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개에서의 후복막강경의 접근법, 작업 공간 및 해부학적 특징

Retroperitoneal Laparoscopy in Dogs
: Access Technique, Working Space, and Surgical Anatomy

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Retroperitoneal Laparoscopy in Dogs : Access Technique, Working Space, and Surgical Anatomy

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Abstract

Retroperitoneal laparoscopy—direct access to the retroperitoneal space—is an attractive alternative to transperitoneal techniques for

retroperitoneal organs surgeries. With this advantage, retroperitoneal organs can be operated without retraction of intra-abdominal organs, which have become a standard procedure in human medicine.

The aim of this study was to develop and describe a retroperitoneal access technique, to investigate working-space establishment, and to describe surgical anatomy in the retroperitoneal space as an initial step for clinical application of retroperitoneal laparoscopy in dogs. For these purposes, pilot study with previously-frozen 8 canine cadavers and and experimental CT study with 6 healthy dogs were performed. The retroperitoneal access technique was developed with 3 cadavers. Its application and working-space establishment with carbon dioxide (CO_2) insufflation alone was evaluated in 5 cadavers by observing with a transperitoneal telescope and in 6 dogs by repeated computed tomography (CT) scans at pressure levels of 0, 5, 10, and 15 mmHg. The recordings of retroperitoneoscopy as well as working-space volume and linear dimensions measured within the potential surgical area on CT images were analyzed.

The retroperitoneal access and subsequent working-space establishment with CO_2 insufflation alone were successfully performed in all 6 dogs. Except for 1 dog with subclinical pneumomediastinum, no animal exhibited complications. As pressure increased, working space established from the ipsilateral to contralateral side, and peritoneal tearing eventually developed. Working-space volume increased significantly from 5 mmHg and linear dimensions increased significantly from 0 to 10 mmHg. Overall, the

optimal pressure starting from 5 mmHg and increasing to 10 mmHg as necessary would be suggested for retroperitoneal laparoscopy in dogs. With pneumo-retroperitoneum from 5 mmHg, retroperitoneal organs including kidneys and adrenal glands were easily visualized. Relative to the entry site, the dorsal plane of the displaced kidney was observed ventrally, the pulsating abdominal aorta and caudal vena cava (CVC) were found in front of the trocar. The adrenal glands were located cranial to the renal vessels and closely ventral to the aorta or CVC.

The retroperitoneal approach may allow direct access to retroperitoneal organs in dogs, especially adrenals and dorsal part of kidneys, which would lead to clinical application of retroperitoneal laparoscopy in dogs.

Keyword: dog, retroperitoneoscopy, retroperitoneal laparoscopy, minimally invasive surgery, working space, retroperitoneal space

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Contents

I. Introduction

In minimally invasive procedures, gaining appropriate access to the closed abdominal or thoracic cavity and establishing a proper working space for visualization and instrument manipulation are important initial steps to enable the surgeon to work efficiently. In this context, retroperitoneal laparoscopy—direct access to the retroperitoneal space—is an attractive alternative to transperitoneal techniques for surgeries involving the retroperitoneal organs.

In human medicine, retroperitoneal laparoscopic surgeries have been developed since the early 1990s and have become a standard procedure in retroperitoneal organ surgeries (Ren et al., 2014; Fan et al., 2013; Constantinides et al., 2012; Nigri et al., 2013; Conzo et al., 2016). The advantage of retroperitoneal laparoscopy is direct access to retroperitoneal organs without retraction of intra-abdominal organs, which is especially beneficial for patients with a history of abdominal surgery. Disadvantages mostly involve technical aspects, such as spatial limitations and unfamiliar anatomic landmarks, that require the acquisition of new skills by surgeons. In addition, intra-abdominal exploration and the removal of large tumors are not possible; these limitations warrant appropriate patient selection (Ren et al., 2014; Fan et al., 2013; Constantinides et al., 2012; Nigri et al., 2013;

Conzo et al., 2016). Recent meta-analyses comparing transperitoneal and retroperitoneal approaches for nephrectomy and adrenalectomy found that the overall clinical outcomes were similar (Ren et al., 2014; Fan et al., 2013; Constantinides et al., 2012; Nigri et al., 2013; Conzo et al., 2016), and that retroperitoneoscopic nephrectomy was superior to transperitoneal nephrectomy in operation time, blood loss, and hospitalization (Ren et al., 2014; Fan et al., 2013). In addition, although there were no statistical differences between the 2 approaches for laparoscopic adrenalectomy (Constantinides et al., 2012; Nigri et al., 2013; Conzo et al., 2016), some authors considered that retroperitoneoscopic adrenalectomy, if performed by experienced surgeons in selected patients, was superior (Constantinides et al., 2012; Conzo et al., 2016).

In small animals, most laparoscopic techniques including retroperitoneal organ surgeries have been performed with a transperitoneal technique (Fransson, 2015). Therefore, the evaluation of retroperitoneal laparoscopy in veterinary patients is warranted, considering the promising benefits in humans. To the author's knowledge, the only study describing retroperitoneoscopy in dogs was performed by medical doctors in 1979 as a technical feasibility research for clinical application in humans (Kaplan et al., 1979). In this study, the retroperitoneal space of 13 dogs was insufflated with nitrous oxide (N_2O) at 25-30 mmHg pressure through a 20-gauge spinal needle placed pre-sacrally. This was based on a retroperitoneal pneumography technique; pneumo-retroperitoneum was confirmed on a lateral radiograph. Then, an 11-mm trocar with a sharp obturator was inserted and a renal biopsy was performed via the working port of an operating peritoneoscope. Six dogs were sacrificed immediately, 1 dog died after 6 hours due to renal vein perforation, and 6 dogs were maintained healthy for at least 48 hours of observation. The study showed that retroperitoneoscopy is feasible in dogs; however, the procedure was not designed or evaluated in the perspective of clinical application in veterinary patients.

The aim of this study was to develop and describe a retroperitoneal access technique, to investigate the establishment of working space, and to describe surgical anatomy in the retroperitoneal space in dogs as an initial step for future clinical applications. For these purposes, a pilot study with cadavers and an experimental computed tomography (CT) study were performed. We hypothesized that the retroperitoneal space could be accessed safely with an open-access technique on both sides and that adequate working space could be established with carbon dioxide (CO_2) insufflation alone at low pressure levels, which would provide direct access to retroperitoneal organs, especially the adrenal glands and the dorsal part of the kidneys.

II. Materials and Methods

1. Pilot study

Previously deep-frozen cadavers of intact male beagle dogs (n = 8) that had been euthanized for purposes unrelated to this study were obtained. These animals had no history of abdominal surgery and were of similar body size with a body condition score of 4–5 out of 9 (Laflamme, 1997). A 5 mm disposable trocar (Kii Shielded Bladed Access System; Applied Medical, Rancho Santa Margarita, CA) was placed in the peritoneal space cranially at the cranial margin of the iliac crest on each side (Fig 1A), and a 5 mm telescope (Karl Stortz, Tuttlingen, Germany) was inserted for anatomic observation of the visceral peritoneum and retroperitoneal organs during the study. The peritoneal space was insufflated with 5 mmHg pressure of CO_2 for visualization. The access technique for retroperitoneoscopy was established on the basis of the human technique in the first 3 cadavers (Walz et al., 2006). In humans, with the patient in the prone position allowing the ventral abdominal wall to hang through, an incision just below the tip of the twelfth rib – a landmark to locate the kidneys – and subsequent blunt and sharp dissection of the abdominal wall to reach the retroperitoneal space are performed. Under finger guidance, instrumentation ports are inserted 4 to 5 cm lateral beneath the eleventh rib and medial to the initial wound through a skin incision about 3 cm below the twelfth rib. Finally, a blunt trocar with an inflatable balloon and an adjustable sleeve is introduced into the initial incision site and blocked. The developed technique was applied in the next 5 cadavers. The retroperitoneal space was approached in 3 cadavers from the right side and 2 cadavers from the left side; cadavers were selected blindly and operated on by 1 surgeon.

Cadavers were positioned in sternal recumbency with the abdomen suspended to facilitate gravitational displacement of the abdominal viscera, as described by Naan et al. (2013). A 1.5 cm vertical incision was created starting from the point where the transverse process was palpated, at the third lumbar vertebra on the left side and the second lumbar vertebra on the right side; the renal region. (Fig 1B) According to transperitoneal observation, the visceral peritoneum around the renal region extended particularly far in a ventral direction by suspended kidneys farther than the other organs closely attached to the dorsal region of the abdomen. It was attached laterally to the abdominal wall between the dorsal and ventral margins of the kidneys, closer to the dorsal margin. The site of entry was expanded by blunt dissection with Metzenbaum scissors, and digital palpation of the lateral margin of the transverse process was used to guide the scissors in the plane of the abdominal wall layers (the oblique muscles, fatty tissues, and deeply lying transverse abdominal muscle), as described by Johnston et al. (1977). The retroperitoneal space was entered with the Metzenbaum scissors by penetrating the deepest division of the thoracolumbar fascia. The soft fatty tissue around the kidney was felt upon entry, which confirmed that the retroperitoneal space had been entered successfully. Subsequently, a 10 mm blunt trocar with an inflatable balloon and an adjustable sleeve (Covidien, Dublin, Ireland) was introduced into the incision site, and a 5 mm 0° telescope (Karl Stortz, Tuttlingen, Germany) was inserted into the access port to ensure that the tip of the trocar was within the retroperitoneal space. A 0° telescope was adopted to provide the simplest spatial orientation similar to that of normal vision, considering unfamiliar orientation was one of technical challenges in humans. The balloon was inflated to prevent leakage of CO_2, (Fig 1C) and the retroperitoneal space was established with CO_2 insufflation starting with a pressure of 5 mmHg and increasing in 5 mmHg increments; this was subjectively evaluated with the telescope via both the transperitoneal and retroperitoneal trocars.

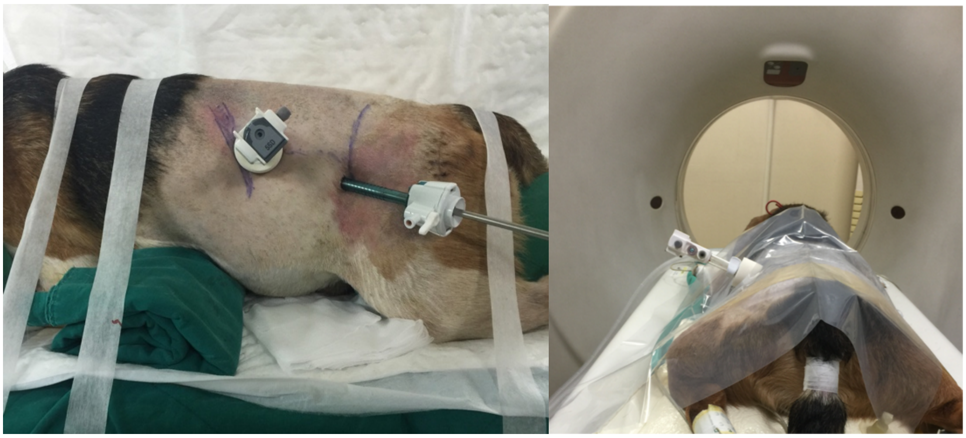

Figure 1. Retroperitoneal access technique (A) A transperitoneal trocar has been inserted cranial to the iliac crest for anatomic observation of the visceral peritoneum and retroperitoneal organs during the cadaveric study. A retroperitoneal trocar was placed at the level of the second lumbar vertebrae on the right side and third lumbar vertebrae on the left side in both the cadaveric and (B) experimental CT study. The most important landmark for this access is a transverse process of the vertebrae.

(C) The 10 mm blunt-tip trocar with an inflatable balloon and an adjustable sleeve used for introduction into the retroperitoneal access site.

2. Experimental CT study

Six clinically healthy intact male beagle dogs (approximate age, 3 years; mean weight, 10.53 kg [range, 7.5 – 12.7]; body condition score, 4 – 6 out of 9) were studied (Laflamme, 1997). Food was withheld from the dogs for 12 hours in preparation for anesthesia. Dogs were premedicated with acepromazine (0.01 mg/kg intravenously [IV]), and anesthesia was induced with alfaxalone (5 mg/kg IV to effect) and maintained with isoflurane in oxygen. Hartmann's solution (5 mL/kg/h) was administered. Urinary catheterization was performed to keep the bladder empty during scanning. Anesthetized dogs were positioned in sternal recumbency with a commercial patient positioning kit (Vacu-positioner kit; Shor-line, Kansas, MO) and secured with adhesive tape. CT was performed with a single-slice helical CT scanner (GE CT/e; General Electronic Medical Systems, Yokogawa, Japan). Scans were performed from the diaphragm to ischial tuberosities in a cranial to caudal direction with a 3 mm slice thickness. After the initial scanning as a baseline for comparison with subsequent scanning, the retroperitoneal space was approached aseptically with the above-described technique. Dogs were randomized to groups of left-sided (n = 3) or right-sided (n = 3) approaches. The working space was established with CO_2 insufflation with an electronic CO_2 insufflator (Karl Stortz) by increasing the pressure within the retroperitoneal space from 0 mmHg to 5, 10, and 15 mmHg at a rate of 1 L/minute. Scanning was carried out at each pressure level unless pneumoperitoneum occurred secondary to a peritoneal tear, at which point further CO_2 insufflation and scanning were aborted to prevent possible complications. During the study, basic anesthetic monitoring was performed including measurement of heart rate, respiratory rate, oxygen saturation as measured via pulse oximetry, non-invasive blood pressure, end-tidal CO_2 ($ETCO_2$) and body temperature. At each new pressure level, further scanning was paused for 5 minutes for stabilization of $ETCO_2$ and monitoring of possible changes affected by pneumo-retroperitoneum. At the study end, the trocar was removed and the port site closed with simple interrupted sutures in the fascia of the thoracolumbar region and the skin. The trocar site was infiltrated with a mixture of lidocaine and bupivacaine, and the dog was allowed to recover from general anesthesia. Post-operatively, the dogs were administered a 5-day course of a non-steroidal anti-inflammatory drug (carprofen 4.4 mg/kg/day), and monitored for pain using a visual analogue scale (VAS) and possible complications by physical examination and visual observation for 2 weeks (Conzemius et al., 1997). This study was approved by the Institutional Animal Care and Use Committee of Seoul National University.

3. Outcome measures

All CT images were imported to OsiriX software (ver. 7.03 for Mac OS; http://www.osirix-viewer.com, Swiss, PIXEMEO) for analysis (Kim et al., 2012). Two different measures of working space were analyzed: pneumo-retroperitoneum volumes and working-space linear dimensions. For the CT volumetry, the regions of CO_2 in the retroperitoneal space were detected semi-automatically with the definition of appropriate thresholds on all transverse images. (Fig 2) The total volume including both ipsilateral and contralateral sides and the ipsilateral volume based on the mid-sagittal plane as the medial border were measured respectively. Inadvertently selected gas regions in the intestines were excluded with visual inspection before volume computation (Cai et al., 2009; Vlot et al., 2015).

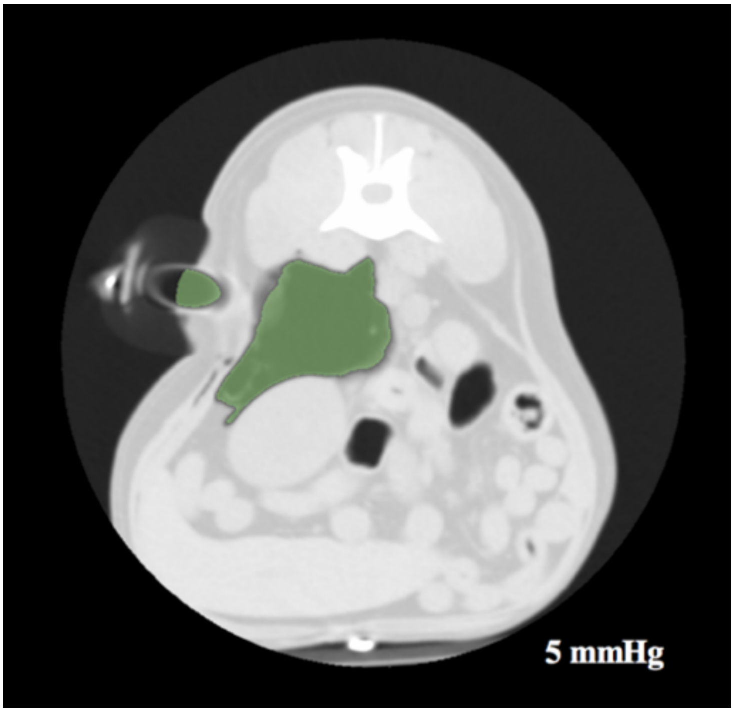

Figure 2. CT Volumetry of the retroperitoneal working space. Transverse computed tomography images at 5 mmHg CO_2 insufflation, demonstrating the region of CO_2 pneumo-retroperitoneum selected in OsiriX. The detected areas on all transverse images were integrated to a total volume of CO_2 pneumo-retroperitoneum.

Maximum linear dimensions (maximum dorsoventral diameter ["height"] and maximum transverse diameter ["width"]) were measured on transverse images at the levels of the second to fourth lumbar vertebrae—a potential working region in adrenalectomy or nephrectomy. (Fig 3) The measurements were performed separately for the left and right retroperitoneal spaces based on the mid-sagittal plane as the medial border, because retroperitoneoscopic procedures would be performed in the left or right side of the space individually. Additionally, maximum linear dimensions (maximum dorsoventral diameter ["height"] and maximum craniocaudal diameter ["width"]) were measured in a para-sagittal plane of the ipsilateral side on multiplanar reconstruction (MPR).

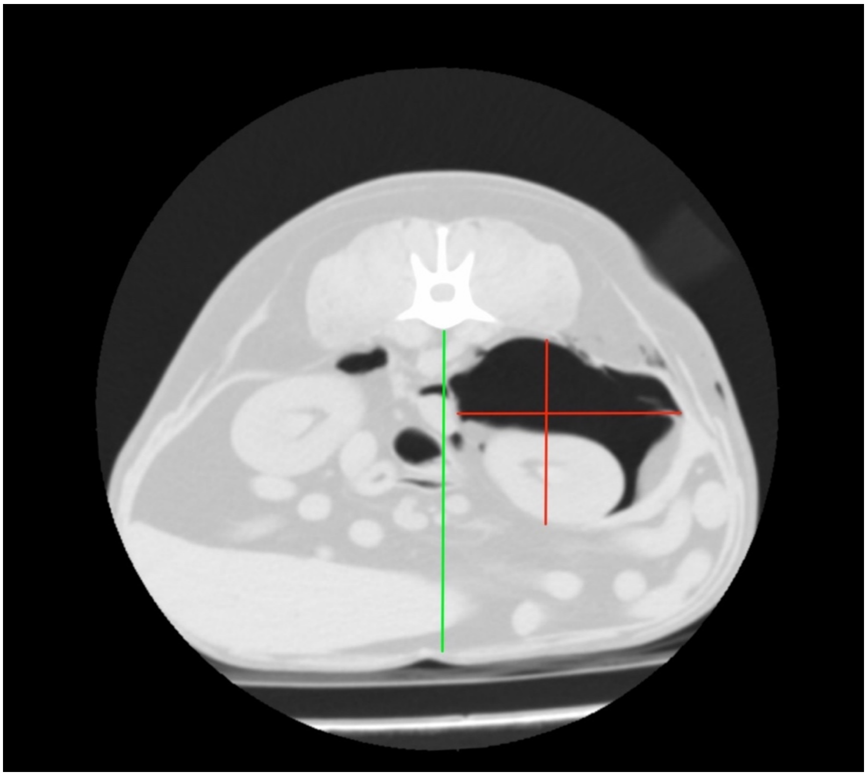

Figure 3. Maximum Linear dimensions of the retroperitoneal working space.

Transverse computed tomography image at the level of the second lumbar vertebra for 10 mmHg CO_2 insufflation pressure. The trocar was placed with the right approach. Maximum linear dimensions (maximum dorsoventral diameter and maximum transverse diameter [red lines]) were measured separately on left and right sides based on the mid-sagittal plane as the medial border (green line).

Finally, abdominal height and width were measured in the transverse plane at the level of the second lumbar vertebra to identify abdominal distention secondary to expansion of the retroperitoneal space. For all measurements associated with the lumbar vertebrae, the images visualizing the most lateral margin of the transverse process—an important palpable anatomic landmark—were selected.

4. Retroperitoneal space observation

Subjective evaluation of the retroperitoneal working space and organs within it was performed non-blindly with images and videos from cadaveric and CT studies. The observations were compared with CT scans to complement the evaluation.

5. Statistical analysis

All statistical analyses were performed using software (STATA/MP 14.1; StatCorp LP, College Station, TX). The effect of the approach side (left, right) on the responses (volume, working-space linear dimensions) was assessed using a repeated-measures 1-way ANOVA. The side of the approach did not have a significant effect, and was not included in any further analysis. A repeated-measures 1-way ANOVA was used to assess the effect of pressure on the volume, with the model including the 0, 5, 10, and 15 mmHg pressures. The effect of pressure on the working-space linear dimensions was evaluated using the same model. Abdominal diameter at the second lumbar level with increasing pressure was assessed using the same repeated-measures 1-way ANOVA. All post hoc comparisons were made with a Bonferroni correction. $P < .05$ was considered statistically significant.

III. Results

1. Pilot study

The retroperitoneal space was successfully accessed in all 5 cadavers while placing a trocar dorsolateral to the kidney and displacing it in a medioventral direction. (Fig 4) In 4 cadavers, adequate retroperitoneal working space was established with CO_2 insufflation from 5 mmHg pressure, expanded further at 10 mmHg pressure, and communicated to the peritoneal space due to peritoneal tearing at 15 mmHg. Early technical issues included peritoneal injury and subcutaneous emphysema during access which were addressed. Peritoneal tearing led to peritoneal insufflation, narrowing of the retroperitoneal space, and abdominal distension.

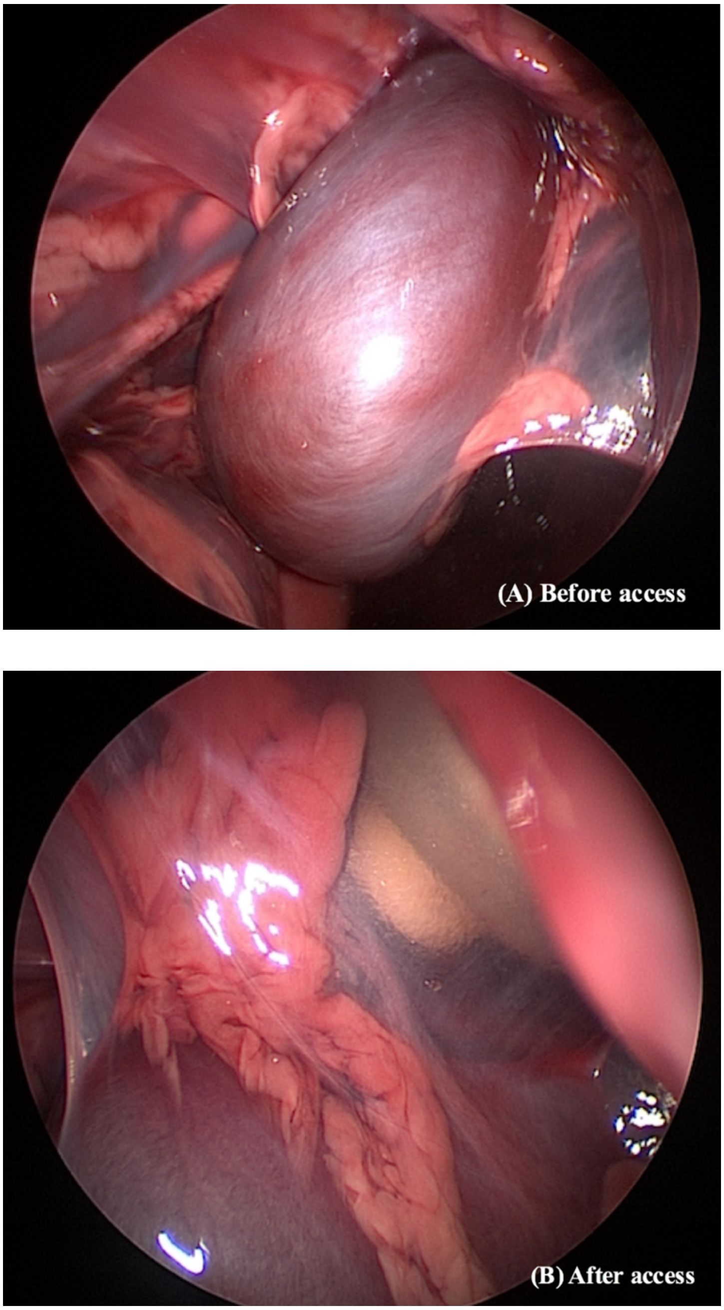

Figure 4. Retroperitoneal trocar placement. Transperitoneal images obtained in a cadaver (A) before and (B) after the retroperitoneal access from the right side (caudocranial view). The kidney is displaced medioventrally by trocar placement.

2. Experimental CT study

The retroperitoneal access and working-space establishment were performed successfully in all 6 dogs. During the approach, hemorrhage was minimal and easily controlled. No subcutaneous emphysema was observed. At 15 mmHg pressure, peritoneal tearing occurred in 4 dogs. Between the dogs with and without peritoneal tearing, the BCS was higher in dogs without peritoneal tearing (5-6/9 versus 4/9), though the procedures were not different. All animals were stable during the study: no changes in anesthetic monitoring were recognized at each new pressure level. They recovered from general anesthesia uneventfully, and walked actively within 30 minutes with no visual pain responses. During the 2 weeks postoperatively, the pain was well-controlled, and prolonged pain medication was not required. All dogs were clinically healthy and did not show any complications.

3. Working-space establishment

The CT images of all animals showed common patterns of working-space establishment. At 0 mmHg (Fig 5A), retroperitoneal working space was established around the trocar. As the pressure increased to 5 mmHg (Fig 5B), the working space expanded radially then extended craniocaudally from the diaphragm to the anus. The working space was limited to the ipsilateral side in 4 dogs, but it did start to extend across the mid-sagittal plane in 2 dogs. With further increase in pressure to 10 mmHg (Fig 5C), it expanded contralaterally, then led to peritoneal tearing at 15 mmHg. The degree and speed of this pattern in association with the pressure varied among individual animals. In 1 dog, pneumomediastinum was identified on transverse images at 10 mmHg. (Fig 6)

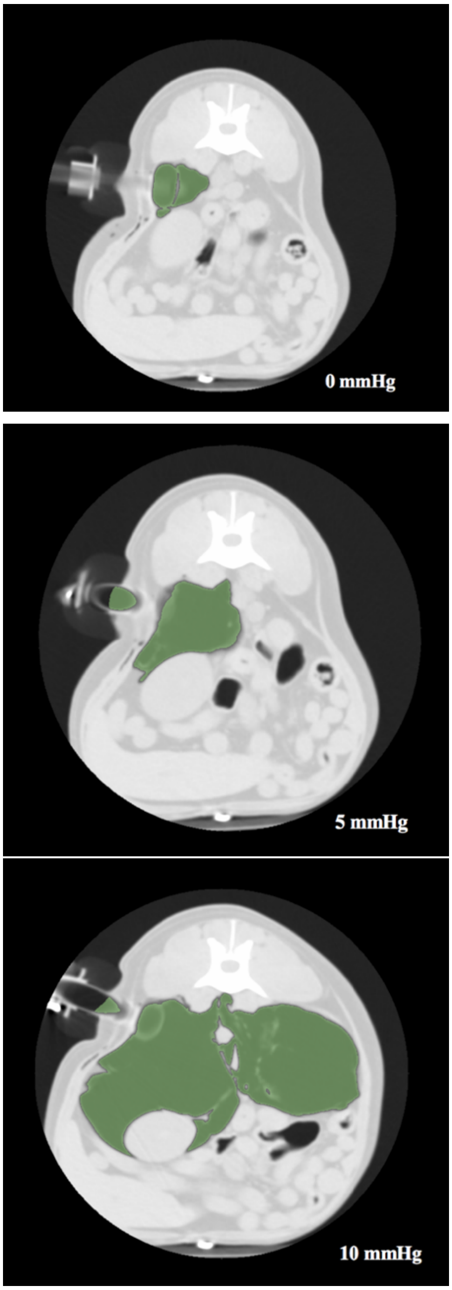

Figure 5. The patterns of working space establishment on transverse computed tomography images (A) At 0 mmHg, the retroperitoneal working space was established around the trocar. (B) At 5 mmHg, it expanded limited to the ipsilateral side in 4/6 dogs (C) At 10 mmHg, it extended to contralaterally. Finally, peritoneal tearing occurred at 15 mmHg in 4/6 dogs.

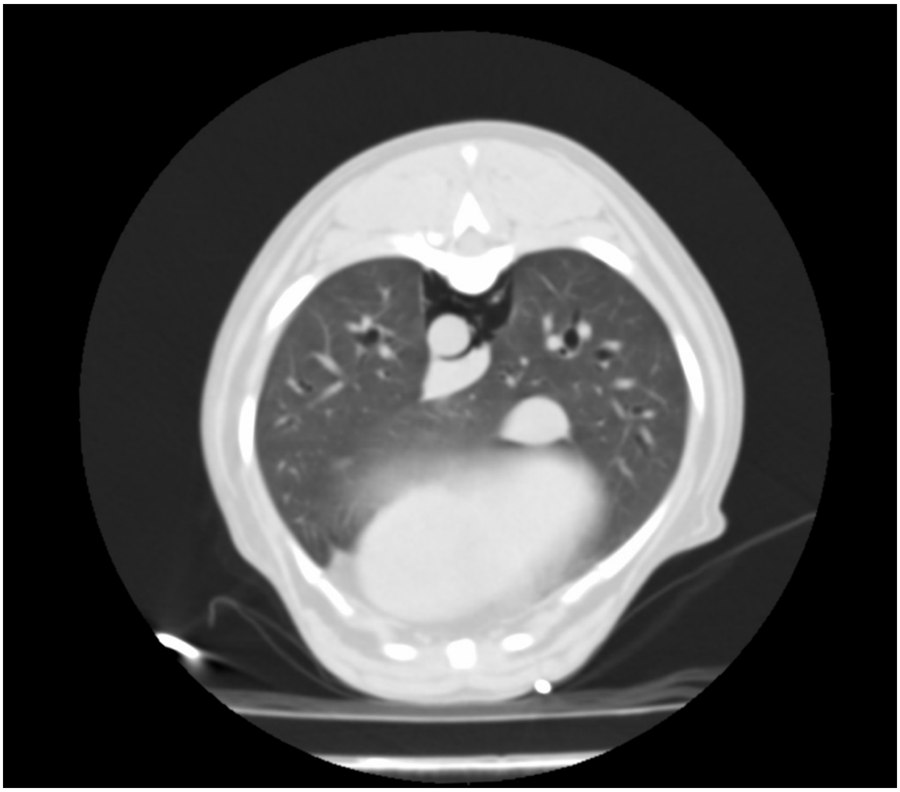

Figure 6. Subclinical pneumomediastinum. Pneumomediastinum was identified on transverse images at 10 mmHg in 1 dog. This dog maintained a clinically healthy status post-operatively.

The relationship of pressure and working-space volume (Table 1) showed that working-space volume on both sides and the ipsilateral side alone increased significantly from 5 to 10 mmHg and 10 to 15 mmHg. On the other hand, work-space linear dimensions (Table 2) were increased significantly from 0 to 5 mmHg and 5 to 10 mmHg on parasagittal images and transverse images at the second to fourth lumbar vertebrae, except linear height on transverse images at the second lumbar vertebra from 0 to 5 mmHg. The establishment of retroperitoneal space from 0 to 5, 5 to 10, and 10 to 15 mmHg resulted in significant changes in abdominal height at the second lumbar vertebra (Table 3). However, abdominal width increased significantly only from 5 to 10 mmHg.

Table 1. Mean (SD) values of working-space volume

Pressure (mmHg)	No. of Animal	Volume (mL)	
		Ipsilateral	Total
0	6	15.09 (3.37)	15.09 (3.37)
5	6	91.59 (51.93)	99.14 (62.34)
10	6	269.18* (94.99)	501.18* (225.10)
15	2	407.54* (41.26)	824.65* (56.48)

* Within a column, the value increased significantly ($P < .05$) when the pressure increased by 5 mmHg.

Table 2. Mean (SD) values of working-space linear dimensions on the ipsilateral side as measured on transverse images and parasagittal images

	Lumbar level	Pressure (mmHg)			
		0	5	10	15
Measured on transverse images					
Linear height (mm)	2	6.19 (9.12)	23.03 (23.70)	63.43* (11.06)	67.25 (1.20)
	3	12.05 (9.97)	35.43* (13.50)	61.72* (13.20)	66.85 (3.46)
	4	7.38 (5.79)	39.10* (16.65)	56.67* (13.98)	67.35 (3.75)
Linear width (mm)	2	4.59 (5.29)	29.28* (20.74)	60.35* (9.95)	77.40 (1.70)
	3	16.15 (14.57)	42.43* (10.13)	66.00* (12.93)	83.95 (1.20)
	4	12.80 (10.48)	41.72* (11.30)	65.03* (12.38)	82.35 (0.64)
Measured in a parasagittal plane					
Linear height (mm)		14.53 (4.40)	37.70* (10.73)	58.03* (18.22)	66.20 (0.71)
Linear width (mm)		36.93 (12.99)	105.43* (28.97)	158.68* (25.83)	157.25 (10.54)

* Within a row, the value increased significantly ($P < .05$) when the pressure increased by 5 mmHg.

Table 3. Mean (SD) value of abdominal diameter at the second lumbar vertebra

Abdominal diameter (cm)	Pressure (mmHg)			
	0	5	10	15
Height	15.01 (0.67)	15.04* (0.76)	15.70* (0.91)	16.06* (0.60)
Width	15.39 (3.31)	15.63 (3.25)	16.26* (3.12)	19.37 (0.69)

* Within a row, the value increased significantly ($P < .05$) when the pressure increased by 5 mmHg.

4. Retroperitoneal space observation

Without insufflation, entry to and visibility of the retroperitoneal space was obscured by the loose connective tissue mesh mixed with fat tissue. (Fig 6A) This tissue was easily pushed aside with the telescope and CO_2 insufflation, leading to identification of the retroperitoneal organs. (Fig 6B) During working-space establishment, the kidney displaced ventrally and the great vessels pushed medially. Therefore, relative to the entry site, the dorsal plane of the displaced kidney was observed ventrally, the pulsating abdominal aorta and caudal vena cava (CVC) were found in front of the trocar, and the renal vessels crossed vertically to connect to the kidney. The adrenal glands could also be identified and were located cranial to the renal vessels and closely ventral to the aorta or CVC, which were consistently found on CT scans at 0, 5, and 10 mmHg in all dogs. Additionally, the phrenicoabdominal vein was located craniodorsally to the adrenal glands. Relative to the trocar, the adrenal glands were located craniomedially.

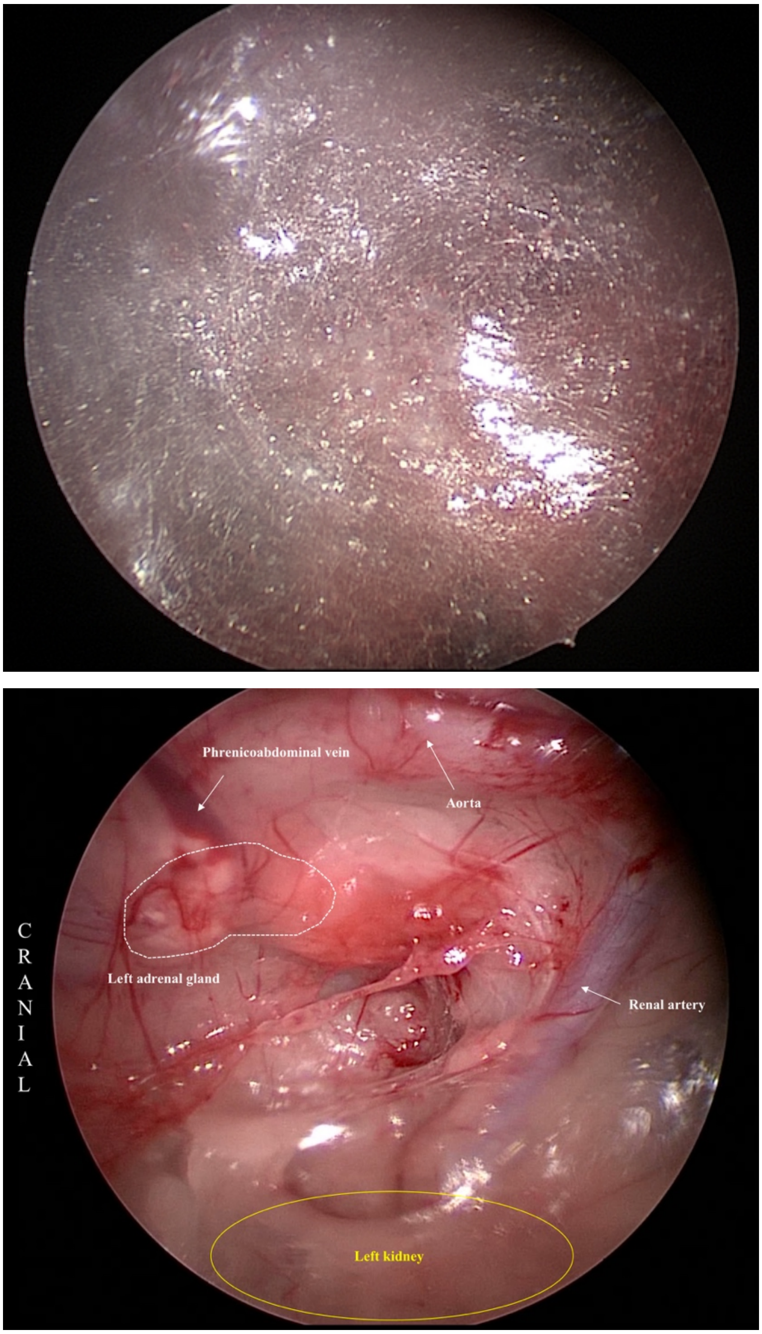

Figure 6. Surgical anatomy of retroperitoneal working space. Telescopic view from a left-sided retroperitoneal trocar in a lateromedial direction. **(A)** Loose connective tissue mesh is seen upon entry. **(B)** Retroperitoneal organs were visualized with CO_2 insufflation and telescope maneuvering.

IV. Discussion

In this study, a retroperitoneal access technique was developed and the retroperitoneal space was successfully entered and subsequent working space established with low-pressure CO_2 insufflation alone in all 6 dogs on both sides (right and left; 3 animals each) without any complications. Further, surgical anatomy of retroperitoneal organs within the working space was visualized, which may allow direct access with appropriate instrumentation for retroperitoneal laparoscopy in dogs.

1. Access technique

The initial consideration for the retroperitoneal approach is reliable anatomic landmarks to identify the proper entry site dorsal to the lateral peritoneal reflection. Current access techniques in humans use the tip of the twelfth rib as a key anatomic landmark (Walz et al, 2006; Joseph and Patel, 2011) based on the fact that it consistently lies within both kidney regions and is posterior to the peritoneal fold (Joseph and Patel, 2011; Capelouto et al., 1994). In the pilot study, the potential region of retroperitoneal approach in dogs was considered to lie between the dorsal wall of the abdomen and the dorsal margin of the kidneys. Unfortunately, there were no palpable anatomic structures or reliable and constantly applicable visual landmarks associated with the upper margin of the kidneys. Therefore, the access site of this technique was designed using the transverse process of a lumbar vertebra as a palpable anatomic landmark to identify the upper margin of entry.

An open-entry technique, currently standard for the retroperitoneal approach in humans (Walz et al., 2006; Joseph and Patel, 2011; Perrier et al., 2008; Caione et al., 2003), was adopted in this study. Without reliable anatomic landmarks delineating the lateral peritoneal fold in dogs, developing a reliable and safe blind Veress needle placement technique in dogs was considered implausible in this study. Fortunately, a study of conventional open adrenalectomy via the retroperitoneal approach (Johnston, 1977) describes surgical access to the retroperitoneal space with finger insertion, which is similar to the human retroperitoneal access technique (Walz et al., 2006; Perrier et al., 2008). This was applicable to the present technique using the transverse process of a lumbar vertebra as an anatomic landmark.

After addressing early stage technical issues in the pilot study, none of the 6 dogs in this study showed any complications of access. In humans, the most important concern during access is inadequate development of the surgical field (Caione et al., 2003), which may be induced by gas leakage or peritoneal insufflation. A major concern of the open-entry technique is gas leakage from the trocar access site, resulting in retroperitoneal space collapse, subsequent loss of effective working space, and subcutaneous emphysema (Joseph and Patel, 2011). To overcome this, most human surgeons use a blunt-tip trocar in retroperitoneal laparoscopy (Walz et al., 2006; Caione et al., 2003), which was also used in this study.

2. Working-space establishment

In the early phases of retroperitoneal laparoscopy in humans, the most important issue that prevented its development was the inadequate creation of working space (Darzi, 1996). Because of the dense connective tissue in the retroperitoneal space in humans, CO_2 insufflation alone is not enough to establish a working space (Darzi, 1996). Therefore, the introduction of a balloon dissector (Gaur, 1992), which provides mechanical expansion of the retroperitoneal space, greatly facilitated the retroperitoneoscopic research (Darzi, 1996). Fortunately, the present study showed that CO_2 insufflation alone was sufficient to establish working space in dogs. By increasing the CO_2 insufflation pressure, the working space was extended not only ipsilaterally, but also contralaterally in all subjects. Further, the entire space was over-expanded at 15 mmHg, resulting in peritoneal tearing in all cadavers and 4 animals. To the author's knowledge, this pattern of working-space development has not been described in the human literature. These findings may be explained by the anatomic differences in the retroperitoneal space of dogs (Johnston and Christie, 1990) that it is filled with loose connective tissue mesh without compartmentalization as found in humans.

During working space establishment, abdominal distention was not perceived until peritoneal tearing occurred and the changes in abdominal diameter measured on CT were mild, even though it was statistically significant. This suggests that retroperitoneal working space is established by reducing intraperitoneal space with mild abdominal wall distension. Therefore, the contents of the abdomen, such as intestinal gas or feces and abdominal fat, would affect retroperitoneal space establishment, which may support that sternal recumbency without abdominal support is beneficial for retroperitoneal working-space establishment, as reported in humans (Walz et al., 2006; Perrier et al., 2008; Urbanowicz et al., 2002). Additionally, when applying restraint measures for patient positioning, those more compliant might minimize the effect on intra-abdominal pressure.

3. Surgical anatomy of the retroperitoneal working-space

In this study, organ displacement in the retroperitoneal working space in dogs was similar to that in humans; pneumo-retroperitoneum acted like a natural retractor by displacing the kidney ventrally, exposing the renal hilum, great vessels, and adrenal glands; this would provide direct access for retroperitoneal laparoscopy in dogs. Further, the adrenal glands could be identified using the vasculature (renal vessels, abdominal aorta, and CVC) as anatomic landmarks. This can be explained by the fact that the left adrenal gland is more closely related in position to the abdominal aorta than the left kidney and that the capsule of the right adrenal gland is closely associated with the CVC (Evans and Lahunta, 2013). In human retroperitoneal adrenalectomy, the first step after entry is finding the cranial pole of a kidney, which can lead to the adrenal glands (Walz et al., 2006; Perrier et al., 2008). Therefore, locating retroperitoneal vasculature could be considered an initial step in retroperitoneal adrenalectomy in dogs.

The degree of fat deposition in the retroperitoneal space was an important factor affecting the quality of visualization. Although the adrenals were visible at a pressure of 5 mmHg in all animals, full visualization as described above was obtained at different pressure levels from 5 – 15 mmHg in different animals; greater visualization was obtained by increasing the insufflation pressure. In the author's opinion, 5 mmHg of insufflation pressure with an understanding of the anatomic relationship and manipulation with instrumentation would be sufficient to visualize the adrenals for surgical procedures.

4. Optimal pressure

Retroperitoneal laparoscopy only requires establishment of a working space on one side. Further, the pressure required to establish adequate working-space linear dimensions representing the actual surgical field of the kidneys and adrenal glands could be valid information. From 0 to 10 mmHg, working space was established limited to the ipsilateral side. The working-space volume significantly increased from 5 mmHg and linear dimensions significantly increased from 0 to 10 mmHg. These findings suggest that working-space creation should start with a pressure of 5 mmHg and that pressure may be increased gradually to 10 mmHg if necessary.

Interestingly, peritoneal tearing was not observed in a previous canine study even though a higher pressure (25 – 30 mmHg) was maintained than in the present study at the same infusion rate (Kaplan et al., 1979). These differences could be explained by the following: different type of gas, higher range of body weight (15 – 60 kg), different breed with different conformation, and unknown body condition score.

5. Complications of pneumo-retroperitoneum

All animals were stable and clinically healthy during and after the procedure. Subclinical pneumomediastinum was found in 1 dog on CT images at 10 mmHg. In humans, pneumothorax and pneumomediastinum are potential complications of pneumo-retroperitoneum (Gill et al., 1998). Pneumomediastinum is rarely of clinical consequence and resolves spontaneously in dogs (Ettinger and Feldman, 2009).

6. Study limitations

This study has several limitations. Subclinical effects were not evaluated. Despite the findings that all animals were stable during the study and suggested pressures were relatively low, pneumo-retroperitoneum would have had a silent effect on hemodynamics, CO_2 absorption, and organ perfusion – specifically the kidneys and adrenals. Before clinical application on patients with retroperitoneal disease, thorough evaluation is warranted.

Instrumentation or any surgical procedure were not performed, as it was not feasible in the repeated CT study design. Further, there are no established standard for measurement methods or clinical relevance in working space studies. Therefore, the findings in this study warrants individual surgeons' interpretation to fill the gap between working space establishment and surgical procedures. In the author's opinion, the working space linear dimensions measured in a parasagittal plane at 5 to 10 mmHg might suggest that both triangulation and a SILS approach could be feasible, especially a SILS approach. The instrumentation techniques described in humans (Walz et al., 2006) such as the finger-guided could be considered for triangulation, since any reliable landmarks for instrumentation were not identified in this study.

The number of subjects was small and the body weight and body condition score varied. The degree and speed of working-space establishment pattern and a quality of visualization were different among individual animals. In the author's opinion, the body fat disposition, specifically retroperitoneal fat, may be considered as a factor affecting these differences. In clinical procedures, obese patients might require adjustment from that suggested in this study. To completely evaluate these factors and the safety of this approach, a large number of subjects or more strictly controlled animals are needed for advanced statistical analysis.

The standardization of insufflator running duration and randomization of insufflation pressure were not applied. The variation in the duration of the insufflator run and the accumulated volume might have affect the working space establishment with different pressure effect. However, from the pilot study, the randomization was considered not applicable to the retroperitoneal space in the repeated-measure design. Further, the variation of the duration of the insufflator run was not avoidable due to the technical issues including CT scanner, retroperitoneal observation time, etc.

Only sternal recumbency was studied; thus, the optimal position for retroperitoneal laparoscopy in dogs was not evaluated. In humans, retroperitoneal laparoscopy is performed in the lateral or posterior position depending on the patient, surgical procedure, and surgeon preference (Joseph and Patel, 2011).

V. Conclusion

The retroperitoneal access technique is reliable for visualization, and working-space establishment with CO_2 insufflation starting with 5 mmHg and increasing to 10 mmHg would provide an adequate visualization of the retroperitoneal organs and may allow direct access by appropriate instrumentation. Before use of retroperitoneal laparoscopy for clinical patients, the subclinical effects as well as additional port placement sites and subsequent surgical procedures (or single port procedures) are required to be studied.

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VII. Abstract in Korean

개에서의 후복막강경의 접근법, 작업 공간 및 해부학적 특징

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후복막 공간으로 직접 접근하여 복강 내 장기를 견인하지 않고 후복강 장기를 수술할 수 있는 후복막강경 수술법은 기존의 복강 접근을 통한 수술법에 대한 매력적인 대안으로 인의에서는 이미 표준화된 수술 방법이다.

본 연구는 개에서의 후복막강경 수술을 위한 후복막강 접근법의 개발 및 적용, 작업공간 형성 및 해부학적 특징에 대한 연구로서, 8마리의 사체를 이용한 예비 실험과 6마리의 건강한 개를 대상으로 반복적인 컴퓨터단

층촬영을 실시한 동물실험으로 구성되어 있다. 예비실험에서 3마리의 사체를 대상으로 개발한 후복막강경 접근법을 5마리의 사체와 6마리의 실험 동물에 적용하였으며, 이산화탄소 단독 주입을 통해 작업공간을 형성한 후, 이산화탄소의 압력을 0, 5, 10, 15 mmHg으로 증가시키면서 예비 실험에서는 복강경을 통한 관찰을, 동물 실험에서는 반복적으로 컴퓨터단층촬영을 실시하여 후복막강경의 작업공간을 평가하였다. 그리고 컴퓨터단층촬영 영상에서의 후복막강경의 작업공간의 용적 및 실제 수술 공간을 고려한 작업 길이와 함께 후복막강경을 통한 영상 자료를 분석하였다.

후복막강경 접근 및 이산화탄소 단독 주입을 통한 후복막강경 작업공간 형성은 실험동물 6마리 모두에서 성공적으로 실시되었다. 컴퓨터단층촬영 상 1마리에서 종격동기종이 관찰된 것 이외에는 합병증이 확인되지 않았다. 이산화탄소 압력의 증가에 따라 작업 공간은 접근한 쪽에서 형성되기 시작하여 반대쪽으로 확장되고, 최종적으로는 복막이 찢어지며 복강으로 연결되는 것이 관찰되었다. 통계학적으로 작업공간의 용적은 5 mmHg에서부터, 작업 길이는 0에서 10 mmHg에서 유의미한 증가를 보였다. 이를 종합하여, 본 연구에서는 후복강의 작업공간을 확보하기 위한 최적 압력 범위로 5 mmHg를 시작하여 필요에 따라 10 mmHg까지 증가하는 것이 적절할 것으로 판단된다.

후복강의 작업공간 형성을 통해 신장과 부신 등의 후복강 장기가 쉽게 시각화 되었다. 접근 위치를 기준으로 변위된 신장의 등쪽 부분은 배쪽에서, 박동하는 복강 동맥과 후대정맥은 정면에서 관찰된다. 부신은 대형 혈관에서 신장으로 연결되는 신장 혈관의 머리 쪽에서 위치하고 있다.

본 연구를 통해 후복강 접근을 통해 후복강 장기, 특히 부신과 신장

의 등쪽으로 직접 접근할 수 있으며, 개에서의 후복강경 수술의 임상 적용이 가능할 것으로 기대한다.

주요어: 개, 후복막강경, 최소침습수술, 후복막 공간, 작업 공간, 접근법

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