The Role of Fenestration in Management of Type I Thoracolumbar Disk Degeneration

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INTRODUCTION

Intervertebral disk fenestration has an interesting history in veterinary medicine. When first introduced as a surgical treatment of thoracolumbar intervertebral disk herniation (IVDH) in the 1950s it was described as a means by which the clinical signs—both pain and paresis—could be alleviated.\textsuperscript{1} During the 1980s and early 1990s, fenestration became popular and widely practiced and was associated with good clinical outcomes.\textsuperscript{2–6} Since then it has lost popularity, particularly as a treatment option, whereas decompressive surgery has become more widely adopted. Prophylactic fenestration has continued to be used by some veterinary surgeons, buoyed by findings that strongly support its prophylactic effect in dogs with previous episodes of symptomatic IVDH.\textsuperscript{7–9}

KEYWORDS

- Therapeutic fenestration
- Intervertebral disk fenestration
- Thoracolumbar intervertebral disk herniation
- Decompressive surgery

KEY POINTS

- Fenestration offers the advantages of prophylaxis without the need for specialized instrumentation and imaging.
- Currently there is a lack of equipoise regarding the efficacy of fenestration relative to decompression for treatment of acute canine intervertebral disk herniation; most veterinary spinal surgeons do not consider the 2 procedures equivalently efficacious.
- Therapeutic fenestration should perhaps be given greater consideration, especially if advanced imaging shows only mild to moderate spinal cord compression or there are restrictions on the duration of surgery, when it might be better to spend the time on fenestration rather than decompression.

INTRODUCTION

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The authors have nothing to disclose.

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Its waning popularity as a treatment coincided with increased veterinary access to cross-sectional imaging of the vertebral column, which made it clear that the spinal cord is often grossly deformed after IVDH, thus suggesting the need for decompression, which cannot be attained through fenestration alone. Contemporaneously, experimental evidence that decompression after contusion and compression improved functional outcome became available, and there were numerous reports of rapid recovery after spinal cord decompression in clinically affected dogs. This weight of evidence led to the current widely held view that fenestration is useful for prophylaxis but should not be considered a useful therapy for canine IVDH.

Despite this point of view there are several questions that remain unanswered regarding the value of decompressive spinal surgery for Hansen type I IVDH. For instance, dogs can have severe spinal cord compression, including that resulting from disk herniation, while showing minimal neurologic deficits. There is also poor correlation between severity of compression and severity of dysfunction or prognosis. Moreover, several investigators have detected residual compressive material after decompressive surgery and, in some dogs, large compressive volumes, raising the possibility that decompression may not be essential for functional recovery after symptomatic disk herniation. Furthermore, the current assumption that the spinal cord requires decompression suggests that previous reports that implied the effectiveness of fenestration must be incorrect. Is it possible that the reports of its apparent efficacy were erroneous and that numerous surgeons were misled?

In an attempt to answer these questions, we recently re-examined the available published data to compare outcomes between the different available therapies for symptomatic Type I thoracolumbar IVDH. Surprisingly, the analysis suggests that fenestration is an effective therapy, with a total of 951 dogs across a total of 11 publications showing an overall recovery rate of 94% for dogs with intact pain sensation in the hindquarters and 45% for dogs that had lost deep pain perception before surgery. These results compare well with reported recovery rates after decompressive surgery. This article explores further what this finding implies about treatment of Type I thoracolumbar IVDH in dogs, after first summarizing what is known about fenestration as prophylaxis.

**PROPHYLACTIC FENESTRATION**

**Evidence of Effect**

Traditionally, disk fenestration describes the procedure in which a window is cut into the lateral aspect of the annulus fibrosus and the nucleus is removed with a variety of sharp and blunt manual instruments, often dental instruments. Although the technique was originally used as a means of promoting functional recovery, it is currently most commonly used for prophylaxis against further herniations in the same region. Even this effect has been controversial and discussion of the risks and benefits continue to the present day. The underlying problem is that it is known that IVDH is a body-wide condition in many affected animals and those that have symptomatic disease at 1 site are at high risk for recurrence at another. Approximately 90% of thoracolumbar Type I IVDH occur between T11 and L3, meaning that it is possible to target susceptible areas for prophylaxis. The usefulness of fenestration as an adjunct to decompressive surgery has traditionally been most controversial mainly because it is not straightforward to compare outcomes from series in which decompression was or was not accompanied by fenestration. Despite this, fenestration has been suspected of reducing the risk of recurrence for many decades and more recent studies continue to support this viewpoint.
Comparison of recurrence between the large group of dogs reported by Mayhew and colleagues\(^\text{25}\) that did not receive prophylactic fenestration and the large group reported by Brisson and colleagues\(^\text{26}\) that were fenestrated strongly suggested a protective effect of fenestration (recurrence rates of 19% vs 5%). A subsequent well-designed prospective trial reported by Brisson and colleagues\(^\text{9}\) compared the recurrence rate in dogs that underwent decompressive surgery for symptomatic disk herniation and were either fenestrated at a single site (of symptomatic disk herniation) or all disks between T11 and L3. There was a substantial reduction in risk of recurrence in the multifenestrated group (7% vs 17%) strongly confirming the previous tentative conclusions from observational studies. This same trial also confirmed that 87% of recurrences occur adjacent to the site of previous herniation.\(^\text{9}\)

Other investigators have suggested that disk calcification is a risk factor for recurrence\(^\text{25}\) and it is undoubtedly associated with disk degeneration.\(^\text{20,27}\) Because fenestration of all disks from T11 through L3, especially when combined with hemilaminectomy, is an invasive and time-consuming procedure, the judgment of many surgeons is to fenestrate the affected disk plus those immediately adjacent to it, particularly if those disks are calcified on imaging studies. Nevertheless, even this is a difficult decision to justify, bearing in mind that disks that appear radiographically normal at one time point may appear calcified within a short period of time afterward\(^\text{28}\) and that there is reason to suppose that noncalcified disks are just as likely to undergo extrusion.\(^\text{27}\) It has also been noted that calcification may disappear with age,\(^\text{19,20,28}\) implying that it cannot be used as a reliable indicator of sites of irreversible progression to herniation (Fig. 1).

**Further Questions**

**Risk-benefit ratio**

The remaining discussion around the prophylactic benefits of fenestration centers on the risk-benefit ratio.\(^\text{18}\) It is true that there are many possible adverse effects of the procedure, including pneumothorax, increased surgical time, and inadvertent spinal cord or nerve damage as well as the more general risks of surgical infection.\(^\text{12,17,29}\) Such adverse effects seem uncommon, with only a small percentage of treated dogs developing these complications, many of which are self-limiting and need no further intervention to resolve.\(^\text{22,26,29}\) A more difficult, philosophic, question centers on whether it is appropriate to treat a certain number of dogs to prevent a much smaller number from developing recurrence.\(^\text{18}\) (Based on data from Brisson and colleagues,\(^\text{9}\) on average 10 dogs are treated to prevent 1 recurrence within 2–3 years.)

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**Fig. 1.** Reconstructed midsagittal CT scan of the thoracolumbar junction of a 5-year-old dachshund. There is evidence of recent disk herniation (arrow) but there is also mineralization in every other intervertebral disk, providing evidence of widespread intervertebral disk degeneration in this individual.
The answer probably is different for each dog owner but there is a real risk (of unknown magnitude) of owners not pursuing any further treatment if their dog suffers recurrence; anecdotally, such affected dogs are sometimes euthanized, although how commonly this occurs is currently unknown.

**Completeness of nuclear removal**

Other than efficacy in preventing recurrence, the most contentious aspect of prophylactic fenestration is probably the amount of material that must be removed for the procedure to be efficacious. The original purpose of fenestration was to eliminate the dynamic component of disk herniation, so it could be argued that simply making a scalpel incision through the annulus might suffice because, in experimental animals, this is sufficient to allow escape of large volumes of nucleus into the surrounding tissues. It has also been found, however, that the incision in the annulus rapidly heals and there is replacement of the nucleus with fibrocartilage, leading to suggestions that complete evacuation of the nucleus may be required for optimal results.

Air-powered burs, cavitron ultrasonic surgical aspirator (CUSA), and a vacuum-assisted device can all augment removal of nucleus and have been used safely in clinical patients. However, none of these techniques has been shown to have outcome benefits superior to those achieved through manual fenestration alone and there is evidence that no technique will completely evacuate the nucleus nor that it is essential for effective prophylaxis. Therefore, the question as to whether removal of more nucleus corresponds to a greater prophylactic benefit has not yet been answered. As a related question, it has been suggested that making a smaller hole in the annulus might also be beneficial—because the disk space will not then collapse to the same degree but, again, although this is entirely plausible there currently is no evidence in support of this effect.

**Surgical Approach**

Many veterinary surgeons continue to use the dorsal approach to the thoracolumbar vertebrae for decompressive surgery, although access for hemilaminectomy, minihemilaminectomy, and pediculectomy is often more easily, and less traumatically, achieved via dorsolateral or lateral approaches. There are many benefits to the more lateral approaches, such as the reduced requirement for muscle trauma or detachment from bone, but also the dorsolateral approach provides much better access for multilevel fenestration and was designed for this purpose. More recently, the various techniques have been compared for their provision of access for fenestration and the dorsolateral approach seems optimal (the lateral approach provides a smaller window).

In traditional manual fenestration a #11 blade is used to create a window in the annulus. The disk is identified by locating either the transverse process or rib head and following these structures cranially and slightly dorsally until the disk can be palpated with a needle or blade. Sometimes it can be useful to use gauze held in hemostats to dry the region so as to be able to clearly see the dorsoventral striations in the annulus. The neurovascular bundle together with adjacent muscle is then retracted cranially to protect it from the sharp instruments used to cut the annulus. After incising the annulus, nuclear material is removed with the use of a dental scraper, House curette, 16-gauge hypodermic needle, or similar implements. It has been postulated that recurrence after fenestration may in some cases be due to remaining nuclear material that is not removed because of unfavorable access to the disk governed by the surgical approach, but this has not yet been shown to be a clinically significant factor.
Percutaneous laser disk ablation has been adopted from human medicine as a minimally invasive procedure that could provide the same potential prophylactic benefits as traditional surgical fenestration. An initial report demonstrated that this procedure is safe and efficacious, and more recently reported data strongly suggest a useful prophylactic effect. In this procedure, fluoroscopy is used to guide percutaneous placement of needles into a series of intervertebral disks (Fig. 2). A fine fiberoptic cable is passed through the needle and positioned in the center of the disk; the laser is activated for a 40-second period and ablates the nuclear material. In a large series of cases \( n = 277 \) there was a very low complication rate (5 dogs; <2%) and only 1 dog that showed neurologic signs afterward (of a total of 3) required surgery for resolution (and it is probable that this was a developing lesion when the laser procedure was carried out). In a second report examining recurrence of clinical signs at a minimum of 3 years after laser fenestration there were 60 of 303 (20%) dogs suspected of having recurrence, but recurrence was only confirmed by imaging or surgery in 11 of 303 (3.6%) dogs.

There is some doubt about whether this procedure may be dangerous to the spinal cord if there is rupture of the annulus, and current recommendations are only to perform laser fenestration 6 weeks or more after recovery from an IVDH episode to allow time for the annulus to heal. This, therefore, requires a further procedure under general anesthesia. Sensitive owner counseling along with accurate reporting of recurrence rates of IVDH may be necessary for some owners to be willing to agree to this, but it is likely to be worthwhile for many dogs suffering an acute severe episode of IVDH. The low rate of complications and evidence suggestive of high efficacy when

Fig. 2. Percutaneous laser-assisted fenestration after aseptic preparation in lateral recumbency spinal needles are placed into the targeted intervertebral disks under fluoroscopic guidance (A); lateral (B) and ventrodorsal (C) radiographs showing needle tips accurately positioned in the centers of the intervertebral disks. (Courtesy of Dr Danielle Dugat, Oklahoma State University, Stillwater, OK.)
contrasted with the high risk of disk herniation in some breeds suggest that it is worth exploring its use as routine prophylaxis in young nonsymptomatic chondrodystrophic dogs when they undergo other routine health care, such as spaying and neutering.

**FENESTRATION AS THERAPY**

When fenestration was first used as therapy for intervertebral disk herniation, the rationale was that it would reduce intradiscal pressure and eliminate the presumed dynamic lesion by reducing the pressure applied from within the disk to communicate with the epidural space. There is good evidence for the first proposition: reduction of intradiscal pressure would be expected to reduce pain because it would eliminate nociceptive activation associated with stretching of the annulus in the degenerate disk. There is direct evidence of pain from a stretched annulus in human low back pain patients: discography (injection of a low volume of contrast into the disk nucleus) is a well-established diagnostic method because the consequent increase in intradiscal pressure evokes a painful response from the affected disk. Fenestration remains the first choice of surgery for some veterinary neurosurgeons for dogs with Type I IVDH that show pain alone.

On the other hand, the notion that relief of intradiscal pressure might aid spinal cord decompression nowadays is regarded by most spinal surgeons as a little fanciful. Nevertheless, as we recently summarized, there is still the inconvenient finding that, according to the available data, the functional recovery rate after fenestration seem similar to that after decompressive surgery. There are several explanations, including (1) recovery of spinal function does not depend on a surgical intervention to decompress the spinal cord, (2) the original data were flawed in some way, and (3) relief of intradiscal pressure does alleviate the pressure on the spinal cord and so allows recovery of function. Each of these is considered in turn.

**Does Recovery Depend upon Decompression?**

Although not a currently widely accepted viewpoint, partly because there is such obvious distortion of spinal cord shape in cross-sectional images, there is evidence that functional recovery after acute IVDH does not depend on decompression. Notably, there is plentiful evidence that a majority of dogs that suffer acute Type I IVDH recover with conservative therapy alone. This clinical evidence seems at odds with experimental data suggesting that early spinal cord decompression is important for recovery. The difficulty in translating such experimental results is that it is impossible to create in the laboratory the unique combination of compression and contusion that occurs in each clinical case of acute thoracolumbar IVDH and the timescale in which experimental decompression is completed may not be readily achievable in the clinic. Often clinicians cannot even be sure how long the spinal cord has been compressed, let alone accomplish decompression within 6 hours to 8 hours.

Furthermore, there is imaging evidence that the material that causes cord compression after IVDH can disappear with time. A potential explanation of this observation is that the material that causes the compression is often composed of a not-very-dense mixture of blood and fragmented herniated material. Initially, this may perhaps be repulsed by spinal cord pulsations in a similar way to that proposed to occur with fragments of bone in the vertebral canal after fractures. During subsequent stages the extruded material can be cleared by phagocytosis.
On the other hand, it is a recurrent theme that the recovery rate after conservative therapy is not thought to be as good as that after surgery, especially for the more severely affected cases, and this conclusion is supported by a recent meta-analysis.\textsuperscript{51} One problem with such meta-analysis is that it is dependent on the data that are available. For instance, the period over which conservatively treated dogs are followed up is, in many case series, not equivalent to that for surgical cases. In some studies, for instance, dogs were taken to surgery if they deteriorated or failed to recover within a period of up to 1 month,\textsuperscript{52} meaning that the outcome with conservative therapy alone is not known. For dogs that have severe spinal cord injury, the conclusion has to be even more circumspect because there are so few dogs with loss of pain perception (ie, deep pain negative) and treated conservatively for which outcomes have been reported. On the other hand, perhaps it is possible that compression plays a more important role if the initial contusive lesion is more severe.

Another viewpoint is that because, in most cases, loss of function after IVDH can largely be attributed to the contusion injury,\textsuperscript{53} for which there is no effective therapy, there may well not be a difference between decompression and fenestration because the spinal cord must recover spontaneously (or not) after either procedure (Fig. 3). This

Fig. 3. Not all acute intervertebral disk herniations are associated with clinically important spinal cord compression. The sagittal T2-weighted MRI scan (A) identifies a region of mild cord distortion overlying an intervertebral disk; transverse scans just cranial (B) and caudal (C) to the epicenter confirm minimal spinal cord compression associated with nuclear herniation (asterisk). Such a case may be appropriate for fenestration alone rather than attempted decompressive surgery.
provides an explanation for why fenestration may be beneficial compared with conservative therapy: it prevents more material from extruding into the epidural space thereby preventing worsened compression, which then allows the spinal cord to recover as well as if it had been decompressed.

It is also possible that the decompressive procedures in previously published series were suboptimal, meaning that the spinal cord of many animals that undergo the procedure remain compressed, and there is evidence for residual compression in a large proportion of reimaged cases. This potentially reduces the recovery rates associated with decompressive surgery and may provide another reason for the similar recovery rate after fenestration alone. Because loss of function can largely be attributed to contusion injury, it might be that suboptimal decompression is not important, meaning that fenestration and decompression then become equivalent procedures. In articles on decompression, the focus is usually on whether the animal recovers or not rather than the quality of recovery; it is possible that there might be a need for complete decompression to allow full recovery. Similarly, for both fenestration and decompression there are few data on swiftness of recovery. Decompressive surgery is often stated as leading to a quicker and more complete recovery than medical treatment. Nevertheless, both propositions remain speculative at present because there are no published data to support these assertions.

Did Original Fenestration Reports Suggest an Unduly Positive Outcome?

In the process of examining the literature reporting the results of treatment of acute IVDH with fenestration alone, we made every effort to treat these articles in the same way as those reporting the results of decompressive surgery. The bulk of the literature reporting the results of lateral fenestration comes from the late 1970s, 1980s, and early 1990s, with some more recent publications also reporting on other ways of performing fenestration, such as percutaneously or via a ventral approach. There are some large case series, with good detail on inclusion criteria, neurologic status before surgery, and outcome; there seems little reason to consider them inferior to the comparative decompression articles and no reason to suppose that those investigators were untruthful about their outcomes. What may be in question is whether the dogs are classified in the same way now as they were many decades ago: is a dog designated as “deep pain negative” now the same as a deep pain negative dog diagnosed in the 1950s? If modern methods of diagnosis have improved, perhaps more recent series include dogs that would have been designated deep pain negative in previous decades, meaning that earlier series (which focused more on fenestration) might contain a greater proportion of more mildly affected dogs. From the current vantage point, it is unlikely that this question can be addressed adequately, meaning that the only definitive answer would come from a randomized trial to compare the 2 interventions.

Does Fenestration Actively Improve Spinal Cord Function?

As a final explanation, perhaps it is plausible to consider that fenestration does work in some way to alleviate the spinal cord damage caused by acute IVDH. This explanation suggests that Olsson was correct: fenestration eliminates a dynamic effect of the herniated disk, which then allows recovery. A possible mechanism could be that fenestration causes—as a side effect of the surgical approach and procedure itself—muscle spasm around the affected area that then stabilizes the region. Similar effects on paraspinal musculature have been proposed as mechanisms for increased stiffness in the cervical vertebral column after laminectomy. The elimination of the dynamic effect might then be proposed to promote recovery of the injured spinal cord.
CAN THE COMPRESSION THAT IS VISIBLE ON CROSS-SECTIONAL IMAGING BE IGNORED?

For most dogs affected by acute thoracolumbar IVDH, cross-sectional images provide an almost irresistible reason to decompress the spinal cord. And, as discussed previously, there seems to be laboratory evidence in support of decompression as therapy.\textsuperscript{10,57,58} Even so, it is difficult to be sure that it is reasonable to translate the inferences made in experimental rat spinal cord injury with short follow-up periods and comparatively early decompression into clinical IVDH in dogs. Most experimental compression and decompression studies are carried out in rats within a period of 8 hours—which is rarely achieved in dogs—and, clinicians rarely know how long the spinal cord has been compressed. Extensive compression commonly affects other parts of the nervous system, such as brain tumors or cervical disk herniations and does not always require urgent decompression. On the other hand, rapidly accumulating small compressing volumes, such as subdural hematoma, are recognized as highly dangerous and warrant emergency interventions.

Clinical studies in dogs provide some evidence that spinal cord compression after thoracolumbar IVDH need not necessarily be an emergency. For instance, in a study on dogs that had lost hindquarter pain perception, there was no apparent benefit to early surgery in promoting recovery of locomotion,\textsuperscript{59} although there are also other data suggesting the opposite conclusion.\textsuperscript{60} If it is assumed, however, that late surgery is just as effective, perhaps that means that no decompression is also just as effective? On the other hand, there is indirect evidence that failure to remove material from within the vertebral canal might, at least in some individuals, risk the development of persistent spinal pain.\textsuperscript{13} Unfortunately, there is insufficient current information to know how commonly this occurs.

For clinical cases undergoing routine investigation, perhaps it might be preferable to pose the question other way round—if compression can be seen on cross-sectional images, why would decompressive surgery be foregone? Although this must be a decision made by each individual veterinary spinal surgeon, perhaps it is worth considering the following:

- The time that is spent on decompression might perhaps be better used doing other procedures. Currently, many surgeons carry out decompressive surgery but then do not fenestrate. It is established that this means that many of these cases remain at relatively high risk for recurrence,\textsuperscript{9} and some of these might be euthanized by their owners if they develop a second symptomatic episode. Optimally, the treatment of each affected dog is decompression and multilevel fenestration but, if a choice is made of 1 or the other (perhaps because of time budgeting), then it could be argued that fenestration might be the better option.
- Many owners find that the cost of cross-sectional imaging and surgery is prohibitive, so they decline surgery, and, sometimes, dogs are euthanized as a result. Such an outcome is depressing because a large proportion of these cases, no matter how severely affected at presentation, still recover with conservative therapy alone.\textsuperscript{11} It is important to stress to owners that decompressive surgery is not imperative, but, if they are able to afford fenestration, there is evidence that it will accomplish as much as decompressive surgery for dogs that present with intact pain sensation.
- Therapeutic fenestration may extend owner access to effective spinal surgery. Fenestration does not require much specialized equipment and there is minimal need for preoperative imaging (because the site of herniation does not need to be accurately diagnosed). In many early studies on fenestration, plain radiographs alone were used to rule out bone destructive lesions (mainly discospondylitis...
or neoplasia) before the surgery. Other differential diagnoses to consider in small chondystrophic dogs with acute-onset thoracolumbar pain or paraparesis are infectious or inflammatory diseases that are routinely diagnosed using cerebrospinal fluid and blood analyses. In practice, most cases presented for potential decompression of acute IVDH have typical history and signalment that suggest a high likelihood of acute IVDH. Many primary care veterinarians have access to appropriate equipment to carry out fenestration and offer this option to owners with financial or travel limitations.

A factor mentioned against fenestration is the risks involved, many surgeons do not believe the risk is worth the benefit. Certainly, it can be technically demanding procedure, particularly in larger dogs and in the thoracic region. Theoretic risks include creation of pneumothorax when fenestrating the more cranial thoracic intervertebral disks, iatrogenic damage to the neurovascular bundle or even the spinal cord through inadvertent entry into the spinal canal via the intervertebral foramen, and severe hemorrhage due to iatrogenic penetration of the aorta. Currently available data suggest that, in practice, the risks of fenestration are very low.

SUMMARY AND RECOMMENDATIONS

There is clear and strong evidence to use prophylactic fenestration to reduce the risk of future Type I IVDH. When a dog presents with acute intervertebral disk herniation, the choice initially is between surgical and medical management; if the decision is made to go ahead with decompressive surgery, then consideration should be given to performing concurrent prophylactic fenestration. The choice is then of how many disks to fenestrate; performing the procedure on 5 disks (T11 to L3) may be considered optimal because this treats the disks involved in 90% of acute IVDH but inevitably prolongs surgical time and carries increased, albeit still low, risk of morbidity. Basing the decision on imaging findings may be worthy of consideration but needs further investigation before definitive conclusions may be drawn. If only the disk affected by the episode of herniation is fenestrated, then it may be anticipated that the chances of delayed recovery due to further herniation or recurrence associated with that disk should be significantly reduced. However, because recurrences of symptomatic Type I IVDH more than after 1 month from the initial surgery are a result of herniation at another site, fenestrating just the affected disk is unlikely to have much effect on the long-term recurrence rate. Because recurrence can be a devastating event for many owners leading perhaps to greater consideration of euthanasia of the affected animal, fenestration of at least the disks adjacent to the affected one should always be considered.

Therapeutic fenestration offers the advantages of prophylaxis without the need for specialized instrumentation and imaging but currently there is a lack of equipoise regarding the efficacy of fenestration relative to decompression for treatment of acute canine IVDH: most veterinary spinal surgeons do not consider the 2 procedures equivalently efficacious for reversing clinical signs after acute disk herniation. However, therapeutic fenestration should perhaps be given greater consideration, especially if advanced imaging shows only mild to moderate spinal cord compression or there are restrictions on the duration of surgery, when it might be better to spend the time on fenestration rather than decompression. There also remains the possibility that, because there is no guarantee that herniated material in the vertebral canal will disappear with time, therapeutic fenestration may not eliminate the risk of long-term spinal pain.
Laser disk ablation seems safe and effective for removal of the nucleus pulposus and reduces risk of future herniation. Currently it has limited availability but in the future it may become more widely available and could perhaps be used for more generalized prophylaxis.

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