

## Review

# Use of the holmium yttrium aluminum garnet laser for percutaneous ablation of thoracolumbar discs in dogs: A historical summary

## Einsatz des Holmium:YAG-Lasers zur perkutanen Bandscheibenablation beim Hund: Eine Übersicht

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### Abstract

Percutaneous holmium yttrium aluminum garnet (Ho:YAG) laser ablation of the nucleus pulposus of thoracolumbar discs in dogs as a prophylactic procedure for prevention of catastrophic intervertebral disc protrusion/extrusion has been utilized at Oklahoma State University Center for Veterinary Health Sciences (CVHS) since 1992. Over 400 animals have been treated using percutaneous laser disc ablation (PLDA) with minimal post-treatment complications and a decreased rate of neurologic recurrence. The purpose of this summary is to provide a brief historical background of this minimally invasive procedure as well as its current status in clinical practice in the USA.

**Keywords:** ablation; canine; intervertebral disc; laser; neurologic surgery.

### Zusammenfassung

Die perkutane Laserablation des Nucleus pulposus der Bandscheibe mit dem Holmium:YAG-Laser wird am Center for Veterinary Health Sciences (CVHS) der Oklahoma State University seit 1992 bei Hunden als prophylaktische Prozedur durchgeführt, um eine schwere Bandscheibenprotrusion oder den Austritt des Gallertkerns zu vermeiden. Es wurden bisher über 400 Tiere mittels perkutaner Laser-Diskus-Ablation (PLDA) behandelt, mit nur minimalen post-operativen Komplikationen und sinkender neurologischer Rückfallrate. Der vorliegende Artikel gibt einen kurzen historischen Abriss sowie eine Übersicht zum aktuellen klinischen Stand dieser minimal-invasiven Prozedur in den USA.

**Schlüsselwörter:** Ablation; Hund; Bandscheibe; Laser; Neurochirurgie.

### 1. Introduction

Thoracolumbar (TL) intervertebral disc disease (IVDD) is a common surgical problem encountered in chondrodystrophic and smaller breeds of dogs. Surgical intervention that provides decompression with removal of the attenuating mass of disc material (nucleus pulposus) is the most accepted method of treatment for dogs with progressive or severe neurologic deficits [1, 2]. Concurrent surgical fenestration of the affected disc space to prevent continued extrusion of degenerate disc material through the ruptured annulus fibrosus in the immediate postoperative period is also frequently recommended by a number of authors [3–7].

Surgical fenestration of TL intervertebral discs performed at adjacent disc sites to prevent recurrence of severe neurologic signs is still considered controversial by some. Efficacy of TL disc surgical fenestration for prevention of further disc herniation is questioned due to a lack of controlled prospective studies, differences in reported surgical techniques [1, 2, 6, 7], and potential for complications associated with surgical techniques [8].

More recent reviews have provided reasonable confidence that some dogs diagnosed with thoracolumbar IVDD are affected by multiple discs [9], and that prophylactic fenestration may decrease the rate of recurrent disease in small-breed dogs [6, 10]. Dogs in another study that had five to six radiographically opacified thoracolumbar discs were considered a high-risk subpopulation for recurrence. Another review, although not advocating prophylactic fenestration provided retrospective evidence that ambulatory dogs, treated medically with either corticosteroids or non-steroidal anti-inflammatory drugs, had a 50% recurrence rate of IVDD [11].

A percutaneous, minimally-invasive approach for photothermal ablation of the nucleus pulposus in TL discs using the holmium yttrium aluminum garnet (Ho:YAG) laser has been previously reported [12, 13]. Originally developed for use in an animal model to study Ho:YAG laser energy associated photothermal, photoacoustic/photomechanical, and

histopathologic changes in TL intervertebral discs, percutaneous laser disc ablation (PLDA) became an accepted clinical technique. Since the original report, over 400 dogs have undergone the procedure at Oklahoma State University Center for Veterinary Health Sciences (CVHS). PLDA is also performed at a number of specialty veterinary practices in the US where it is recommended as a prophylactic procedure for dogs. The purpose is to prevent further herniation of nucleus pulposus from a partially herniated disc, and exacerbation of associated clinical signs. It may also reduce the chances of subsequent herniation of adjacent discs in eight significant locations in the TL area. The use of PLDA for canine TL intervertebral discs decreases postoperative complications when compared to surgical fenestration, and shortens recovery time.

## 2. Materials and methods

Dogs are included in the CVHS protocol when they have a history of TL disc disease and have recovered from either medical or surgical treatment. That is, they exhibit no neurologic abnormalities including lumbar pain, and they ambulate normally. If a dog is presented with only lumbar pain and confirmed to have TL disc disease through physical and radiographic examination usually confirmed with myelographic evaluation or computerized tomography (CT), it will be treated conservatively for at least 2 weeks prior to laser disc ablation. If it deteriorates neurologically, decompression and removal of the attenuating mass will be performed on an emergency basis. Dogs included in the PLDA protocol are not administered oral or parenteral corticosteroids for a minimum of 2 weeks prior to admission for disc ablation.

Acceptable candidates for PLDA undergo a pre-surgical evaluation which includes general physical and neurologic evaluations, hematologic and serum biochemical analyses, and urinalysis. If results are within normal parameters, the dog is anesthetized and the hair on the left TL area is clipped and aseptically prepared for surgery. It is placed in right lateral recumbency on either the radiographic exam table or the surgery table, depending on the method of imaging for needle placement. Images from a fixed uniplanar fluoroscopy unit



**Figure 1** Dog in sternal recumbency as viewed from the left side. Needles were placed with the dog in right lateral recumbency, using fluoroscopic guidance.

have been used in the past with the PLDA performed by an interventional radiologist. This required positioning the dog in both lateral and dorsoventral positions for accurate needle placement using a “uniplanar technique” (Figure 1). For the past few years, however, a mobile fluoroscopic system (portable C-arm) has been utilized by the surgical staff to perform PLDA in the operating room (Figure 2). No re-positioning of the dog has been required using the C-arm which expedites the procedure. Survey radiographs (lateral and dorsoventral views) are taken prior to and after needle insertion to ascertain potential anatomic variability and possible calcified discs (Figure 3).

Using sterile technique, eight needles (20 gauge/0.90 mm, 2.5 inch/63 mm, spinal needles or 3.5 inch/88 mm needles on larger or more obese dogs) are placed percutaneously through the skin using a dorsolateral approach through the epaxial musculature. The spinal needle, with stylet in place, is carefully positioned through the annulus towards the center (nucleus) of eight disc spaces (T10–11 to L4–5). Repeated 1–2 s fluoroscopic images are taken to check position of the needle as it is advanced toward the disc. Palpation of the needle against bone and soft tissue is used to ascertain when the needle encounters the vertebral body or disc space. A characteristic soft, gritty feel of the needle tip entering the annulus fibrosis is usually detected, and the needle is advanced carefully into the outside edge of the nucleus pulposus. Entry of the needle into the nucleus often is accompanied by a slight extrusion of the needle stylet, presumably attributable to intradiscal pressure. Needles are placed sequentially into each disc from T10–11 through L4–5. When needles are placed, the bevel of each tip is positioned so it faces the center of the disc rather than the vertebral end plate (Figure 4A). Insertion of spinal needles is often aided by use of a needle holder to stabilize the needle near the hub (Figure 4B).

A sterile, cleaved 320  $\mu\text{m}$  low-OH quartz optical fiber (New Star Lasers, Roseville, CA, USA) is used for laser ablation of



**Figure 2** Positioning of dog in the surgery site in the surgery suite using the C-arm for PLDA needle positioning.



**Figure 3** Ventrodorsal radiograph showing seven, 20-gauge, 2.5 inch spinal needles in place within the intervertebral discs from the T10–11 through the L3–4 intervertebral junctions. Currently, eight needles are placed from T10–11 through the L4–5 intervertebral spaces.

the nucleus pulposus. Prior to sterilization of the fiber, it is measured and the outside cladding is stripped so only 2–3 mm of bare fiber extend beyond the end of the spinal needle; the remainder of the cladding encasing the fiber acts as a “stop” which ensures entry into the nucleus but prevents complete penetration of the disc space. The same fiber is used for the

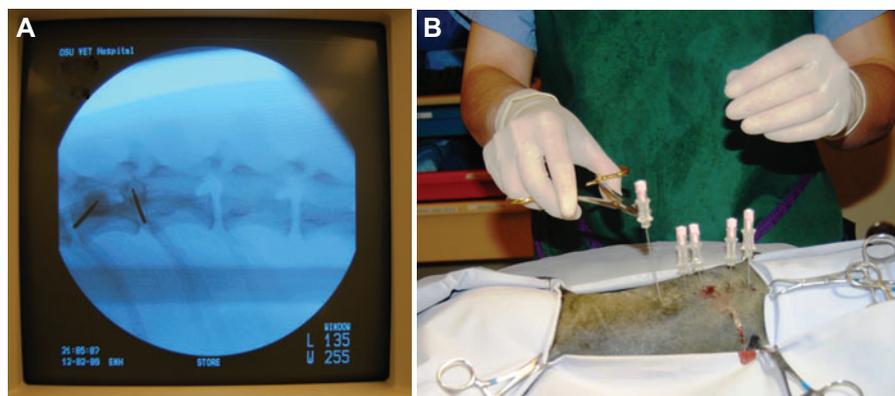
entire procedure, unless it is determined between applications that energy transmission is blocked due to fiber degradation/carbonization. Fiber viability is determined by viewing the spot size of the aiming beam (from the integral 630–640 nm diode laser) before each exposure. If the aiming beam is not visible or dim, the used fiber is replaced with another pre-packaged sterile fiber. The fiber SMA adapter is securely connected to a Ho:YAG ( $\lambda=2100$  nm) laser (NS 1500; New Star Lasers, Roseville, CA, USA).

The fiber end is inserted into each needle beginning at T10–11 (Figure 5). The precise position of each needle is rechecked fluoroscopically after removal of the stylet and prior to insertion of the laser fiber. The laser is activated for 40 s at 2 W of power and a 15 Hz repetition rate, resulting in a total energy dose of 80 J and a fluence of  $10^5$  J/cm<sup>2</sup> at the fiber tip.

After treatment at each site, the needles are removed. The dogs recover from general anesthesia and observed for further 24 h in the hospital. Discharge instructions include a recommendation of restricted activity for 2 weeks. It is recommended that animals be examined by the referring veterinarian if any problems develop. Examination should be performed on an emergency basis if the dog exhibits any neurologic signs including severe lumbar pain or paresis/paralysis of the rear legs.

### 3. Results

In a preliminary study of 262 cases evaluating outcome and complications associated with PLDA performed at Oklahoma State University between 1992 and 2001, recurrence of hind limb paresis or paralysis was reported in nine dogs or 3.4% [13]. Follow-up ranged from 1 to 85 months with a mean of 15 months. Acute perioperative complications, i.e., those that occurred within 1 week of PLDA, occurred in five dogs and included pneumothorax ( $n=1$ ), a skin abscess at a needle insertion site ( $n=1$ ), and increased proprioceptive deficits ( $n=3$ ). One of these animals required hemilaminectomy because of progression of neurologic signs to severe paresis. It recovered completely. Another dog developed discospondylitis at two



**Figure 4** (A) A needle holder is often used for aiding needle placement during C-arm fluoroscopic exposure. (B) Myelographic needles have been placed for delivery of laser energy to the nucleus pulposus of discs.



**Figure 5** The 320 µm diameter, low-OH Ho:YAG laser fiber with cladding removed is placed through myelographic needle lumen. The tip of the laser fiber protrudes through the needle lumen with the tip of the fiber barely protruding from the needle bevel into the center of the nucleus pulposus.

ablation sites (L1–2, L3–4) 7 weeks postoperatively and was successfully treated medically. All others with acute perioperative complications recovered uneventfully with medical treatment.

The number of chronic neurologic (3–52 months post-PLDA) complications associated with recurrent extrusion/protrusion of an ablated disc, based on the 262 cases studied, included confirmed recurrence of thoracolumbar IVDD in nine dogs (3.4%). A hemilaminectomy was performed on eight of these animals and each recovered uneventfully.

Since the completion of the previous study [13], approximately 200 more dogs have undergone PLDA. An updated retrospective study is being compiled at the time this summary was submitted. To date positive results are based on long term (6 months–10 years) outcome regarding recurrence of displaced disc material at the laser ablated disc sites. Considering immediate post-PLDA outcome, a dog that exhibits no neurologic abnormality (lumbar pain, proprioceptive deficits, paresis, or paralysis) upon anesthetic recovery is considered a successful case outcome.

#### 4. Discussion

A study citing percutaneous photothermal ablation or vaporization of the nucleus pulposus in lumbar discs in human beings by use of laser energy was reported in 1987 [14]. Laser-assisted disc decompression is a technique for the treatment of symptomatic, non-sequestered herniated nucleus pulposus in human beings that have failed conservative treatment [15–18]. Other lasers including the Nd:YAG, KTP, and diode laser have been used for PLDA in both human and veterinary medicine [19–23]. The Ho:YAG laser has some advantage over other approved lasers since its wavelength is more strongly absorbed by water, so the depth of tissue penetration is limited, and zones of necrosis and collateral thermal effects are minimized because of the high water content of the nucleus pulposus in non-calcified discs. In veterinary medicine, the Ho:YAG laser has also been used primarily for laser lithotripsy of urologic calculi [24]. Regarding laser-tissue interaction, the Ho:YAG laser is characterized as generating both a

photothermal and photomechanical effect in tissue, which can be considered as an advantage when performing lithotripsy of urologic calculi, or as a disadvantage when performing delicate soft tissue surgical procedures.

TL laser disc ablation is not recommended by our group as a therapeutic procedure for dogs suffering from acute, severe disc protrusion or extrusion. If attenuation of the vertebral canal is suspected and confirmed with a myelogram and/or CT exam, a hemilaminectomy is recommended, depending on the dog's history, severity of clinical signs, and the owner's decision. For dogs exhibiting less severe neurologic signs and treated by medical therapy alone, PLDA is not performed for a period of at least 2 weeks. This is done primarily for one reason: the Ho:YAG laser used for this procedure is a pulsed laser. Therefore, its photomechanical effect could potentially push more material into the spinal canal causing a more severe attenuation of the spinal cord. Allowing a period for fibrotic stabilization and decrease in inflammation is deemed appropriate based on previous experience. In addition, medical therapy which included steroidal therapy was a disqualifying factor during the 2 week pre-operative period since the potential for increased movement by ambulatory dogs was considered an additional risk for further disc herniation [12, 13]. Dogs that underwent decompressive surgery were disqualified as candidates for PLDA until a later date, usually until they were assessed as neurologically normal. Disc sites that had previously undergone a hemilaminectomy were ablated in the same manner as non-operated disc sites. As a final observation, the laser fiber used for PLDA is 320 µm in diameter and inserted through a 20-gauge myelographic needle. The inside diameter of a 20-gauge regular wall hypodermic needle is 603 µm in diameter. During the disc vaporization process, presumed intradiscal pressure produced by the ablation of the nucleus pulposus is released through the larger needle lumen. Laser plume as well as charred nuclear material is often detected at the hub of the myelographic needle during PLDA. Because of this fact, it is presumed no adverse effects have been noted due to the disc vaporization process itself and a potential increase in pressure that could result in more displaced disc material. Right lateral and ventrodorsal survey radiographs, as well as CT exams in many dogs, of the TL portion of the vertebral column were obtained and examined for evidence of mineralized disc material prior to PLDA. This was performed primarily for documentation of potentially herniated calcified disc material but also provided retrospective information on recurrence rates of extrusion/protrusion of metaplastic calcified discs.

Initially, locations of intervertebral discs selected for PLDA were similar to those selected for surgical fenestration as originally described, except for discs between L4–5 and L5–6 [3, 4]. These two sites were not included in the initial clinical protocol because they were not part of the preliminary investigation designed to prove safety and efficacy of the ablation procedure. Prevalence of disc herniation at these sites is also reported to be lower, and a surgical approach to these discs was initially thought to potentially cause postoperative complications due to iatrogenic trauma to closely related anatomic structures. Currently, however, a protocol that includes

intervertebral disc L4–5 has been implemented. Therefore, a total of eight discs (T10–11 to L4–5) now undergo PLDA.

PLDA can be technically difficult to perform. A “learning curve” must be expected, even when experienced interventional radiologists and surgeons perform the procedure. Prior to introduction of this procedure into a clinical setting, the needle insertion technique and laser ablation should be performed progressing from cadaveric to laboratory dogs. Discs at T10–11 through T13–L1 may also be more difficult to approach due to the close proximity of the associated ribs. A number of dogs with degenerative disc disease may also undergo spondylosis which can also prevent easy access to that particular disc space. If any of the disc spaces designated for PLDA cannot be approached due to anatomic or technical difficulties, extrusion/protrusion of the unoperated disc can occur in the future. To date, however, there has not been an increased incidence of these unoperated, adjoining discs herniating due to changes in biomechanics of the spine. Additionally, although not studied extensively, surgical disc fenestration or the PLDA procedure in the dog have not resulted in biomechanical complications involving vertebral/spinal articulation. That is, an immobile or fused spinal column has not resulted from the procedure [25, 26].

For the majority of PLDA cases, laser energy parameters described for the protocol are consistently effective in our clinical setting, except for dogs with documented calcified discs. Variations in ablation efficiency for the nucleus pulposus of each disc potentially occur due to differences in laser-tissue interaction. Different effects relating to laser-tissue interaction can result from interaction of laser wavelength and energy parameters coupled with the optical absorption characteristics of the disc material. A nucleus pulposus that has undergone age related degenerative, metaplastic change (calcification) could vary as far as energy parameters required for laser ablation from disc to disc. Further work regarding the potential variation in laser energy necessary for adequate ablation in relation to the degree of disc degeneration, especially the effect of disc calcification, is necessary. A study investigating the feasibility of an *in vitro* based single-fiber spectroscopy system to probe scattering changes associated with water content and mineralization in the canine intervertebral disc is currently underway. Those results may provide additional information for the necessary laser fluency changes to ablate calcified discs more effectively. Fluency settings for effective tissue ablation (pulses per second, exposure time, and power) of the nucleus pulposus may vary when using different Ho:YAG lasers. It is essential the surgeon acquaint himself/herself with the variability of devices and ensure disc ablation is controlled and confined to the nucleus. Varying pulse rate and pulse duration, while maintaining lower power output (2 W) may require less exposure time to accomplish the desired effect.

## 5. Conclusions and clinical relevance

Percutaneous Ho:YAG laser disc ablation is a minimally invasive technique to photothermally vaporize or coagulate the nucleus pulposus of intervertebral discs. With few

complications, this technique potentially reduces the recurrence of IVDD at ablated sites in dogs at risk by preventing further herniation of nucleus pulposus from a partially herniated disc, and reducing the chance of subsequent herniation of other discs at eight significant locations in the TL area (T10–11 to L4–5). PLDA is a minimally invasive technique that can be considered a positive extension of current therapeutic treatment interventions and provide a procedure for prevention of catastrophic neurologic complications from extrusion/protrusion of the nucleus pulposus from ablated TL discs. Continued work is being performed to review additional cases on a retrospective basis. The results of this study are pending. PLDA of cervical discs has also been performed on a limited basis with satisfactory results.

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