, also include small 2 to 4 mm disc protrusions, and many interventionalists and surgeons even consider discogram-identified annular tears without a significant protrusion as a type of subligamentous protrusion. Whether patients with small protrusions or annular tears with axial greater than extremity pain are candidates for percutaneous decompression is debated, but both surgical endoscopy and percutaneous nucleotomy procedures are commonly used to treat this structural pathology.

Smaller protrusions are postulated to cause referred extremity pain due to neural inflammation and axial pain due to a combination of a sensitized outer annulus and increased outer annular tension (30). During surgical endoscopy, the most common finding is an inflamed outer annulus adjacent to the disc protrusion. Directly removing the herniated disc within the protrusion is the most logical goal for decreasing outer annular inflammation and pressure. The medium and smaller diameter techniques, however, were not designed to remove nucleus directly behind the protrusion and, unless the protrusion lies in the path of the posterior-lateral approach, directly removing the source of inflammation is not achieved. Several studies have, however, reported reduction in inflammatory cytokines in rabbits and in Petri dishes following nuclear laser heat vaporization and bipolar radiofrequency heat ablation (61).

The most often stated goal of central nuclear decompression is to lower the pressure in the nucleus and to allow room for the herniated fragment to implode inward. The theory postulates that intact outer annular fibers will be able to contract enough to reduce the tension on both the nerve root and annulus. While sounding logical, there is little proof this actually occurs. In fact, Delamarter et al (62) reviewed the MRI scans of 33 patients with radicular pain due to a disc herniation before and after APLD decompression and saw no measurable changes at six weeks.

The goal of lowering the pressure in the nucleus has been documented in cadaver and animal studies. Using 350 joules of laser energy delivered by a Nd-YAG laser, Yonezawa et al (63) vaporized central nuclear tissue in rabbit discs, creating a hole in the nucleus that, over an eight week period, gradually filled with fibrous tissue. The immediate effect was to lower the vertically measured intra-discal pressure by about 50%. Similarly, Choy and Altman (64) used 1000 J from a Nd:YaG, 1.32 micron laser delivered through a quartz fiber to lower the mean intradiscal pressure in cadaver discs by about 43%. Using nuclear coblation, Chen et al (65) showed a 100% drop in pressure in normal discs in young cadavers, but a negligible drop in pressure in degenerated discs after making six channels within each disc by advancing the Spine Wand (ablation) and retracting it (coagulation) with coblation energy.

Although nuclear pressure can be lowered by ablating central nuclear tissue, no one has actually measured the tensional forces in the outer annulus following nuclear ablation. Increasing nuclear pressure by injecting the disc with fluid will be reflected as a proportional increase in outer annular pressure when a radial annular tear extends to the outer annulus (66, 67). This increased pressure is probably analogous to compressing a well-hydrated nucleus and transmitting horizontal forces through the herniated nuclear ma-

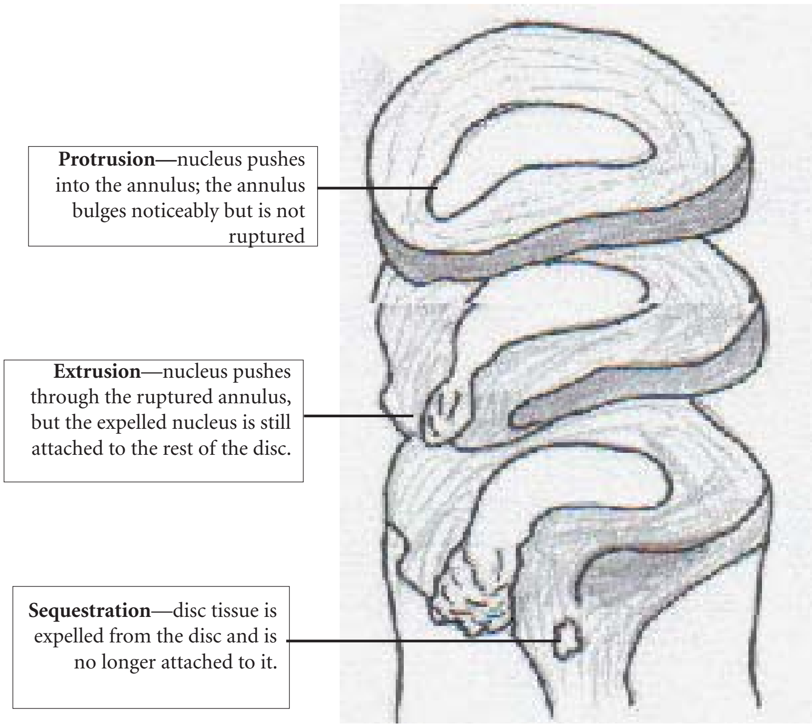

Fig. 1. *Commonly understood disc herniation terminology*

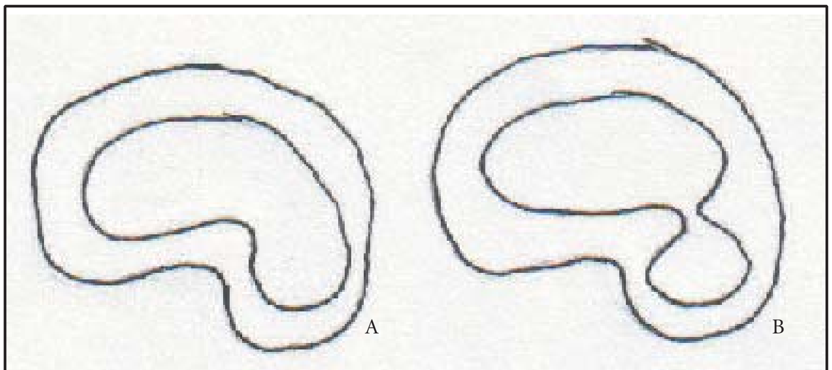

Fig. 2. *This illustration shows the appearance of two different disc displacements. A-The wide neck herniation allows easy retraction of the herniation, making this patient an excellent candidate for PDD. B-The narrow neck herniation makes PDD more difficult.*

terial to the outer annulus. There are, however, no studies that correlate the amount of nucleus removed with a decrease in tensional pressure on the outer annulus, and no one has studied how outcome correlates with the amount of nucleus removed. If more is not necessarily better, perhaps it would be preferable to use smaller needle techniques which remove less nucleus but lessen annular trauma caused by larger cannulae. In addition, Castro et al (68) showed that for every gram of nucleus removed, the disc space narrows 1.42 mm and the disc bulge increases 0.45 mm. Since 4 to 5 grams is removed during APLD and only an estimated 1 gram is removed with the DeKompressor device and vaporized during nucleoplasty procedures, the consequence to long-term stability of the segment would argue for removing less if the outcome is similar.

Regardless of how much nucleus is removed, it is prudent to remove the herniated nucleus within the protrusion and as close to the outer annulus as possible. By using a more lateral approach, one can place the introducer needles or cannulae in a more posterior position. Also, if one is careful not to damage the healthy annulus by not straying into the epidural space, one should be able to safely perform a more localized decompression. In this respect, herniations with a broad base should be easier and perhaps safer to decompress than narrow-necked herniations (Fig. 2). In addition, Castro et al (69) reported better outcomes following percutaneous laser discectomies, which he attributed to broad-based herniations. He felt that centrally decompressing this type of herniation allowed the "nucleus to more easily implode inward."

Before deciding which method to use, one should perform provocative discography followed by a post-discogram CT scan to assess the size and location of the annular tear or protrusion and to confirm that stimulating the annulus recreates the patient's typical pain. Although false positive discograms may confound the results in distressed patients with a low pain tolerance, categorizing positive discograms according to pressure criteria and using precise methods may help predict outcome (70-72). Ohnmeiss et al (73) reported a 70.7% success rate when APLD decompression was based on the results of a positive discogram and only a 44% success rate in cases where a discogram was not performed. Similarly, Botsford (74) found an overall success rate of 73% following posterior lumbar laser decompression. An abnormal CT discogram correlated with PLDD success in all patients treated (100%), whereas an abnormal MRI, CT, or myelogram correlated with success in 75% or less of patients' cases.

Complications

Percutaneous disc decompression has produced a small number of complications, despite the fact that the most recent studies indicate minimal risk when the procedure is performed by a skilled technician. Potential complications include: infections, bleeding, nerve damage, worsened pain, failure of technique, recurrence of herniation, paralysis, idiosyncratic reaction, anaphylaxis, and death.

Nerve root trauma can occur at the time of cannula placement. An appropriately trained physician performing the procedure with live imaging on a conscious patient is the best safeguard against this potential complication. Vascular injury can occur if the device comes into contact with an artery or vein. This is especially true when using heat, as it may cause necrosis at the vascular plexus of the endplate and cause potential nutritional deficits. Particular care should be taken to avoid puncture of the anterior annulus.

Complications specific to Nucleotome are as follows:

- ♦ The probe tip can be damaged or broken if it is forced against the vertebral endplates.
- ♦ The probe may become clogged with nucleus material during the procedure.
- ♦ The patient will feel radicular pain if the operator hits the anteriorly traversing nerve with the cannula.

Complications specific to LASE® include the following:

- ♦ In a study by Choy (75), discitis complications occurred in four out of 518 patients, giving a complication incidence rate of less than 1%.
- ♦ Farrar et al (76) reported a case of chronic discitis and vertebral osteomyelitis following laser decompression of the L4/5 disc for symptomatic disc protrusion in a 50-year-old Asian man.
- ♦ In a three month follow-up study on PLDD by McMillan et al (77), the incidence of new onset or worsening mechanical low back pain following PLDD was said to be 63%. However, no instances of infection, nerve injury, or clinical significant bleeding were identified.
- ♦ PLDD is generally evaluated with a complication rate of 0.5% using Nd-YAG laser (78).

Critical failure of a percutaneous discectomy probe requiring surgical removal during disc decompression has been reported (35).

Complications of IDET include catheter breakage, nerve root injuries, post-IDET disc herniation, cauda equina syndrome, infection, epidural abscess, spinal cord damage, and osteonecrosis (1, 79-82).

Conclusion

Internal disc disruption and contained disc herniations are common causes of low back and/or lower extremity pain, which may become chronic if not diagnosed in a timely manner. Percutaneous disc decompression has been shown to be effective in relieving pain due to symptomatic contained disc herniation. Consideration of various complications and proper patient selection improve the chances of procedure success. Reherniation, disc instability, and potential for accelerated degeneration may be associated with percutaneous disc decompression procedures.

Provocative discography is essential as the diagnostic and confirmatory standard for discogenic pain. It allows interventionalists to evaluate the exact source of pain, the extent of the herniation, and whether the nuclear material is contained within the annulus.

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