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Percutaneous endoscopic limited-lumbosacral-dorsal laminectomy in eight dogs – A cadaveric study

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Abstract: This study aimed to investigate the technical feasibility of a percutaneous endoscopic limited-dorsal laminectomy (PELDL) and to evaluate if the decompression and examination of the lumbosacral vertebral canals could be achieved using an endoscope in small dogs. A total of eight fresh canine cadavers were used for the study. Following the injection of a barium and agarose mixture (BA-gel), which simulates intervertebral disc herniation, a PELDL was performed over L7–S1 in these animals. Computed tomography (CT) scans were obtained pre- and postoperatively to evaluate the surgical outcomes. All the procedures were completed with a clear visualisation of the spinal cord and removal of the BA-gel. The mean surgery time for the PELDL was 30.00 ± 12.01 minutes. In two dogs, iatrogenic nerve root injuries were caused by the surgical instruments during the operation. The CT scans showed that the amount of BA-gel removed was sufficient for a spinal-cord decompression. A PELDL could be used for the BA-gel removal to decompress the spinal cord and provide a clear view of the spinal canal. Therefore, it could be used as an alternative surgical option to treat lumbosacral disc disease in dogs.

Keywords: endoscopic laminectomy; lumbosacral disc disease; minimal inasive spinal surgery

In human medicine, minimally invasive spine surgery (MISS) results in less tissue trauma, improved visibility, minimal blood loss, an easier approach in obese patients, an easier revision of surgery due to less scarring, lower complication rates, the use of a possible local anaesthesia, lower costs and given the shorter surgical times, less pain, and shorter inpatient stays (Weber et al. 1997; Schick et al. 2002; Li et al. 2014; Hettlich 2018).

However, the application of MISS to the spinal surgery of veterinary patients is still at its infancy, with several experimental and clinical reports available (Wood et al. 2004; Carozzo et al. 2011; Lockwood et al. 2014; Guevar and Olby 2020).

In single-port endoscopic spine surgery, the surgical procedure is performed through a single port on the endoscope. Hwang et al. (2016) were able to use this technique to perform a percutaneous endoscopic thoracolumbar pediculectomy, demonstrating that spinal surgery through an endoscopic approach is possible in veterinary medicine. However, a traditional pediculectomy can omit extruded disc material, and there is poor access to the vertebral canal compared to a standard hemilaminectomy and mini-hemilaminectomy (Arthurs 2009; Brisson 2010). Moon et al. (2017) demonstrated that a mini-hemilaminectomy in the thoracolumbar region was possible in canine cadavers. As endoscopic procedures may provide benefits

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for veterinary practices, a percutaneous endoscopic mini-hemilaminectomy or pediculectomy could be recommended for patients with thoracolumbar disc extrusion. However, in these previous studies (Hwang et al. 2016; Moon et al. 2017), access to the lumbosacral vertebrae using this approach was limited because of the presence of the iliac crest. Therefore, appropriate minimally invasive methods for accessing the lumbosacral vertebrae are needed using an endoscope in small dogs.

Although various procedures have been described for lumbosacral disc disease (Danielsson and Sjostrom 1999; Godde and Steffen 2007; Golini et al. 2014), such decompression is still performed through an open dorsal approach to the lumbosacral junction (Danielsson and Sjostrom 1999). The clinical application of MISS to the lumbar spine of small-breed dogs has not been achieved in veterinary medicine, and studies on appropriate surgical techniques are needed. The aim of the current study was to evaluate the feasibility of a percutaneous endoscopic limited-dorsal laminectomy (PELDL) in veterinary practice. We formulated three hypotheses. First, the minimally invasive percutaneous endoscopic approach would provide an appropriate pathway to the exact surgical site; second, the bone removal using the endoscope would allow for creating a window dorsally to provide a good view of the spinal cord; third, the decompression through the endoscope would be feasible for the removal of the injected gel.

MATERIAL AND METHODS

Animals and experimental disc herniation model

Overall, eight fresh canine cadavers weighing 4.21 ± 1.70 kg were prepared for this study. The dogs were euthanised for reasons unrelated to this study, and the computed tomography (CT) scans showed a normal vertebral structure, with no obvious signs of spinal disease, in all the dogs.

The experimental model of the intervertebral disc disease (IVDD) was based on methods described in previous studies (Lockwood et al. 2014; Moon et al. 2017), with some modifications. Powder of barium sulfate (0.4 g; Daejung, Seoul, Republic of Korea) and agarose (0.15 g; USB Corporation, Cleveland, OH, USA) were melded with tap water (10 ml) in a flask, sealed with cotton to minimise vaporisation. The mixture was heated in a microwave oven until boiling; it was withdrawn using a 1 ml syringe and allowed to solidify before injection at room temperature. Each cadaver was positioned in sternal recumbency, and the surgical site was clipped. A spinal needle was guided through the L7–S1 dorsal intervertebral space with access to the ventral aspect of the vertebral canal. Under fluoroscopic guidance, 0.5 ml of the BA-gel was injected through a 21-G spinal needle at the level of the L7–S1 intervertebral foramen. The injected BA-gel was identified using CT scanning preoperatively. The spinal cord was compressed using the BA-gel through the L7–S1 intervertebral dorsal foramen space at the ventral portion of the spinal canal in the same manner in each dog for the experimental disc herniation model.

Surgical technique

OPERATIVE INSTRUMENTS

The operative instruments were used as previously described (Hwang et al. 2016; Moon et al. 2017). Briefly, the rod lens optics of the discoscope, with an outer diameter of 6.9 mm and a usable length of 207 mm that we used contained an intra-endoscopic, eccentric working channel with a diameter of 4.1 mm and inlets for light and rinsing fluid (25° of vision angle). Moreover, a working sleeve (8-mm outer diameter with a 45° bevelled opening), dilator (5.9-mm diameter, 2-channel), micro-rongeur (290-mm length, 2.5-mm diameter), passive irrigation system, trephine (195-mm length, 5.9-mm diameter), and a micro-bone punch (290-mm length, 2.5-mm diameter) (Richard Wolf GmbH, Knittlingen, Germany) were used, as well as an electrocautery device (Trigger-Flex® Bipolar System; Elliquence, The Hague, The Netherlands). A burr connected with a Combidrive® (Richard Wolf GmbH, Knittlingen, Germany) was used for the drilling.

DORSAL APPROACH AND PERCUTANEOUS ENDOSCOPIC DORSAL LIMITED LAMINECTOMY

All surgical planning and operations were performed by the same surgeon and assistant. A spinal

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needle was inserted dorsally under fluoroscopic guidance to confirm the surgical sites, which were the L7–S1 laminae. A 0.8-mm K-wire was used to guide the dilator. The K-wire was superficially inserted into the L7–S1 intervertebral foramen and advanced from the cranial to the caudal side to obtain flexibility during the procedure. The K-wire tip was positioned at the centre of the L7–S1 intervertebral foramen. The insertion was performed at an inclination of 90 degrees from the lumbar vertebra to the parasagittal plane. Under fluoroscopy, dorsoventral images were acquired to confirm the exact K-wire position. A skin incision (< 10 mm) was made after the K-wire was correctly placed. Sequentially, the dilator and working sleeve were placed on the L7–S1 intervertebral foramen of the K-wire site until achieving contact with the bony structure under fluoroscopic guidance. The dilator and K-wire were removed, and the endoscope was passed through via a working sleeve (Figure 1).

Continuous passive irrigation with normal saline was used during the PELDL procedure. Although the procedure was performed on cadaveric dogs, we assumed the presence of blood vessels, and haemostasis was performed using electrocautery prior to levelling the epaxial muscle using the micro-punch and the micro-rongeur. The diamond burr was then advanced to the L7–S1 vertebral dorsal laminae. Pre-drilling was performed to prevent the potential loss of orientation using the screen. After removal of the outer cortical and cancellous bone layers, the drilling continued until the inner cortical layer was observed on the endoscope's screen. The inner cortical layer was cautiously broken using a trephine and micro-rongeur. The bony defect was extended cranially and centred caudally from the window of the dorsal laminectomy, but did not include both sides of the articular joint of the lumbosacral joint. A micro-bone punch and micro-rongeur were used to create the bone window. An elevator and micro-punch were used to remove the BA-gel, following which, the spinal cord was elevated to ensure the proper visualisation of the ventral portion of the spinal canal in the event of any remaining BA-gel.

Data collection – Procedure (operative) assessment

The procedure time, incision length, intraoperative complications, and pre- and postoperative scans were evaluated. The surgical time was divided into five groups: endoscope-approach

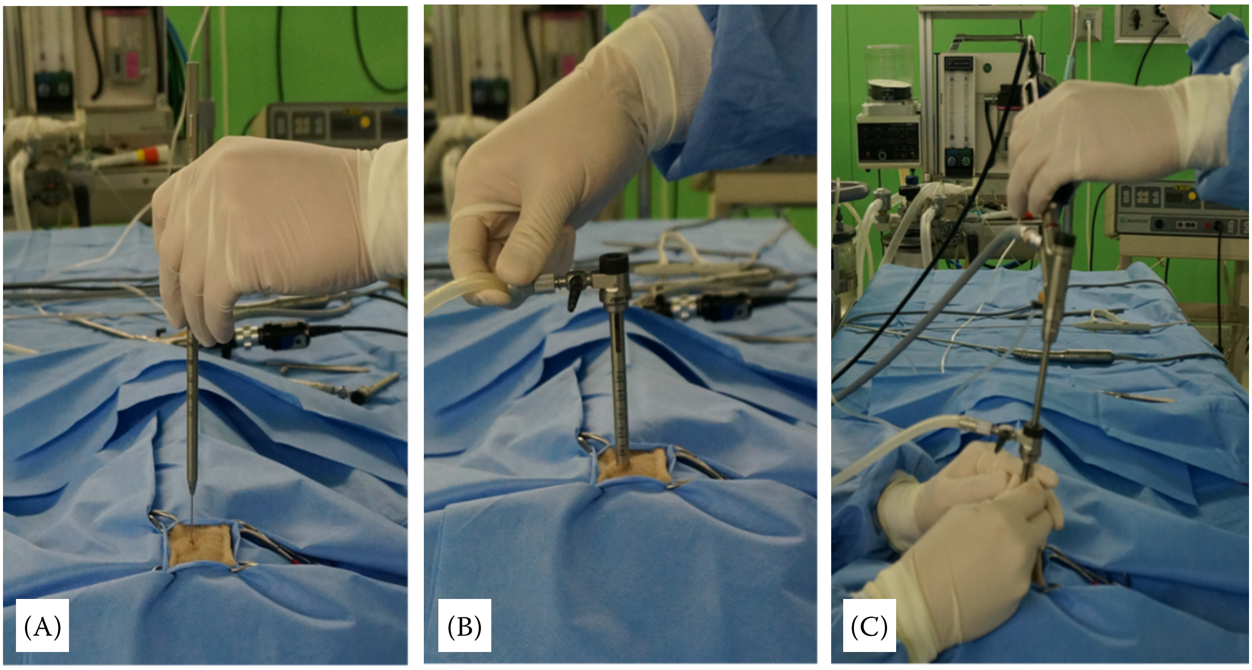

Figure 1. Minimally invasive approach to the L7-S1 lamina under fluoroscopic guidance

(A) Skin was incised under 1 cm after a 0.8-mm K-wire was positioned on the lamina. The dilator was advanced over the K-wire. (B) Working sleeve was placed over the dilator. (C) K-wire and dilator were removed. The endoscope was passed through the working sleeve

https://doi.org/10.17221/33/2020-VETMED

time, bone-exposure time, bony and artificial disc material (BA-gel) removal time, suture time, and total procedure time. The total time was defined as the time required from the first stab incision to the end of suturing procedure. Surgical videos were recorded using the endoscope. The PELDL was successfully performed, and observation of the cauda equina was achieved.

Additionally, the amounts of BA-gel removed to induce the spinal decompression were evaluated on the pre- and postoperative CT images, which were obtained using a two-channel multi-detector row CT scanner (Somatom Emotion; Siemens Medical Systems, Erlangen, Germany) (36 mAs, 110 kV, 1-mm or 2-mm thick slices). CT scanning was performed from the middle of the L6 vertebral body to the middle of the S2 vertebral body. CT images were transferred to a separate workstation and evaluated with the Lucion software v1.50 (Infinitt Healthcare, Seoul, Republic of Korea).

Postoperative CT scanning also confirmed the amount of remaining BA-gel, the window size of the bony defect, and the decompression. The Lucion software was used to inspect the window size of the bony defect and the amount of artificial disc materials removed, which was calculated as the difference between the injected and remaining BA-gel volume.

Statistical analysis

The removal volume of the BA-gel is reported as the mean ± standard error (SEM). The statistical analysis (Mann–Whitney *U* test) was performed using SPSS v23 (IBM Corp., Armonk, NY, USA).

RESULTS

Experimental model of IVDD

The BA-gel volume was determined and the spinal compression was induced by injecting 0.5 ml of the BA-gel into the L7–S1 sites. In all the dogs, 0.5 ml of the BA-gel was sufficient to induce the spinal cord compression as confirmed on the CT images. As it was difficult to prevent the BA-gel spreading to the cranial vertebral spaces, smaller amounts of the BA-gel were introduced via a spinal needle into the intervertebral space. Although the gel itself was soft and filled the spinal canal, compression was not completely induced. Furthermore, the remaining amounts of BA-gel were observed owing to the BA-gel spreading through the caudal part of the sixth lumbar vertebral canal.

Percutaneous endoscopic limited-dorsal laminectomy

The PELDL was successfully performed in all eight dogs. During the approach phase, the epaxial muscle and the dorsal lamina between L7 and S1 were identified through the endoscope. The epaxial muscle was easily removed using forceps. Adequate visualisation of the cauda equina was accomplished after creation of the dorsal bone defects between the L7 and the sacrum (Figures 2 and 3).

The endoscopic procedure allowed the removal of the artificial disc materials in the ventral portion of the L7–S1 spinal canal, although friable BA-gel debris obstructed the field of view during the removal of the BA-gel (Figure 3).

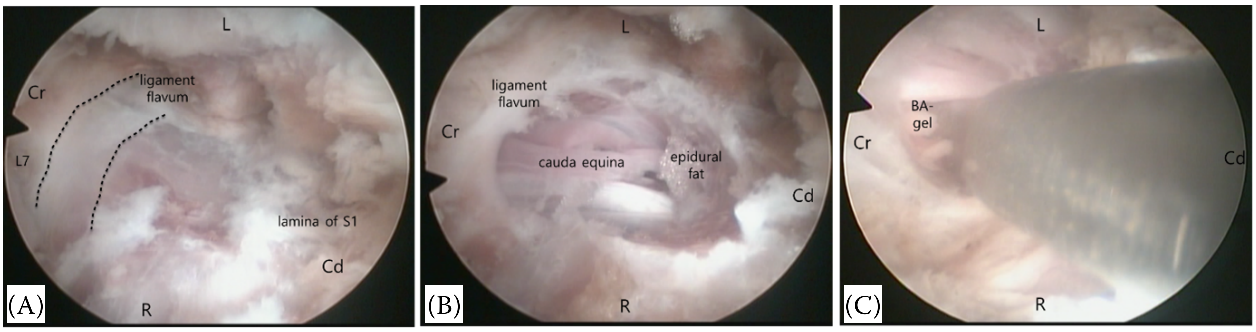

Figure 2. View of the dorsal laminectomy using an endoscope after a percutaneous approach to the dorsal space between the level of the L7 and S1

(A) Micro-rongeur and micro-punch were used to remove the epaxial muscles, and after the lamina exposure, the burr was used to remove the dorsal lamina. (B) The exposed cauda equine and some of the epidural fat was observed after removing the ligamentum flavum. (C) BA-gel was checked and removed using a micro-rongeur

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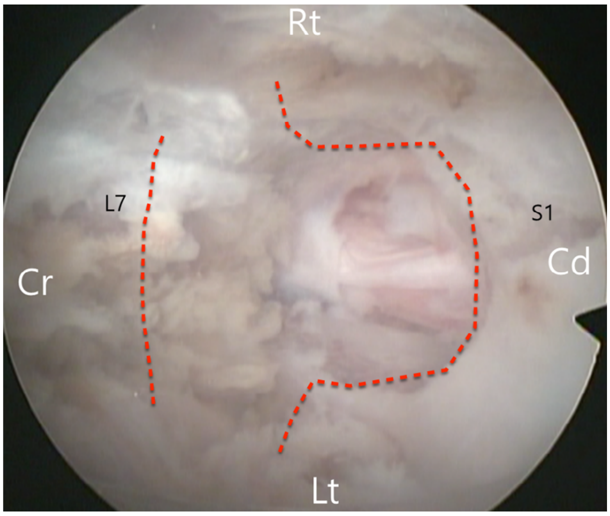

Figure 3. View using an endoscope after the dorsal laminectomy at the level of the L7 and S1. The dorsal limited laminectomy was successfully performed

The photo shows that the dorsal lamina was removed at the caudal part of the L7 and at the cranial part of the S1. The cauda equina was observed

The endoscope-approach time, bone-exposure time, bone and artificial disc material removal time, and suture time were 4.13 ± 0.83 min, 8.38 ± 5.07 min, 16.50 ± 9.06 min, and 1.00 ± 0.00 min, respectively. The total procedure time was 30.00 ± 12.01 minutes. Most of the procedure time was dedicated to the bone and artificial disc material removal. As suturing required only one bite (a simple interrupted suture) for all the procedures, the suturing required less than 1 minute (Table 1).

CT findings

The removal of the artificial disc materials was confirmed on the CT scans postoperatively (Figure 4). The average volume of the artificial disc materials removed was 40.00 ± 21.91 mm^3 (Table 2). There was no significant difference between the injected volumes and the remaining BA-gel (P-value = 0.128). Remaining BA-gel was observed in all the dogs after the procedure, although it did not appear to compress the cauda equina. The average bony defect size was 29.50 ± 13.61 mm^2 (Table 2). In addition, the CT images were 3D reconstructed and evaluated (Figure 4C). The remaining BA-gel was likely the result of the uncontrolled spreading of the gel into the L6–S1 spinal canals. However, no cauda equina compression was detected at the dorsal laminectomy site (Figure 4B).

Complications

Nerve root injuries caused by the surgical instruments (e.g., the micro-punch and -rongeur)

Table 1. Procedure time and incision length. Data are given as mean ± SEM

Procedure time (min)					Incision length (mm)
endoscope approach	bony exposure	BA-gel & bony remove	suture	total procedure	
4.13 ± 0.83	8.38 ± 5.07	16.50 ± 9.06	1.00 ± 0.00	30.00 ± 12.01	8.00 ± 0.76

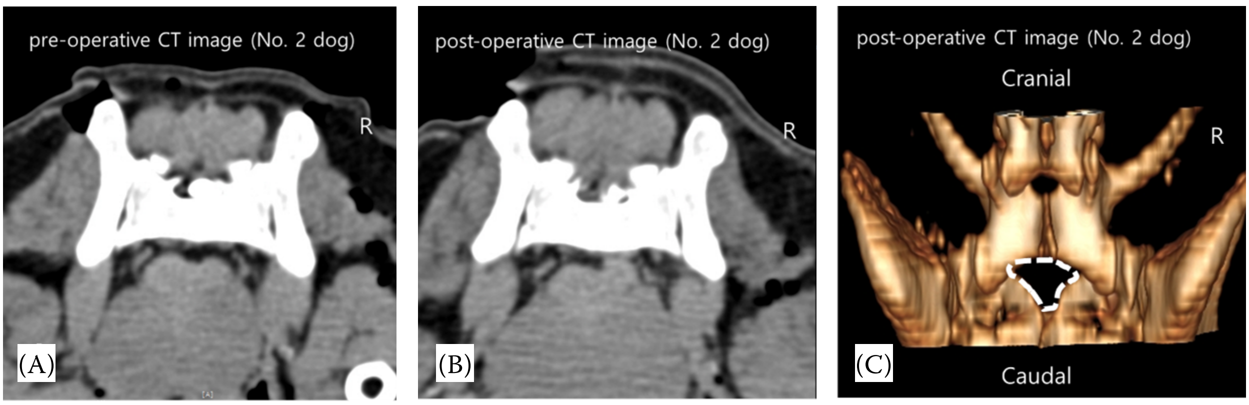

Figure 4. Pre-operative and post-operative CT scan images

(A) Pre-operative thoracic images (dog No. 2) and (B) Post-operative images at the level of the lumbosacral vertebra. (C) Three-dimensional reconstruction images were also obtained. The white dotted line shows where the laminectomy was performed

https://doi.org/10.17221/33/2020-VETMED

Table 2. The amount of removed BA-gel and window size. Data are given as mean ± SEM

Pre-OP BA-gel	Post-OP BA-gel (mm^3)	Removed BA-gel	Window size (mm^2)
226.25 ± 61.63	180.00 ± 48.11	40.00 ± 21.91	29.50 ± 13.61

were noted in two cadavers (dogs No. 3 and No. 5) (Figure 5). In this study, complications were noted in two of the eight cases.

The overall frequency of complications in this study was two out of eight cases. Dog No. 3 was injured in the process of creating a window and removing the obstructive muscles. Dog No. 5 was injured as the endoscope was displaced during the approach and in the process of removing the epaxial muscle due to the wrong position of the working sleeve and the endoscope.

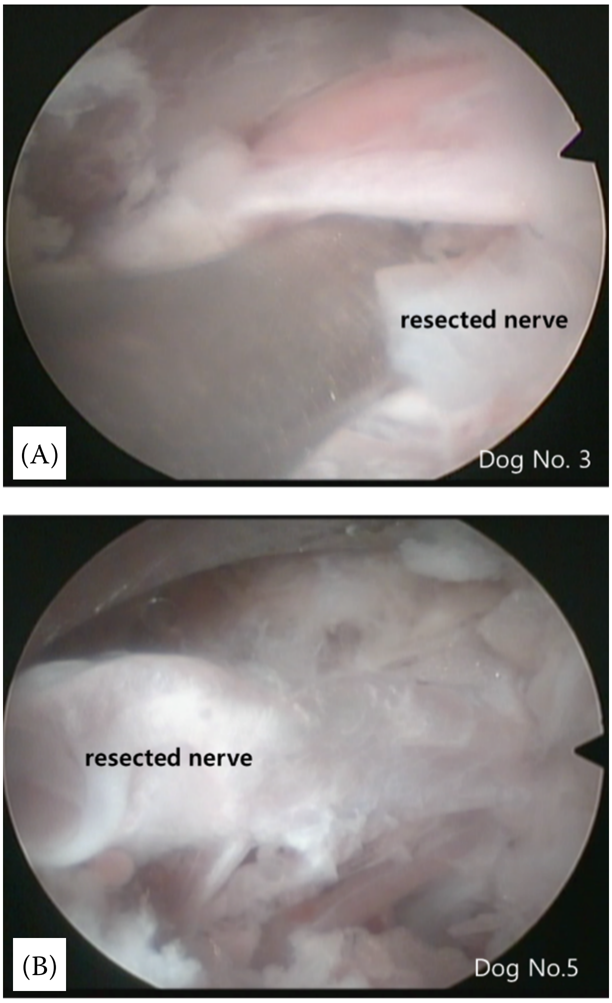

Figure 5. Two intra-operative complications were recorded; iatrogenic nerve root injuries caused by the micro-rongeur and burr in (A) dog No. 3 and (B) dog No. 5

DISCUSSION

The aim of the present study was to evaluate the feasibility of decompressing the spinal cord through a minimally invasive dorsal laminectomy at the lumbosacral vertebrae of dogs. Spinal decompression was performed by removing artificial disc materials using an elevator and micro-rongeur/punch. The removal of the BA-gel was confirmed on the pre- and postoperative CT scans. This procedure required a < 1-cm skin incision and a short surgical time (30.00 ± 12.01 min), was minimally invasive, and allowed a clear view during the procedure. These results suggest that sufficient decompression and removal of actual disc materials can be achieved via a PELDL.

In the experimental IVDD modelling employed in this study, the BA-gel extending along the spinal canal could be identified in several segments on the preoperative CT, as also shown by Lockwood et al. (2014) and Moon et al. (2017). However, in this study, the direction that the BA-gel tended to spread from the lumbosacral injection point was cranially rather than caudally. This is because the spinal cord narrows steeply at the sacrum.

The postoperative CT scan showed that the BA-gel was removed at the lumbosacral level. However, unlike the findings of Moon et al. (2017), there was no significant difference in the BA-gel volume before and after the procedure, as shown on the pre- and postoperative CT scans. This may be attributed to the individual differences in the lumbosacral spinal canal among the individuals and might be influenced by the differences in the injected volume in spinal canals of varying size.

Regardless of the operation, be it at the thoracolumbar or lumbar spine, differences in the length of the skin incision may be affected by the instrument and approach used. Standard laminectomy procedures (e.g., dorsal laminectomy, hemilaminectomy) in the thoracolumbar vertebrae in dogs require an incision of three vertebral lengths cranial and caudal to the region of interest (Coates 2000; Brisson 2010), whereas a MISS requires an incision of < 2.2 cm (Hwang et al. 2016; Guevar and Olby 2020).

Dent et al. (2016) reported that comparing an open surgery procedure with a minimally invasive approach for the lumbosacral decompression in cadaver dogs, the open surgery procedure required an incision of approximately 11 cm, whereas the

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MISS technique using a specific retractor required a 5.5 cm skin incision. In our study, the skin incision required for the working sleeve was < 1 cm, possibly because of the minimally invasive characteristics of the endoscopic surgery and those of the instruments used.

In Dent et al.'s MISS cadaveric study, the mean surgical time was 18.5 min, i.e., much shorter than that in our study (Dent et al. 2016). In the present report, the total operating time for the PELDL was 30.00 ± 12.01 minutes. Two factors could have contributed to this difference; first, in our study, a discectomy was not performed, and second, the BA-gel and bone removal time accounted for 16.50 ± 9.06 min, suggesting that the BA-gel removal is a time-consuming process.

In two (25%) of eight cadavers, nerve root damage was caused by an intraoperative endoscope position shift. However, as the dorsal part of the lumbosacral vertebra does not contain blood vessels or nerves that enter into the spinal canal (Evans and Lahunta 2010), it was expected that fewer complications would occur compared with other minimally invasive spinal approaches, such as a thoracolumbar hemilaminectomy via an endoscopic approach.

The surgical technique presented in this study can be used to remove artificial disc materials at the level of the lumbosacral vertebra. No bleeding is expected as a complication because there are no nerves and blood vessels in the corridor of the dorsal approach used to remove the dorsal bone. However, as a discectomy was not included, there are some limitations. This study suggests that procedures using an endoscope could be performed in large-breed dogs, especially German Shepherd dogs, which may often develop degenerative lumbosacral disc diseases (Tarvin and Prata 1980; Wheeler 1992; Saunders et al. 2018). However, routine fenestration and distraction may be warranted as a degenerative disease (Wheeler 1992; Danielsson and Sjostrom 1999; Willems et al. 2018). Additionally, the use of cadavers did not allow the assessment of postoperative neurological deficits or potential intraoperative complications (e.g., bleeding, soft tissue injury).

In this study, the nerve roots appeared as complications in 25% of the dogs, and this is an important consideration when performing an endoscopic dorsal laminectomy procedure. Therefore, further research on the technical methods to reduce this complication is needed. Moreover, further investigation is also required to access the lumbosacral vertebra and perform an endoscopic fenestration.

These results suggest that a PELDL via a single port endoscope was feasible in alleviating a spinal compression with minimal invasiveness. This dorsal approach using a single port endoscope required a small skin incision (< 1 cm) and a relatively short surgical time (< 30 min), was minimally invasive, and allowed a clear view during the operation on the lumbosacral vertebrae. The PELDL could be used to remove disc materials to decompress the cauda equina and provide a clear view of the spinal canal. Therefore, it could be used as an alternative surgical option to treat lumbosacral disc disease in dogs.

Conflict of interest

The authors declare no conflict of interest.

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