Computed Tomography Determined Changes in Position of the Hepatobiliary and Gastrointestinal Systems after CO_2 Insufflation to Determine Optimal Positioning for Abdominal Laparoscopy

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Abstract

Objective: To evaluate changes in body position and effect of CO_2 insufflation on the hepatobiliary and gastrointestinal systems using computed tomography (CT) to determine optimal laparoscopic approach.

Study Design: Experimental study.

Animals: Healthy intact female Beagles (n = 6) of similar age, weight, and body condition score.

Methods: Urinalysis, peripheral blood smear, and abdominal ultrasonography were performed to determine dog health. A series of pre insufflation (PrI) CT scans in ventrodorsal routine (VDR), ventrodorsal Trendelenburg (VDT), left lateral (LL), and right lateral (RL) recumbency were performed before and after abdominal insufflation (PoI) with CO_2 (10–14 mm Hg). Pre-determined measurements were made on PrI and PoI scans and differences compared.

Results: Liver position was affected by body position and under gravitational influence moved to the dependent part of the abdominal cavity. The gallbladder was best exposed in LL. Stomach position was not significantly changed after insufflation. Different areas of small intestine were dependent on gravitational effects. The pancreas maintained a similar position after insufflation.

Conclusions: VDR was the ideal position for all laparoscopic procedures of the liver. The LL position could be used for surgery of the gallbladder but likely provides poor exposure to the rest of the liver. In approaching the stomach and intestines, the area of interest should be used to determine the best position.

Laparoscopy provides a minimally invasive method of performing complex abdominal surgery[1-3] provided adequate working space for instrumentation and manipulation can be created within the abdominal cavity. In the normal animal the abdominal cavity is only a potential space filled with a small amount of serosal fluid.[4] An increase in the potential space to a working space is created by CO_2 insufflation of the abdomen to a pressure of 10–14 mm Hg.[1, 2] Once insufflated, an endoscope can be introduced into the abdominal cavity through a cannula for viewing, illumination, and magnification of abdominal organs.[1] These images can be viewed on a monitor allowing clear observation of the structures and procedures for surgical assistants, and for teaching.[1]

In dogs, laparoscopic procedures for the hepatobiliary system, including biopsy, which is superior for histopathologic diagnosis to a tru-cut biopsy technique,[1] as well as liver lobectomy and cholecystectomy, have been described.[1, 5] Laparoscopic prophylactic gastropexy is performed in young large breed dogs to help prevent gastric volvulus[6-8] and is commonly performed at the time of laparoscopic ovariohysterectomy.[6, 9] Dogs have been used as a research model for humans in performing pyloroplasty.[10] Foreign bodies have been retrieved from the stomach, feeding tubes placed, and biopsy of the entire gastrointestinal tract and pancreas using laparoscopic-assisted procedures have been reported.[4-6, 11-14]

Positioning of the anesthetized dog to create optimal laparoscopic working space has been determined through experience. Trendelenburg position has been recommended for ovariohysterectomy[1] typically by elevating the pelvis 30° above the abdomen, so that the viscera moves away from the uterine body to improve surgical exposure of the reproductive tract.[1, 2] Computed tomography (CT) provides excellent abdominal detail because of spatial resolution and lack of superimposition.[15-20] Surface detail of viscera should be enhanced by the presence of a negative contrast medium such as CO_2 in the peritoneal space.

In combination, CT and laparoscopy provide minimally invasive diagnostic and treatment approaches for most surgical diseases of the abdominal cavity. For this study, we assumed that post insufflation CT anatomic depictions will be an accurate representation of laparoscopic anatomy during surgery although this is unproven. Thus, we hypothesized that using abdominal CT images after insufflation as a reference, will accurately depict normal canine anatomy and thus mimic any anatomic alterations of the hepatobiliary and gastrointestinal systems that can be expected during laparoscopy.

Thus, our purpose was to develop a reference atlas for abdominal laparoscopy based on CT images to reflect expected anatomic changes and to provide a rationale for the selection of certain body positions to facilitate laparoscopic surgery by using gravitational movement of viscera to create an adequate working space.

MATERIALS AND METHODS

Dogs

Clinically healthy, intact female Beagles (n = 6), aged 2–4 years, weighing 11–13 kg with body condition scores ranging from 3 to 4[21] were studied. All dogs had peripheral blood smear, urinalysis, and abdominal ultrasonographic examinations. Dogs were dewormed with praziquantel, febantel, and pyrantel embonate. Food, but not water, was withheld for at least 12 hours before abdominal CT. All procedures were approved by the institutional Animal Use and Care Committee.

Experimental CT Protocol

Dogs were premedicated with acetylpromazine (0.05 mL/kg intramuscularly [IM]) and buprenorphine (0.02 mg/kg IM) and anesthesia induced with propofol (6.6 mg/kg intravenous [IV] to effect) and maintained with isoflurane in oxygen. Lactated Ringer's solution (10 mL/kg/h) was administered. A 10 Fr Foley catheter was placed in the bladder, the bulb inflated with 3 mL sterile water, and connected to a closed continuous drainage system to keep the bladder empty during CT scan.

CT was performed with a helical dual slice sliding gantry CT machine (Somatom Emotion, Siemens AG, Erlangen, Germany). Respiratory movement was eliminated by administering a bolus of 1% propofol (1 mg/kg IV) together with manual hyperventilation. Hypocarbia (<40 mm Hg CO_2) was induced leading to temporary apnea for the scan duration. Scans were performed in a cranial to caudal direction to minimize the potential effect of respiratory movement in the cranial abdomen should respiration start before scan completion. A lateral tomogram was performed before all CT scans and the field of view adjusted to include the diaphragm and ischial tuberosities. IV contrast was not administered because repeated administration with positional change could have potentially resulted in iatrogenic contrast induced nephrotoxicity.[19]

Slice collimation of 2.5 mm, slice thickness of 3 mm, a pitch of 2 and a soft tissue algorithm (B41s medium kernel, window level 40, and window width 400) was used for all dogs. Tube rotation speed of 0.8 seconds and 110 kV were maintained for all scans. Trendelenburg position was achieved by placing the dog on a custom made foam wedge in the shape of a right angle triangle with 30° and 60° angles and the legs secured with ties connected to heavy sandbags (Fig 1). For all scans, the table was maintained at 90° to the gantry. For Trendelenburg position, the gantry was tilted at 30° to keep the scan plane perpendicular to the abdomen.

Figure 1. Dog positioned in Trendelenburg position before the post insufflation (PoI) CT scan.

Pre-insufflation (PrI) scans were performed in ventrodorsal routine (VDR), ventrodorsal Trendelenburg (VDT), left lateral (LL), and right lateral (RL) positions. A screw-in disposable laparoscopy 10 mm plastic cannula (Karl Stortz, Tuttlingen, Germany) was inserted at the umbilicus using the Hasson technique.[1] A metal cannula was avoided because of potential beam hardening artifacts interfering with the images. The abdomen was insufflated (10–14 mm Hg) with CO_2 using an insufflator. Post insufflation (PoI) scans were taken. The cannula was removed, the port site closed with a single simple interrupted suture in the fascia of the rectus sheath and a simple interrupted suture in the skin, and the dog recovered from general anesthesia.

All scans were reconstructed with a slice thickness of 1.5 mm to minimize multiplanar reconstruction artifacts. All images were examined in transverse and in dorsal, sagittal, and parasagittal planes after multiplanar reconstruction. These scans were then analyzed on the basis of a statistical and a subjective descriptive method.

Anatomic Evaluation

Measurements were made on PrI and PoI scans for each body position.

Hepatobiliary System and Spleen

The distance from the caudal aspect of the xiphoid to the liver was measured from the most caudal transverse slice through the xiphoid process to the nearest ventral surface of the liver in a transverse image (Fig 2). The percentage of contact between the liver and the body wall at T11 was measured by outlining the circumference of the liver in contact with the peritoneal surface of the body wall. This was taken as a percentage of the entire circumference of the body wall in the same transverse image. The circumference of the liver in contact with the body wall and the body wall circumference were both recorded as well as the percentage (Fig 3).

Figure 2. Ventrodorsal recumbency (VDR) position pre-insufflation (PrI) transverse image showing the distance, represented by the white line from the xiphoid (A) to the liver (B).

Figure 3. Ventrodorsal recumbency (VDR) position PoI transverse image showing the measurements of the apex of gallbladder (A) to body wall (arrow), the gallbladder with a white oval (B) demarcating its circumference. The xiphoid (C) is clearly visible. Liver–body wall contact is measured by a line joining the areas of contact of the liver with the body wall (D). An open hepatic fissure (E) and the cystic duct (F) are visible.

The distance from the lesser curvature of the stomach to the caudal part of the caudate liver lobe was measured. This was taken as the shortest distance in a straight line from the middle of the caudal surface of the caudate lobe to the nearest portion of the lesser curvature on a sagittal/parasagittal image (Fig 4). The distance from the head of the spleen to the left lateral liver lobe was measured as a straight line from the most dorsal part of the spleen on a sagittal or parasagittal image to the nearest part of the left lateral liver lobe (Fig 5).

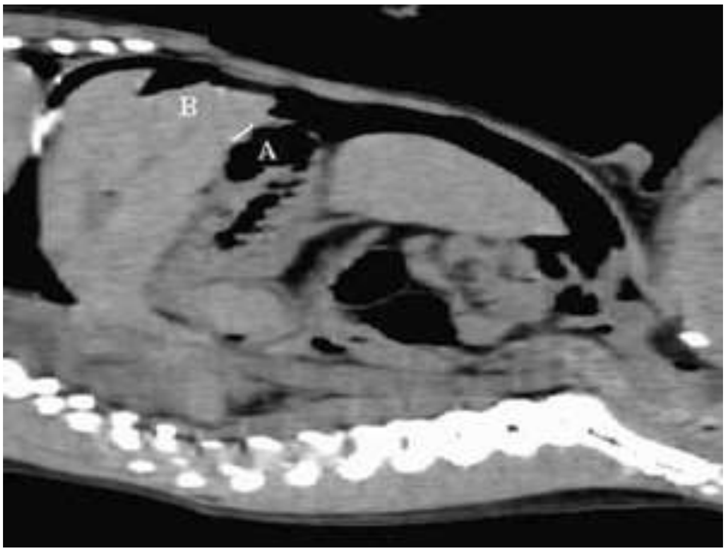

Figure 4. Right lateral (RL) position PoI parasagittal image showing the contact represented by the white line between the stomach by means of the lesser curvature (A), and the liver (B).

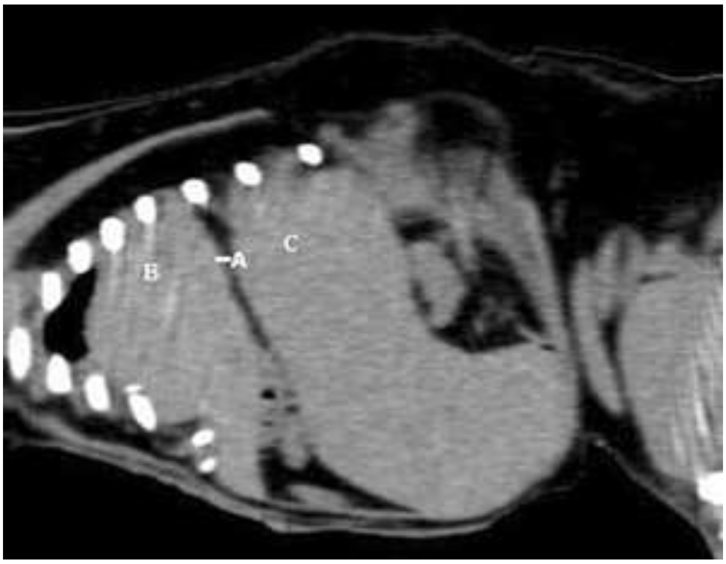

Figure 5. Left lateral (LL) position PoI parasagittal image showing the measurement (A) between the liver (B) and the spleen (C).

The distance from the apex of the gallbladder to the right abdominal wall was measured as a straight line from the apex of the gallbladder at the level of the widest cross sectional diameter of the gallbladder to the lateral abdominal wall on a transverse image (Fig 3). Consecutive slices were observed to find the point of the gallbladder nearest to the body wall. A right angle was drawn from the tip toward the body wall to ensure a strait consistent line (Fig 3). The percentage contact of hepatic parenchyma to the gallbladder was measured as the circumference of the serosal surface of the gallbladder in contact with hepatic parenchyma as a percentage of the entire circumference of the gallbladder on a transverse image (Fig 3). This consisted of 2 measurements, the gallbladder circumference, and contact of the hepatic parenchyma with the gallbladder circumference. The percentage gallbladder exposed was taken as a percentage of the gallbladder serosal surface exposed beyond the hepatic parenchyma of the entire gallbladder circumference on the same transverse image. Cystic duct visibility was taken as a yes or no answer if there was visibility of any portion of the cystic duct and ensuring the duct was not confused with adjacent hepatic veins (Fig 3). This was performed by following the cystic duct, if visible, from its junction with the gallbladder on sequential CT images and noting its visibility.

Gastrointestinal System

The position of the pylorus and its movement relative to the vertebral column was measured. A line was drawn perpendicular to the vertebral column through the middle of the pylorus and the vertebral column intersection point was measured in a sagittal/parasagittal image. The vertebra were then divided into thirds and the point of intersection recorded (Fig 6). The stomach long and short axis cross section diameters were measured on a transverse image at the widest visible part of the stomach (Fig 7).

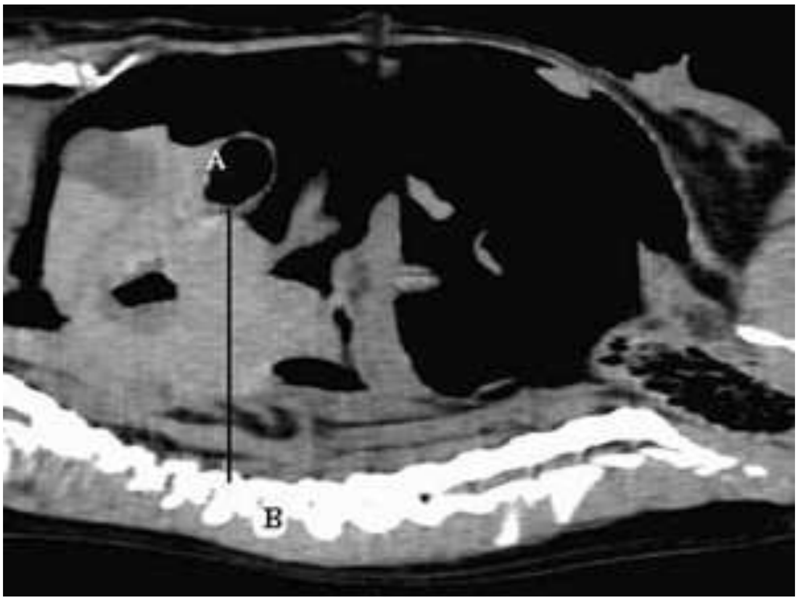

Figure 6. Right lateral (RL) position PoI parasagittal image showing the measurement (black line) from the pylorus (A) to the vertebral body (B).

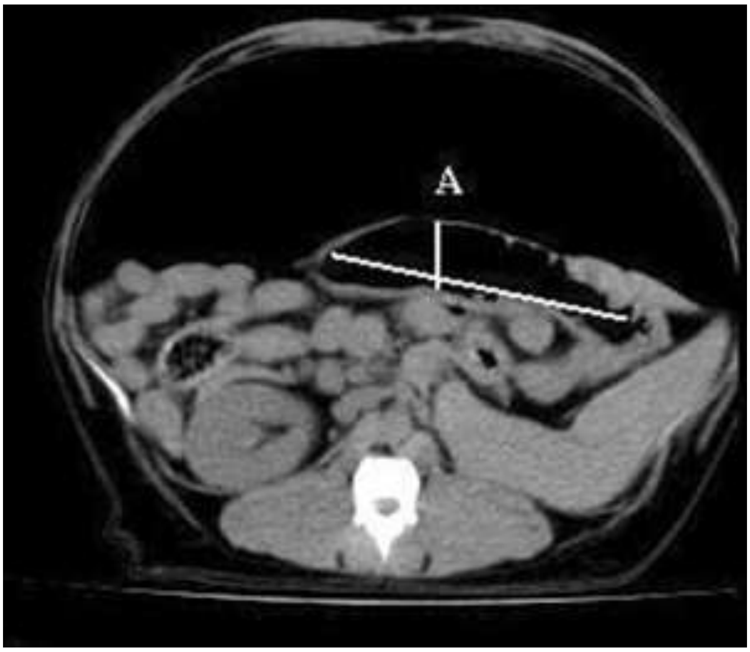

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Figure 7. Ventrodorsal recumbency (VDR) position PoI transverse image showing the long and short axis of the stomach (A) (white lines).

The distance of the mid descending duodenum from the body wall was measured as a straight line from peritoneal surface of the right lateral body wall to the mid straight portion of the lateral surface of the descending duodenum on a transverse image at the level of the pelvis of the right kidney (Fig 8). The distance of the cranial duodenal flexure to the gallbladder was measured as a straight line from the cranial edge of the duodenal flexure to the junction of the cystic duct and the gallbladder on a parasagittal image. The distance of the pelvis of the right kidney to the descending duodenum was measured on a transverse image at the level of the pelvis to the nearest portion of the serosal surface of the wall of the descending duodenum (Fig 8).

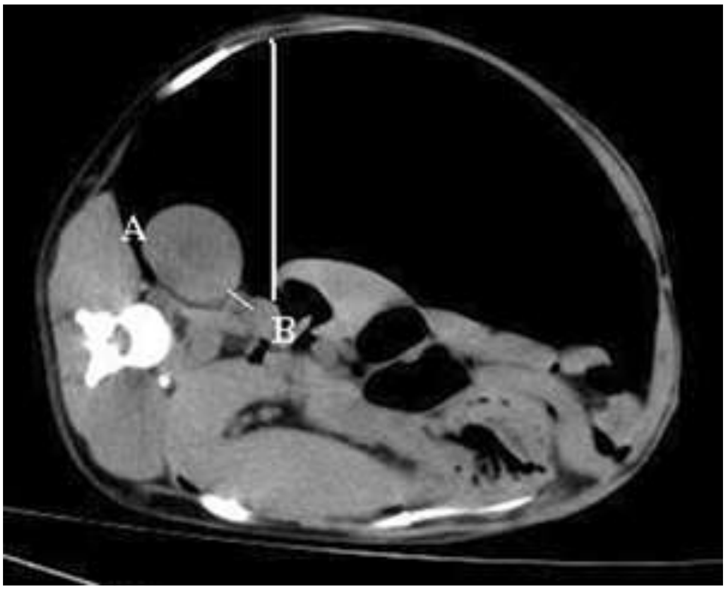

Figure 8. Left lateral (LL) position PoI transverse image showing the right kidney (A) at the level of the renal pelvis and the descending duodenum (B) with the distance from the body wall represented by the thick white line. The thin white line represents the measurement from the duodenum to the right kidney.

Pancreas

The views where the right limb, the body, and the left limb of the pancreas could be identified were recorded to determine which provided the best view on CT scans. This was defined by which portions of the pancreas were visible in which body positions, if at all, and this was recorded.

Statistical Analysis

All data were entered into a spreadsheet. These data were then transferred into a statistical program (Stata 10.0, StatCorp, College Station, TX) for analysis. Medians and ranges were determined. Kruskal–Wallis one-way ANOVA and the Tukey–Kramer multiple comparison test were used to compare the influence of different dog body positions. Statistical significance was set at $P < .05$.

RESULTS

Hepatobiliary System and Spleen

When comparing PrI and PoI measurements, there was a significant increase in distance from the xiphoid to the liver in all body positions (Table 1) with VDR (Fig 9) and VDT inducing the most significant change. LL (Fig 10) and RL (Table 1) resulted in a significant decrease in liver contact with the body wall. There was a significant increase in liver surface contact with the abdominal wall in LL (Fig 10) and RL positions; however, there was a decrease in percentage contact between the liver and the body wall in all positions (Table 2). There was no significant change in distance from the lesser curvature of the stomach to the caudate lobe of the liver in any position (Table 3). There was no significant change in distance between the head of the spleen and the left lateral liver lobe (Fig 11) in either PrI or PoI scans (Table 3).

Table 1. Summary Data (Median, Range) for Liver, in Different Body Positions, Before and After Insufflation

	Median (Range) cm		
	Pre Insufflation	**Post Insufflation**	***P*-Value**
Distance of xiphoid to liver			
VDR	0.98 (0.7–2.05)	6.43 (5.3–7.13)	.001
VDT	1.23 (0.38–2.54)	5.12 (4.24–5.59)	.001
LL	0.83 (0–1.26)	4.55 (2.79–7.43)	.002
RL	0.68 (0–1.08)	3.56 (1.56–4.53)	.002
Distance of liver contact with the body wall			
VDR	24.45 (17.2–29.3)	20.16 (11.72–21.1)	.055
VDT	31.35 (10.4–39.9)	21.03 (9.98–28.92)	.17
LL	26.28 (17.6–29.97)	14.65 (12–19.66)	.011
RL	24.9 (16.22–33.2)	14.9 (8.16–19.46)	.001

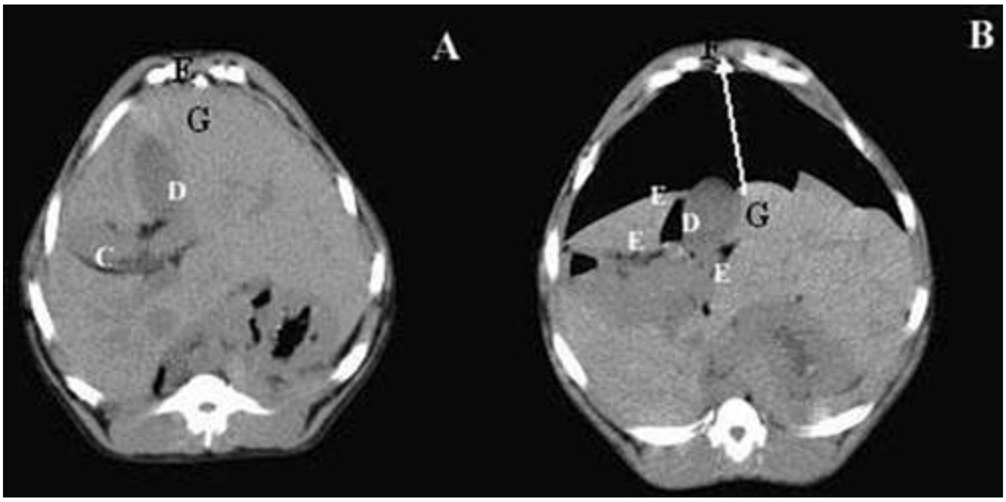

Figure 9. Ventrodorsal recumbency (VDR) position PrI (A) and PoI (B) transverse images showing an open fissure (C) in PrI and the gallbladder (D). In the PoI scan, other hepatic fissures open up (E), exposing the gallbladder. The contact between the liver (G) and xiphoid (F) is seen in the PrI. The PoI shows the contact increased distance between the xiphoid and the liver represented by the white line.

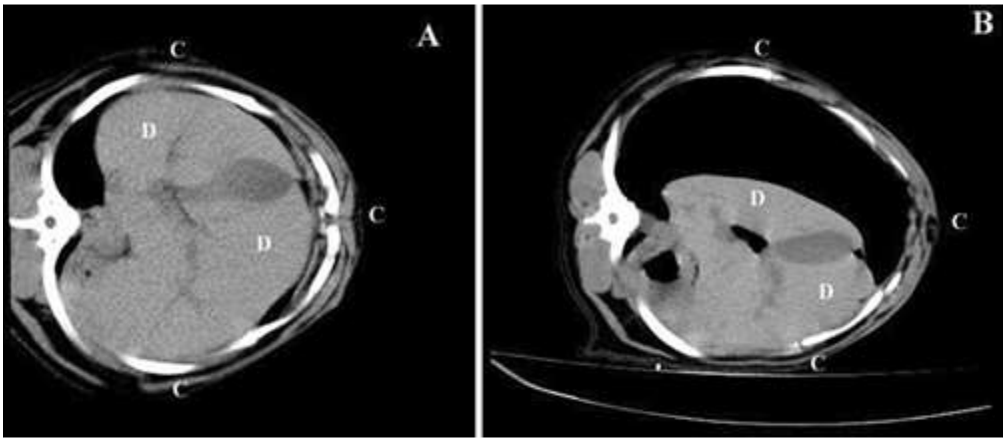

Figure 10. Left lateral (LL) position PrI (A) and PoI (B) transverse images showing liver (D) contact with the body wall (C). The PrI shows about 65% contact and the PoI scan about 35% contact with the body wall.

Table 2. Abdominal Circumference (cm) and Liver Contact as a Percentage of Abdominal Circumference, in Different Body Positions, Before and After Insufflation

	Pre Insufflation		**Post Insufflation**		
	Median (Range) cm	**% PrI**	**Median (Range) cm**	**% PoI**	***P*-Value**
VDR	42.59 (39.34–44.3)	52	47.18 (44.8–49.6)	42	.055
VDT	43.95 (41.43–48.14)	71	46.68 (43.08–50.42)	45	.085
LL	40.38 (39.39–42.54)	57	46.08 (43.56–50.96)	31	.002
RL	40.12 (40.03–42.3)	64	46.99 (43.09–49.23)	31	.001

% = contact of the liver circumference as a percentage of body wall circumference.

Table 3. Summary Data (Median, Range) for Stomach, Spleen, and Gall Bladder, in Different Body Positions, Before and After Insufflation

	Median (Range) cm		
	Pre Insufflation	**Post Insufflation**	***P*-Value**
Distance of the lesser curvature of the stomach to the caudate liver lobe			
VDR	2.24 (1.3–4.25)	2.1 (0–3.68)	.328
VDT	3.55 (0–6.68)	2.25 (0–5.03)	.595
LL	2.83 (0–5)	2.3 (0–4.78)	.662
RL	2.44 (0–5.3)	2.4 (0–4.19)	.754
Distance from the head of the spleen to the left lateral liver lobe			
VDR	0.85 (0.15–1.61)	0.54 (0–1.1)	.261
VDT	0.31 (0–1.16)	0.18 (0–1.4)	.9
LL	0.76 (0–2.41)	0.48 (0–1.1)	.259
RL	0.98 (0–3.29)	1.36 (0.2–2.37)	.789
Distance from the apex of the gallbladder to the right body wall			
VDR	1 (0.3–2.6)	4.41 (3.6–5.84)	.001
VDT	1.17 (0.7–2.15)	3.32 (2.7–3.74)	.001
LL	0.93 (0.29–1.91)	2.71 (1.28–3.96)	.012
RL	0.62 (0.23–1.4)	0 (0–0.41)	.011
Gallbladder circumference			
VDR	10.04 (7.15–12.07)	9.84 (7.15–11.01)	.923
VDT	9.89 (8.47–11.9)	10.23 (8.45–11.9)	.833
LL	9.29 (8.32–11.01)	9.4 (8.73–11.94)	.602
RL	9.93 (8.75–10.78)	9.59 (8.03–11.12)	.661
Gallbladder exposed			
VDR	0 (0–0.58)	2.37 (1.03–3.02)	.007
VDT	0.15 (0–0.91)	2.99 (1.51–5.94)	.007
LL	0 (0)	2.32 (2.02–3.55)	.001
RL	0 (0)	0 (0)	-

Figure 11. Ventrodorsal recumbency (VDR) PoI left parasagittal image showing the relationship between the liver (A) and the spleen (B).

There was a significant increase in distance from the apex of the gallbladder to the right body wall in all positions except RL (Fig 12; Table 3), which had a significant decrease when PrI and PoI images were compared. LL position had the largest increase in this distance. There was no significant change in the circumference of the gallbladder between PrI and PoI scans (Table 3). For VDR and VDT, there was a significant decrease in contact distance between liver and gallbladder (Table 4), with a decreasing trend in LL and RL. All positions except RL (Table 3) resulted in a significant increase in exposure of the gallbladder surface when comparing PrI and PoI scan. When comparing PrI and PoI scans, there was no position that provided better access to the cystic duct or observation on CT. For VDR, the cystic duct was visible in 3 dogs in PrI scans and in 2 of these on PoI scans. These were the only dogs in which the cystic duct was visible on PoI scans. For VDT, the cystic duct was visible in 1 dog on PrI scans and in 2 other dogs on PoI scans. For LL, the cystic duct was visible in 4 dogs on PrI scans and in the same dogs on PoI scans. In RL (Fig 13), the cystic duct was visible in 5 dogs on PrI scans and in 3 on PoI scans. The cystic duct was not visible in 1 dog on PrI or PoI scans in RL position.

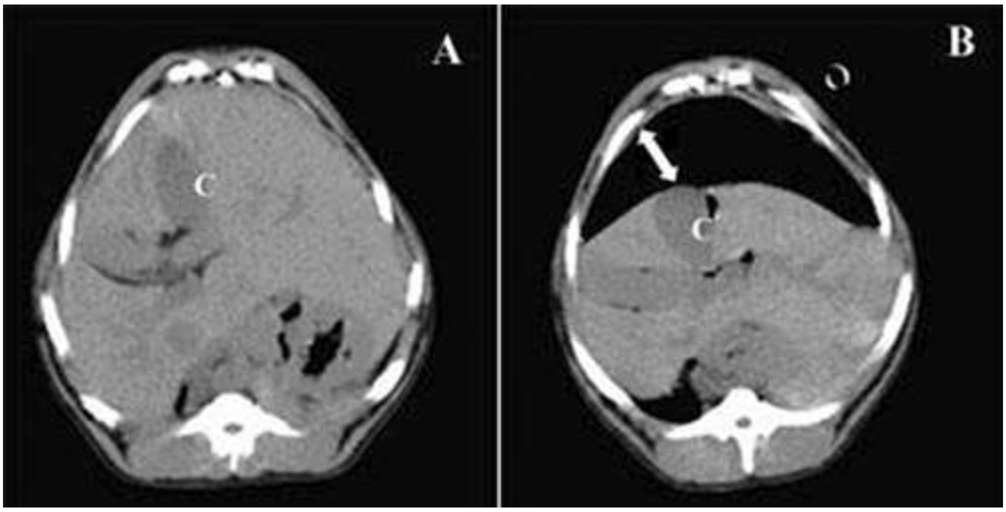

Figure 12. Ventrodorsal recumbency (VDR) position PrI (A) and PoI (B) transverse images showing the increasing distance (arrow) from the apex of the gallbladder (C) to the body wall between PrI and PoI scans. Exposure of the gallbladder and decreased hepatic contact can be seen.

Table 4. Gallbladder Contact With Hepatic Parenchyma, in Different Body Positions, Before and After Insufflation

	Pre Insufflation		Post Insufflation		
	Median (Range) cm	**% PrI**	**Median (Range) cm**	**% PoI**	***P*-Value**
VDR	9.92 (7.15–11.49)	98	7.03 (2.87–9.98)	70	.019
VDT	9.49 (8.47–11.01)	95	5.66 (4.2–10.16)	55	.039
LL	9.29 (8.32–11.01)	100	6.04 (5.26–9.92)	64	.06
RL	9.93 (8.75–10.78)	100	8.63 (6.65–10.04)	89	.068

% = the change in hepatic contact with the serosal surface of the gallbladder as a percentage of the entire gallbladder circumference

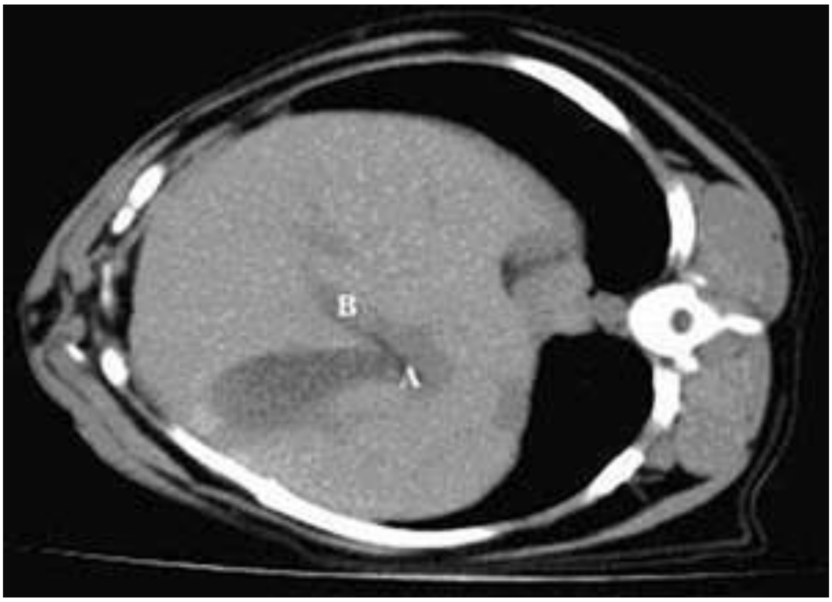

Figure 13. Right lateral (RL) position PrI transverse image showing the cystic duct (A) within the liver tissue. The hepatic veins (B) can be seen and the lung fields are to the right of the image.

Gastrointestinal System

There was no cranial or caudal movement of the pylorus when PrI and PoI scans were compared (Fig 14). There was no change in long axis diameter of the stomach except for VDT (Table 5), where there was a significant decrease in long axis diameter. There was no significant change in short axis diameter of the stomach (Fig 15) when comparing PrI and PoI scans (Table 5). There was no significant change in distance from the right body wall to the descending duodenum except for LL (Fig 16) when comparing PrI and PoI scans (Table 6). There was no significant change in distance from the cranial duodenal flexure to the gallbladder (Table 6) or in the distance from the right kidney pelvis to the descending duodenum (Fig 16; Table 6) for any body position when comparing PrI and PoI scans.

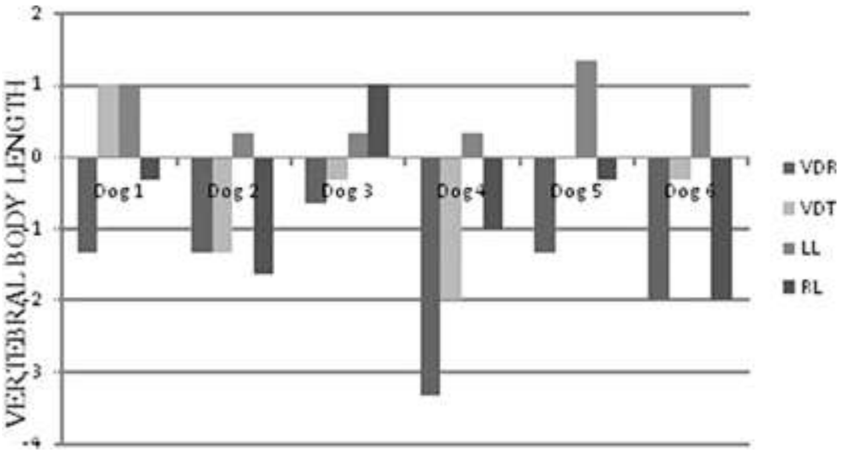

Figure 14. Graph of the movement of the pylorus in vertebral body length in all positions PrI and PoI. A negative value indicates caudal movement and a positive value cranial movement of the pylorus.

Table 5. Stomach Long and Short Axis Cross Section, in Different Body Positions, Before and After Insufflation

	Pre Insufflation		Post Insufflation			
	Long Axis Median (Range) cm	**Short Axis Median (Range) cm**	**Long Axis Median (Range) cm**	**Short Axis Median (Range) cm**	***P*-Value Long Axis**	***P*-Value Short Axis**
VDR	9.04 (7.59–11.02)	2.44 (1.86–3.2)	9.21 (8.83–9.71)	1.81 (1.73–2.61)	.850	.085
VDT	10.4 (9.95–11.24)	2.6 (1.94–2.79)	8.4 (6.94–10.6)	2.49 (1.88–2.69)	.14	.679
LL	10.03 (8.6–11.55)	2.64 (1.17–4.75)	11.92 (10.23–13.04)	2.57 (2.13–3.34)	.16	.799
RL	9.72 (9.2–11.38)	2.28 (1.8–4.65)	10.28 (9.71–11.54)	2.5 (1.8–3.1)	.286	.868

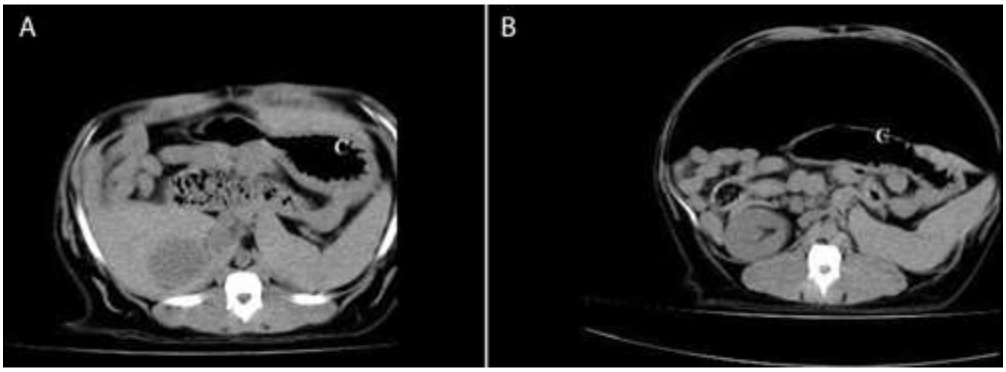

Figure 15*. Ventrodorsal recumbency (VDR) position PrI (A) and PoI (B) transverse images showing* comparative stomach (C) size and orientation.

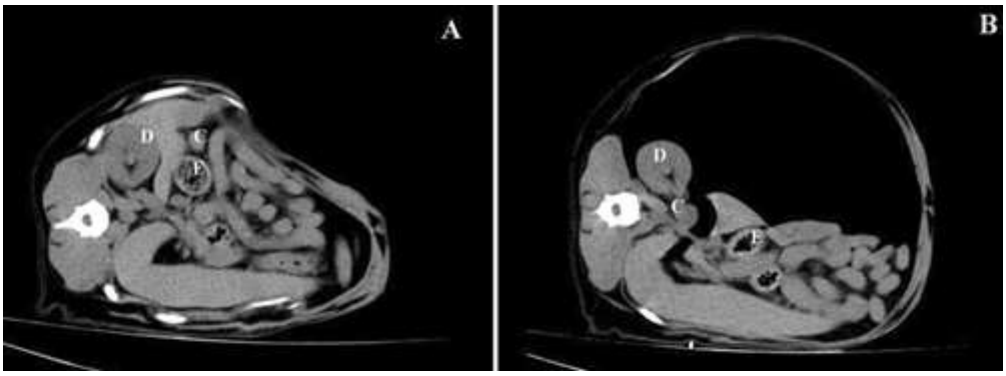

Figure 16. Left lateral (LL) position PrI (A) and PoI (B) transverse images showing the relationship between the duodenum (C), right kidney (D), and colon (E). The PrI and PoI images show the close association between these structures is maintained.

Table 6. Summary Data (Median, Range) for Duodenum, in Different Body Positions, Before and After Insufflation

	Median (Range) cm		
	Pre Insufflation	**Post Insufflation**	***P*-Value**
Distance from the body wall to the descending duodenum			
VDR	0.05 (0–0.64)	0 (0–0.1)	.235
VDT	0 (0–0.73)	0 (0)	.363
LL	0 (0–0.63)	8.48 (7.11–9.4)	.001
RL	0 (0–0.99)	0 (0)	.341
Distance from the cranial duodenal flexure to the gallbladder			
VDR	1.95 (0.71–2.29)	1.78 (1.1–1.88)	.714
VDT	1.63 (0.15–2.86)	1.88 (0.6–2.77)	.793
LL	2.17 (1.3–2.76)	1.77 (0.45–2.33)	.147
RL	1.79 (0.87–2.32)	1.83 (0.7–4.03)	.504
Distance of right renal pelvis to the descending duodenum			
VDR	4.39 (3.09–4.59)	3.62 (2.39–4.14)	.122
VDT	6.04 (4.23–6.49)	4.46 (3.23–7.17)	.315
LL	5.11 (4.81–7.98)	6.12 (4.17–8.95)	.776
RL	5.87 (4.62–7.19)	5.71 (4.1–9.82)	.387

Pancreas

There was no body position that allowed better observation of any of the limbs of the pancreas on CT images when comparing PrI and PoI scans (Fig 17). The right limb of the pancreas (Fig 18) was most often seen followed by the body and then the left limb, which was the most difficult to accurately identify.

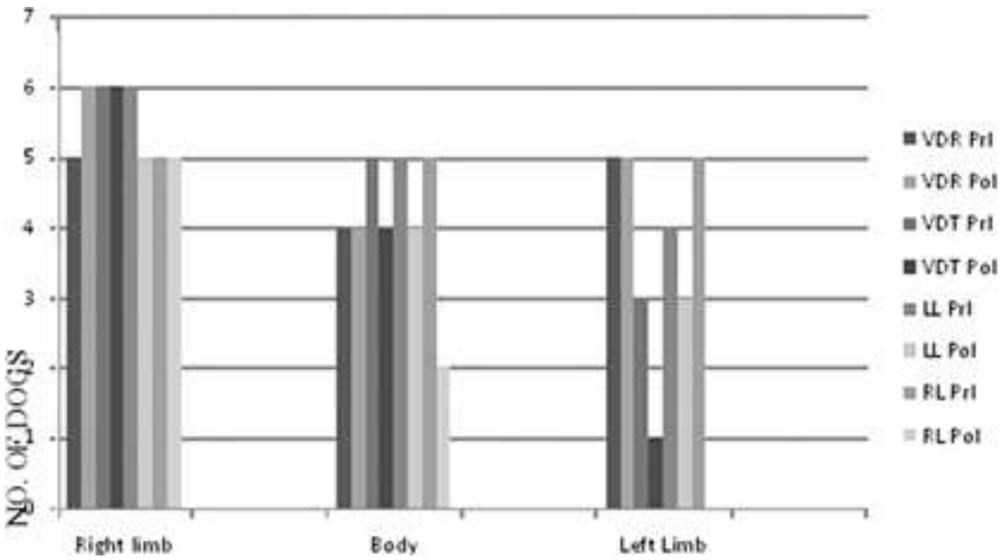

Figure 17. Graph showing the visibility of the different parts of the pancreas in all positions.

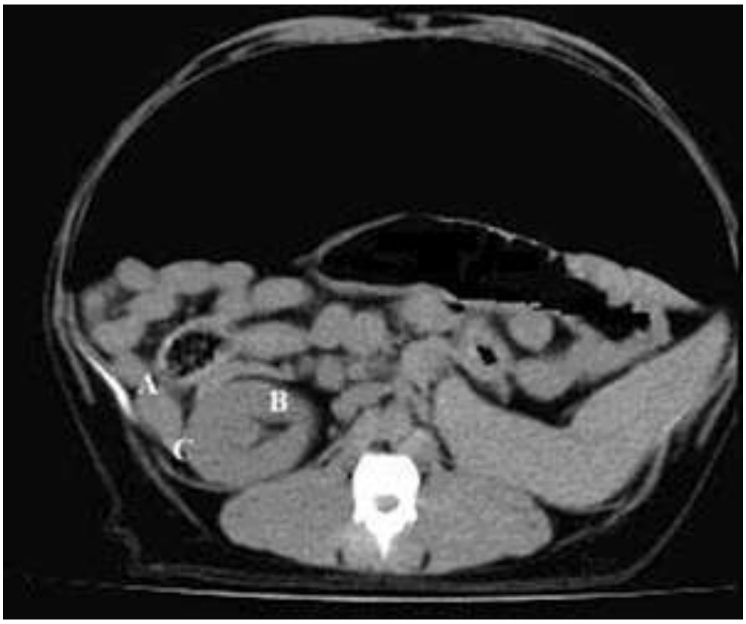

Figure 18. Ventrodorsal recumbency (VDR) position PoI transverse image showing the relationship between the duodenum (A), the right kidney (B), and the right limb of the pancreas (C).

DISCUSSION

Hepatobiliary System

Liver

For all body positions, there was a significant increase in the distance from the dorsal surface of the xiphoid cartilage to the ventral serosal surface of the liver. This was expected because there are no attaching peritoneal reflections or ligaments from the xiphoid to the serosal surface of the liver. The falciform ligament plays a very small role in suspending the liver.[4] In VDR and VDT before insufflation, the liver moved dorsally because of gravity. After insufflation, the increased distance was because of the additive effects of insufflation and gravity. The suspending ligaments of the liver tend to lie dorsally so the change can be explained by the liver collapsing on itself. In VDT after insufflation, the liver moved against the diaphragm, which tended to make the PoI distance slightly less than in VDR PoI scans.

With this distance representing the available working space ventral to the liver, VDR positioning seems to provide the best general approach to the liver because there is no cranial pull on the liver from gravity with the Trendelenburg position. In both lateral positions, with the liver suspended by its dorsal ligaments, the degree of collapse was less, with RL inducing the least change. This was believed to be because the large right sided caudate process of the caudate lobe creates a larger mass of liver tissue allowing less collapse on this side. These changes were increased after insufflation.

Clinically, these findings suggest that VDR position allows access to most of the liver and entire biliary system. With VDR, there is little gravitational effect on the liver compared with VDT where the liver tends to move cranially; however, in VDT there appears to be less exposure of the liver. Thus, the body position used to access the liver will depend on the region suspected to be affected by pathology. There was a substantial decrease in liver contact with the body wall after insufflation, with the largest decrease occurring with VDT, where the liver moved cranially resulting in less contact with the ventral and lateral body walls. In RL, given the small increase in distance from the xiphoid to the ventral aspect of the liver, a small reduction in contact might have been anticipated; however, RL position resulted in the largest change with less contact with the body wall. This may be because of the limited attachment of the liver to the body wall except for the dorsal ligamentous attachment allowing the liver to move away from the body wall onto the larger right side of the liver, which would be most affected by gravity.

Gastrohepatic Ligament

The gastrohepatic ligament, which is relatively immobile, showed no significant change in VDR after insufflation. For VDT, there was a trend toward and decrease in this distance after insufflation, indicating that the stomach was more mobile than the liver with gravitational effect causing cranial displacement of the stomach to a greater degree than the liver. There was no significant decrease with RL after insufflation, and this was believed due to the larger right side of the liver providing more support to surrounding structures.

Gallbladder

VDR and VDT positions resulted in the largest increases in distance from the right body wall to the apex of the gallbladder. This was unexpected because it was assumed that LL position would result in the largest increase given the right sided position of the gallbladder within the liver. It can be explained by the bile duct running in the gastrohepatic ligament, situated close to the dorsal margin of the liver where the main attachments for the liver are, thus making it less mobile regardless of body position. During celiotomy, this area has very low mobility compared with the rest of the liver. The gallbladder is attached to the right medial liver lobe, which was dorsal and medial and seemed to have a low degree of mobility on measurement. It was believed that the movement of the gallbladder would be minimal and hence the distance from the body wall would be similar for RL and LL positions. For VDR and VDT positions, however, it was suspected that the space created by insufflation combined with positioning would shift the liver medially because of the position of the gallbladder and gravitational effect.

This is because of the liver being in the dependent part of the abdominal cavity and with the gas dissecting laterally to the liver adding to the medial displacement caused by positioning. The liver was observed after insufflation to collapse toward midline and the recumbent side of the abdomen, likely because of its attachments to the dorsal body wall. The insufflated gas distends the abdomen, increasing the distance of the abdominal wall from the abdominal organs, and was observed more so in the lateral than in the ventrodorsal positions. This further increased the distance from the body wall to the gallbladder in LL. For RL, gravity and gas pressure moved the gallbladder closer to the body wall.

Based on these observations, the gallbladder should be approached using either VDT if exposure of the rest of the liver is required or LL if just access to the gallbladder is desired. LL positioning provided the best view of the cystic duct, which was not affected by insufflation. Gallbladder diameter remained similar after insufflation, indicating that there was little change in shape or size from compression induced by increased intra-abdominal pressure. All body positions resulted in a significant decrease in hepatic tissue contact with the serosal surface of the gallbladder after insufflation, because of collapse of the liver onto the dorsal body wall. This decreased contact allows access to the gallbladder in all positions except RL where the exposed portion of the gallbladder lies against the body wall and thus this body position is not recommended for surgical approach to the gallbladder.

Spleen

The spleen is attached to the gastric fundus by the gastrosplenic ligament, which carries the vascular supply to the gastric fundus. It would be expected that the spleen would move in a manner similar to the stomach because of this attachment. In all positions except RL, there was a trend toward a decrease in distance from the head of the spleen to the left lateral lobe of the liver. There was a greater change than observed in the distance from the lesser curvature of the stomach to the liver, likely because the spleen is attached to the fundus, a very mobile part of the stomach as can be seen in gastric dilatation volvulus syndrome. This decrease was expected for all positions because the effect of gravity and increased intra-abdominal pressure would move the head of the spleen cranially to lie closer to the relatively less mobile liver. In RL, the fundus and spleen were more influenced by gravity than the increased intra-abdominal pressure and tended to fall away from the liver increasing this distance. Thus clinically, for best exposure of the left lobes of the liver, the dog should be positioned in RL because this allows the spleen and stomach to fall away from the area of interest and permit better access to the hiatus for procedures involving the terminal part of the esophagus.

Gastrointestinal System

For VDR, there was a trend toward decreasing distance from the duodenal flexure to the gallbladder after insufflation. The position of the pylorus moved caudally in most dogs after insufflation. The only explanation for this may be that with the liver collapsing on itself in the dependent part of the abdomen, the gallbladder may have moved closer to the duodenum. The initial starting point of the gallbladder was in a cranioventral-dorsocaudal orientation before insufflation, changing to a caudoventral-dorsocranial position after insufflation. This collapse moved the pylorus and the cranial duodenal flexure caudally and decreased the distance from the duodenum to the gallbladder.

For VDT, cranially directed gravitational force on the liver resulted in an increasing distance after insufflation. The pylorus and duodenum were restricted in cranial movement by their attachments and tended to fall into the same position as observed for ventrodorsal positions. The cranial force of gravity on the liver in VDT caused less collapse of the liver, which together with the limited cranial movement of the pylorus, exposed the duodenum, pancreas, and associated structures and would be the position of choice for a surgical access.

In LL, there was a trend toward a decreased distance because of cranial movement of the pylorus. This position showed the greatest decrease in distance and could be attributed to the collapse of the right side of the liver, containing the gallbladder. With cranial movement of the pylorus, movement in the mediolateral plane of the pylorus was greater than movement in the craniocaudal plane. The pylorus tended to move cranially and to the left. This would result in a difficult approach to these organs. For RL, there was no significant change in distance with only slight caudal movement of the pylorus. Thus, this positioning cannot be recommended as a surgical approach to these organs.

In all views except for the LL after insufflation, the duodenum was in contact with the right body wall. In LL, the effect of gravity was clearly seen as the duodenum moved away from the body wall and came to lie on top of the mass of soft tissue (primarily intestine). With most of the attachments of the duodenum being on the right side of the body, this was expected and was enhanced by insufflation, with gas pressure adding to gravitational influence and increasing abdominal diameter. In normal dogs, as the duodenum passes the cranial pole of the right kidney, it is nearly in contact with the kidney but more caudally it tends to lie ventral to the kidney. In VDR and VDT, there was a trend toward a decrease in distance from the renal pelvis to the descending duodenum. This was expected because of gravity and insufflation; however, the distances were larger with VDT, which could be explained by the cranial force of gravity on other organs in the abdomen leading to more soft tissue mass between the kidney and duodenum. For LL, there was a marked increase in distance caused by the right kidney being relatively immobile. When the position was changed to LL, the organs moved away from the right kidney creating greater renal exposure, thus LL position should provide the best surgical access to the right kidney and duodenum.

Pancreas

The right limb of the pancreas was more often seen than the left limb in all body positions, because of its close association with the descending duodenum. VDT was the best position to observe the right limb followed by VDR and LL; however, this does not imply that these are the best positions for laparoscopic observation. The VDT position caused cranial traction on the abdominal organs. The duodenum is a relatively immobile in the craniocaudal direction because of its hepatic and colic attachments. With cranial traction from gravity, the organs surrounding the duodenum and the pancreas moved away, allowing better differentiation of the pancreas from the surrounding tissue in VDT.

The body of the pancreas was the next most identified part on CT images because of its association with the relatively immobile cranial duodenal flexure. The PrI scans for VDT, LL, and RL provided the best views but this was not markedly better than on the PoI scans, suggesting that insufflation may actually hinder observation when looking for the pancreas. The left limb was the most difficult to identify because of its position in the omentum adjacent to the greater curvature of the stomach where it was difficult to distinguish from surrounding soft tissue. VDR and RL before insufflation provided the best visibility of the left limb, which allowed observation of the splenic hilus against the parenchymatous organ mass. The hilus provided the best marker to find the left limb on CT. VDR and VDT positions provided the best exposure of all parts of the pancreas on CT images. Based on these observations, it is assumed that these positions would provide the least need for surgical retraction and allow for full exploration of all pancreatic components. The only concern would be the left limb as it courses from medial to lateral into the soft tissue mass,[4] requiring extensive retraction of organs to fully explore its surface.

Study Limitations

A major study limitation was the assumption that CT PoI scans would accurately represent the anatomy encountered during laparoscopy. We believe this was an acceptable assumption as the environment of the abdomen was identical to that expected during laparoscopy. A further limitation was that IV contrast was not used to better define abdominal organs because of the potential risk of nephrotoxicity from repeated injections. Only Beagles were used and thus the findings may not represent the abdominal anatomy of other breed conformations. We were not blinded to the positions, which may have biased our interpretation. Only the most commonly used laparoscopic positions were used to prevent excess radiation exposure of the dogs. Three-dimensional volume rendered techniques would possibly have resulted in a more realistic view of laparoscopic topographic anatomy but were not considered a viable alternative to compare PrI and PoI scans as accurate and consistent measurements would not be possible.

We concluded that the 2 main forces acting on organs in the abdominal cavity are gravity because of dog position and the pressure and space created by insufflation. Gravity has to be considered the main force as organ movement is seen with changes in position alone. Organ position can be manipulated by moving the dog into different positions allowing easier laparoscopic access. VDR was the best approach to the liver (all lobes), the gallbladder, if being approached together with the liver and should be used for the pancreas. VDT provided the best approach to the stomach, pylorus, and as a second choice approach to the gallbladder, first choice if approached on its own, and to the pancreas. LL was the best approach to the right lobes of the liver, cystic duct, duodenum, and a tertiary approach to the gallbladder. RL was the best approach to the left lobes of the liver.

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DISCLOSURE

The authors report no financial or other conflicts related to this report.

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