Pyloric localisation in 57 dogs of breeds susceptible to gastric dilatation-volvulus in the UK using computed tomography

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Introduction

The anatomic location of the pyloric part of the canine stomach is important for the veterinary surgeon particularly when performing a gastropexy procedure either prophylactically in an at-risk individual (Ward and others 2003, Allen and Paul 2014), following an episode of gastric dilatation/volvulus (GDV) or following splenic torsion (Millis and others 1995, Neath and others 1997). The aim of a gastropexy is to create a permanent adhesion between the pyloric antrum and the right abdominal wall without interfering with the stomach's normal position or function (Rasmussen 2003). Following a ventral midline coeliotomy the normal abdominal topography is altered due to patient positioning, pneumoperitoneum and reduced support from abdominal musculature. Therefore, the anatomically correct position to perform a gastropexy is unclear and often based on intraoperative assessment by the surgeon.

CT has been used to evaluate anatomical aspects of the canine abdomen in previous studies, but has not yet been used to define the location of the canine pylorus (Rivero and others 2009, Beukers and others 2013, Hoey and others 2013, De Rycke and others 2014, Gregori and others 2014). The aim of this study was to review abdominal CT scans of dogs of breeds susceptible to GDV in the UK (Evans and Adams 2010) and describe the location of the pylorus within the abdominal cavity. A secondary aim of the study was to determine the position of the pylorus relative to previously reported gastropexy locations. This study represents a preliminary anatomical CT study with a view to performing a subsequent case-control study.

Material and Methods

Study design and ethics

This was a retrospective observational study approved by the University of Liverpool Veterinary Research Ethics Committee (VREC130). All owners gave their written consent for the use clinical records and CT images for the study.

Study population and eligibility criteria

Medical records of dogs presenting to the Small Animal Teaching Hospital, University of Liverpool between January 2007 and March 2013 that had abdominal CT examination were reviewed. Dogs were selected for the study if there was (1) no evidence of cranial abdominal disease, (2) no significant haematological or serum biochemical abnormalities, (3) no splenic changes distorting the splenic capsule, (4) no cranial abdominal organomegaly and (5) the CT scan was performed in sternal recumbency.

Computed tomography

All patients were anaesthetised or sedated to complete the CT scan. Each patient underwent an abdominal CT scan using a four slice helical CT scanner (Siemens Volume Zoom, Siemens AG, Munich Germany). The contrast agent (Omnipaque 350, GE Healthcare, Buckinghamshire, UK) was administered using a power injector at a dose of 700mg iodine/kg bodyweight to a maximum volume 60mLs at a rate of 3mL/s. Data were acquired using the following parameters: 120 kVp, 84-185 effective mAs, 2.5 mm slice collimation and 0.5s rotation time. Images were acquired after hyperventilation to induce apnoea. Contiguous images with 3mm slice thickness were reconstructed using a fast body kernel (B30F kernel). Consensus review of CT images was made by an ACVR board-certified radiologist (SL) and an ECVS resident in small animal surgery (AT). All images were assessed and measured using DICOM image reading software (OsiriX v.4.1.1 64-bit; Pixmeo, Switzerland), with images being viewed in a soft tissue window (window width 350, window level 50). The position of the pylorus was defined as the point where the pyloric part of the stomach joined the descending duodenum (Figure 1) in the transverse image slices. The 'point' tool in the image reading software was used to generate a 3D coordinate for the pylorus at the agreed location. The most caudal aspect of the right thirteenth rib (R13) was located in the dorsal plane image slices. The z value (craniocaudal plane) was recorded at this location. The z value of the caudal aspects of the right 9th (R9), 10th (R10) and 11th (R11) ribs were made in the same image slice (Figure 2). The z value 2cm (2CM13) and 3cm (3CM13) caudal to R13 were calculated by adding 2cm and 3cm to the R13 value respectively. To account for variation in body size, linear measurements were divided by ventral abdominal length (defined as the distance between the most caudal aspect of the xiphoid process and the cranial aspect of the pubis as measured on the transverse CT images).

Clock-face angle

The clock-face angle was measured in the transverse plane from a line that intersected the centre of the pyloric canal and the centre of the abdominal cavity (CAC), defined as the point half way along a vertical line from the dorsoventral axis of the vertebral body to the linea alba, relative to the sagittal plane (Figure 3). When the pylorus was located to the left of midline, it was given a negative value. The generated data were sorted in 30° increments, according to units on a clock-face: assuming that the patient was in dorsal recumbency with the surgeon was facing cranially, the ventral midline was defined as the 12 o'clock position, and the vertebral body defined as the 6 o'clock position (Figure 4).

Position of the pylorus

The position of the pylorus was calculated relative to the position of R9, R10, R11, R13, 2CM13 and 3CM13 at the 8, 9 and 10 o'clock positions on the right abdominal wall (RAW) at the predetermined z value locations using the transverse image slices. The 8, 9 and 10 o'clock locations were identified by drawing a line from the CAC that intersected the right body wall at an angle of 120°, 90° and 60° respectively. A 3-dimensional coordinate for each designated location was obtained using the 'point' tool. Distance along the x-axis was calculated by subtracting the x coordinate of the pylorus from the x coordinate of the selected location. Dorsoventral (y axis) and craniocaudal (z axis) distance were calculated in the same manner. A positive value represented left lateral, dorsal or cranial location of pylorus relative to the RAW along the x, y and z-axis, respectively. A negative value represented right lateral, ventral or caudal location of the pylorus relative to the RAW along the x, y and z-axis respectively. All values were corrected for ventral abdominal length. For absolute distance calculations, only absolute values were used to determine the magnitude of the distance of the pylorus from the RAW regardless of relative position. Net distance was calculated taking into account positive and negative values to determine the overall position of the pylorus relative to the RAW.
Overall distance (OD) was calculated using the Pythagorean Theorem in two stages:

$$a = \sqrt{x^2 + z^2}$$

Where *a* is the calculated distance in the combined mediolateral and craniocaudal plane.

$$OD = \sqrt{a^2 + y^2}$$

Statistical analysis

All data are expressed as median (range), except where indicated. Statistical analyses were performed on absolute and overall distance with computer software (Stats Direct version 2.6.8, Stats Direct Ltd), with the level of significance set at $P<0.05$ for two-sided analyses. The Shapiro-Wilk test was used to determine whether or not datasets followed a normal distribution, with parametric and non-parametric tests performed as appropriate. Comparisons amongst three or more related variables (e.g. position of the pylorus relative to different external landmarks) were made with the Friedman test, with *post hoc* comparisons made, where appropriate, using the Conover test. Given the multiple comparisons performed, a Bonferroni correction was applied.

Factors affecting the overall distance of the pylorus relative to the RAW at the 10R 10 o'clock position were assessed using linear regression analysis. Factors tested included signalment (e.g. age, sex, neuter status, breed groups, and breed), body weight, body surface area and body condition score. To assess the effect of breed, dogs were initially assigned to 1 of 3 breed groups (medium, large and giant), and a binary variable created for each group, whereby 1 = from the breed group, and 0 = not from the breed group. However, given that significant differences were seen, for some measurements, for the medium breed group, additional binary variables were created for 3 medium breeds with largest numbers, namely Boxer, English springer spaniel, and Labrador retriever; dogs were classified according to binary variables, whereby 1 = from the breed, and 0 = not from the breed. Weight status was also classified according to a binary variable, whereby 1 = overweight (based upon a body condition score of 6-9/9), and 0 = not overweight (based upon a body condition score of 4-5/9). Initially, simple linear regression was used. A multiple linear regression model was then constructed, which initially included any variables identified as $P<0.2$ on univariable analysis. Colinearity amongst variables was assessed using variance inflation factors and the reciprocal tolerance (O'Brien 2007), and unnecessary collinear predictors were removed. The model was subsequently refined by backwards-stepwise elimination of the least significant variable at each round, with variables being retained in the final model if they were significant ($P<0.05$).

Results

Characteristics of the study dogs

Fifty-seven dogs met the inclusion criteria, with 37 being male (20 neutered) and 20 being female (14 neutered), and their median age was 84 months (range 11 to 151 months). Seventeen different breeds were assessed including Labrador retriever (n=23), Boxer (n=7), English springer spaniel (n=6), Dogue de Bordeaux (n=3), Rhodesian ridgeback (n=3), German shepherd dog (n=3), bullmastiff (n=2) and one each of Japanese Akita, Bassett hound, Bernese mountain dog, bulldog, Dalmatian, Great Dane, Irish setter, Newfoundland, standard poodle and flat coat retriever. Median weight was 34.0 kg (range 16.5-84.3 kg), and median estimated body surface area was 1.1m^2 (0.7-1.9 m^2). Body condition score was available for 48 of the 57 dogs, and median body condition score was 5/9 (range 4-9/9), with 33 dogs in ideal weight and 15 dogs that were overweight.

Clock-face position

The results are summarised in Table 1. In 56 (98%) of patients the pylorus was located in the right hemiabdomen; in forty-nine cases (88%), the pylorus was located in the right ventral quadrant of the abdomen, and was located at the 9-10 o'clock position in 36 (63%) of these cases. In one case, the pylorus was located to the left of midline at the 12-1 o'clock position. The remaining 7 cases were located in the right craniodorsal quadrant.

Position of the pylorus relative to predefined locations:

X-axis distance

The results are summarised in Table 2. For each gastropexy location, the distance between the pylorus and RAW along the x-axis was significantly different at the 8, 9 and 10 o'clock positions. Dorsally (i.e. at the 8 o'clock position), the distance of the pylorus from the RAW along the x-axis was significantly greater at the 9R, 10R and 11R positions compared to the 13R, 2CM13 and 3cm13 positions. Conversely, ventrally (i.e. at the 10 o'clock position), the distance between the pylorus and RAW along the x-axis was significantly greater at the 3CM13, 2CM13 and 13R positions than at the 11R, 10R and 9R positions. Distance between the pylorus and RAW at the 9 o'clock position was consistent regardless of gastropexy location.

Y-axis distance

The results are summarised in Table 3. With the exception of 3cm13R (10 o'clock and 8 o'clock) and 2cm13R (10 o'clock and 8 o'clock), the distance between the pylorus and the RAW along y axis was significantly different at the 8, 9 and 10 o'clock position for each gastropexy location. The pylorus was consistently located ventral to the 8 o'clock position on the RAW. Distance between the pylorus and the 8 o'clock position on the RAW was significantly greater the more cranial the gastropexy location. The pylorus was consistently located dorsal to the 10 o'clock position on the RAW. Conversely distance between the pylorus and the RAW at this location was significantly greater the more caudal the gastropexy location. Distance between the pylorus and RAW along the y-axis was significantly lower at the 9 o'clock position at all locations ($P \leq 0.001$) with the pylorus consistently located in a slight dorsal position relative to the RAW. Total distance at the 2cm13R 9 o'clock position was less than at all other locations ($P < 0.0001$), but there were no other differences amongst other locations.

Z-axis distance

The results are summarised Table 4. For the 3CM13, 2CM13, R13, and R11 locations, median absolute distance were significantly different from each other and significantly greater than the median absolute displacement at R10 and R9 ($P<0.001$). The R10 and R9 location result in a median absolute distance of 5.8% and 5.4% of ventral abdominal length respectively which were not significantly different from each other ($P=0.1$). A net caudal and cranial position of the pylorus relative to the RAW occurred at R9 and R10 respectively.

Overall Distance: The overall distance between the pylorus and the RAW is shown in Table 5, and was greatest at the 3CM13 location in the 10 and 9 o'clock positions, being significantly different from all other locations ($P<0.001$). Overall distance was least at the 10R and 9R 10 o'clock position which were not significantly different from each other ($P=0.31$) but significantly less than all other locations ($P<0.001$). Finally, there was no difference between 11R 8 o'clock position and the 10R 9 o'clock ($P=0.1$) and 9R 9 o'clock ($P=0.17$) positions.

Factors affecting overall distance at the 10 o'clock position of the 10th rib

On simple linear regression analysis (Table 6), factors associated with overall distance at 10R 10 o'clock were medium-sized ($R=0.43$, $R^2=0.19$, $P<0.001$) and large ($R=-0.35$, $R^2=0.12$, $P=0.008$) breed dogs. No other factor was found to be of significance, although age was also eligible (at P<0.2) for inclusion in the preliminary multiple linear regression model (R= -0.18, R^2= 0.03, P=0.171). Therefore, a multiple regression model was then built including three factors: medium breed, large breed, and age. After refinement by backwards stepwise elimination, the best-fit model was one that included a single variable, medium-sized breed dogs (R=0.43, R^2=0.19, P<0.001, Table 6). Given this finding, the effect of breed was explored further by repeating linear regression analysis, to include binary variables for the three most common medium-sized breeds (e.g. Labrador retriever, English springer spaniel, and boxer). On simple regression analysis, both Labrador retriever (R=0.26, R^2=0.07, P=0.047) and English springer spaniel (R=-0.61, R^2=0.37, P<0.001) were also significant. Therefore, a second multiple regression model was built, which included five factors: medium breed, large breed, age, Labrador retriever, and English springer spaniel. After refinement by checking collinearity and by backwards stepwise elimination, the best-fit model was one that included a single variable, English springer spaniel (R= -0.61, R^2= 0.37, P<0.001, Table 6).

Discussion

The objective of the current study was to define the location of the pylorus in canine breeds considered susceptible to GDV in the UK. Using CT, we demonstrated that the pylorus was located in the right hypochondriac/epigastric region typically at the level of the 9th intercostal space. In 88% of cases, the pylorus was located in the right cranioventral abdominal quadrant and in the vast majority of cases (63%) at the 9 – 10 o'clock position. Our results suggest that the most frequently used gastropexy locations are significantly different to the natural anatomic location of the pylorus.

The overall distance between the pylorus and the RAW is the summation of distance in all three planes. This was calculated using the Pythagorean Theorem in two stages (Table 5). The overall distance between the RAW and R13 and 3CM13 is equivalent to 29 and 36% of ventral abdominal length respectively, significantly greater than the distance between the RAW and 11R (average distance 18 – 20% ventral abdominal length). Least overall distance between the pylorus and RAW occurs at the 9R and 10R 9 – 10 o'clock position, equivalent to 15 – 18% of ventral abdominal length. This is significantly less than the distance seen between the pylorus and RAW at the traditional gastropexy locations and is largely attributed to mediolateral distance rather than a product of the increased distance between the pylorus and RAW in the craniocaudal or dorsoventral plane which is seen at more caudal gastropexy sites.

By the nature of the gastropexy procedure, displacement of the pylorus/pyloric antrum towards the RAW must occur and will result in a non-anatomical location of the pylorus (Leib and other 1985, Whitney and other 1989). Based on this study mediolateral distance between the pylorus and RAW measured at least 8% and could be as great as 17% of ventral abdominal length. Typically, gastropexy procedures, with the exception of the circumcostal gastropexy, are described between R13 and 3CM13R. Positive contrast gastrography studies have confirmed that a belt-loop gastropexy results in caudal/caudomedial displacement of the pylorus, which based on our study, could represent caudal and mediolateral displacement of up to 31% and 17% of ventral abdominal length respectively (Whitney and other 1989). Positive contrast gastrography studies have also documented displacement of the pylorus following circumcostal gastropexy which, assuming the gastropexy is completed at 11R, could result on average in caudal and mediolateral displacement of 9% and up to 9% respectively (Leib and other 1985).

In the authors' opinion, the location to perform a gastropexy in the dorsoventral plane and the dorsoventral position used in GDV studies is inconsistently reported. To make the locations relevant to the surgeon, a clock face analogy was chosen to represent the dorsoventral locations. The distance between the pylorus and RAW was least at the 9 o'clock position and was equivalent to approximately 4% of ventral abdominal length which is consistent regardless of gastropexy location suggesting that the true location of the pylorus lies close to the 9 o'clock position in the dorsoventral plane.

The short and long term consequences, if any, of excessive gastric displacement are unknown. Recurrent GD was reported in 5 - 10% of incisional (Benitez and other 2013, Przywara and other 2014), 3 - 9% of circumcostal (Leib and other 1985, Eggertsdottir and other 2008) and 3 - 7% of ventral midline gastropexy procedures (Meyer-Lindenberg and others 1993, Ullmann and other 2015). Recurrent GD may represent persistence of factors contributing to the initial GDV episode or be a consequence of the gastropexy procedure. Indeed, the authors would speculate that as previously described inappropriate gastropexy location can result in functional pyloric outflow obstructions and contribute to recurrent episodes of GD (Jennings and other 1992). It is also possible that stretch of antral smooth muscle may alter slow wave propagation and subsequent gastric motility which may contribute to recurrent episodes of GD although these theories are speculative and warrant further investigation (Publicover and Sanders 1985).

One of the main limitations of our study is to base our measurements on the pyloric canal. Whilst the authors accept that the pyloric canal is not the recommended site to perform gastropexy, it is a site which can be consistently and easily identified on CT scans thereby allowing more reliable comparisons between individuals. This does mean that an assumption was made that traction and subsequent displacement of the pyloric antrum would result in proportional displacement of the pylorus. Further studies are required to assess whether a gastropexy performed on the pyloric antrum actually result in significant displacement of the pylorus relative to its normal anatomic position.

Other limitations of this study are mainly attributed to its retrospective nature. Breed selection was made based on findings of Evans and Adams (2010). Ideally, more breeds considered at higher risk of GDV (e.g. Great Dane) would have been evaluated but this was limited by case availability. Patient positioning was optimised for the presenting complaint and not this study. As such, some patients may not have been lying completely square on the gantry and contributed to some variation in the measurements obtained. Sternal recumbency was chosen for this study as it was hypothesised to most closely resemble normal abdominal positioning in the ambulatory and sternally recumbent patient. Studies quantifying the effect of recumbency on the position of abdominal organs in veterinary patients are lacking and are often referenced to a static point rather than the natural location of the target organ. Respiratory motion is reported to cause variation in the position of cranial abdominal organs in human and veterinary studies (Oliveira and others 2014). In human and veterinary patients, respiratory motion artefact is reduced when the patients are placed in prone or ventral recumbency respectively (Kim and others 2007, Oliveira and other 2014). While this may not be of immediate significance on any one individual scan, a scan performed in ventral recumbency may help limit the effect of respiratory induced variation across the sampled population. Table-top pressure has been shown to cause variation in the position of caudal abdominal structures in human patients with prostate cancer which is more pronounced in the supine position (Bentel and others 2000). Similar studies have not been conducted in the veterinary literature although the authors would speculate that the shape of the thoracic cavity should provide some protection from the effects of table top pressure to cranial abdominal organs although the effects of pressure on caudal abdominal structures and secondary effect on cranial abdominal structures is unknown. Daily fluctuation in the volume of the colon and bladder are reported to be responsible for variation in caudal abdominal organ position in human and veterinary studies (Bentel and other 2000, Nieset and others 2011). All patients are typically starved for at least twelve hours before the CT examination is completed. Nevertheless, there was varying degrees of gastric distension either with gas and/or food material. No studies in the human or veterinary literature report the effects of gastric distension on pyloric position, although it is possible this could contribute to variation in the measurements made in this study. Linear measurements were standardised to ventral abdominal length to enable comparison across breeds and individuals of varying size. Both standardising to body weight and body surface area was considered; however, this does not take into account the body condition of individuals which may have resulted in over- or under-estimation of measurements in under- and over-conditioned individuals, respectively.

Conclusion

This study demonstrates that reconstructed CT images can be used to accurately document the location of the canine pylorus. We found that the pylorus is located within the costal arch in all cases and in the right cranioventral abdomen in the vast majority of cases. Current recommended sites to perform a gastropexy could result in significant displacement of the pylorus relative to its natural anatomical location. With this in mind further additional CT studies are required to document the position of the pylorus in dogs which have previously had a gastropexy following GDV. Case-control studies could then be considered where by outcomes are compared between dogs that had a gastropexy performed at different locations

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Table 1

Angle (°)	Clock face position	Number of dogs
-30 - ≤0	12 – 1	1
0 - ≤30	11 - 12	5
30 - ≤60	10 - 11	8
60 - ≤90	9 – 10	36
90 - ≤120	8 – 9	7
120 - ≤150	7 - 8	0
150 - ≤180	6 - 7	0

Table 2

	Distance		
	10 o'clock (mm/mm)	**9 o'clock** (mm/mm)	**8 o'clock** (mm/mm)
3cm13R	0.114^{X} (0.255) *[0.114; 0.255]*	0.145^{WXY} (0.315) *[0.145; 0.315]*	0.078 (0.240) *[0.078; 0.117]*
2cm13R	0.113^{X} (0.272) *[0.113; 0.291]*	0.151^{WX} (0.311) *[0.151; 0.311]*	0.083 (0.246) *[0.083; 0.271]*
13R	0.107^{X} (0.279) *[0.107; 0.296]*	0.147^{Y} (0.317) *[0.147; 0.317]*	0.092 (0.262) *[0.092; 0.237]*
11R	0.091^{Y} (0.260) *[0.091; 0.273]*	0.141^{WY} (0.310) *[0.141; 0.310]*	0.120^{Y} (0.290) *[0.120; 0.290]*
10R	0.086^{Y} (0.240) *[0.086; 0.273]*	0.143^{WYZ} (0.291) *[0.143; 0.291]*	0.128^{Z} (0.301) *[0.128; 0.301]*
9R	0.086^{Y} (0.239) *[0.086; 0.274]*	0.137^{YZ} (0.296) *[0.137; 0.296]*	0.124^{YZ} (0.288) *[0.124; 0.288]*

Table 3

	Distance		
	10 o'clock (mm/mm)	**9 o'clock (mm/mm)**	**8 o'clock (mm/mm)**
3cm13R	0.113$^{\alpha}$ (0.209) *[0.113; 0.225]*	0.036^{X} (0.137) *[-0.017; 0.246]*	0.119$^{\alpha}$ (0.177) *[-0.119; 0.177]*
2cm13R	0.115$^{\alpha}$ (0.202) *[0.115; 0.225]*	0.034 (0.140) *[-0.015; 0.238]*	0.121$^{\alpha}$ (0.183) *[-0.119; 0.405]*
13R	0.109 (0.185) *[0.109; 0.225]*	0.037^{X} (0.147) *[-0.017; 0.237]*	0.133 (0.197) *[-0.133; 0.197]*
11R	0.090 (0.189) *[0.090; 0.388]*	0.040^{X} (0.187) *[-0.020; 0.250]*	0.165 (0.278) *[-0.165; 0.332]*
10R	0.085 (0.161) *[0.085; 0.175]*	0.036^{X} (0.195) *[-0,027; 0.248]*	0.173 (0.232) *[-0.173; 0.232]*
9R	0.078 (0.156) *[0.078; 0.231]*	0.045^{X} (0.198) *[-0.045; 0.245]*	0.179 (0.230) *[-0.179; 0.230]*

Table 4

	Distance	
	Absolute (mm/mm)	**Net** (mm/mm)
3cm13R	0.311 (0.320)	0.311 (0.320)
2cm13R	0.284 (0.317)	0.284 (0.317)
13R	0.226 (0.310)	0.226 (0.310)
11R	0.089 (0.243)	0.089 (0.334)
10R	0.058[x] (0.184)	0.037 (0.328)
9R	0.054[x] (0.200)	-0.027 (0.310)

Table 5

Overall Distance

	10 o'clock (mm/mm)	**9 o'clock** (mm/mm)	**8 o'clock** (mm/mm)
3CM13	0.355$^{\alpha}$ (0.290)	0.363$^{\alpha}$ (0.277)	0.351 (0.230)
2CM13	0.333$^{\alpha}$ (0.286)	0.333$^{\alpha}$ (0.271)	0.330 (0.225)
13R	0.289$^{\alpha}$ (0.272)	0.290$^{\alpha}$ (0.253)	0.288$^{\alpha}$ (0.210)
11R	0.181$^{\alpha}$ (0.225)	0.196$^{\alpha}$ (0.277)	0.238^{x} (0.272)
10R	0.146^{x} (0.216)	0.169^{x} (0.297)	0.231^{x} (0.286)
9R	0.138^{x} (0.236)	0.165^{x} (0.288)	0.235^{x} (0.280)

Table 6

Variable	R	R^2	Probability
<u>Simple regression</u>			
Age (per year)	-0.18	0.033	0.171
Sex [a]	0.11	0.01	0.406
Neuter status [b]	-0.16	0.02	0.249
Body weight (per kg)	0.02	0.00	0.884
Weight status [c]	-0.01	0.00	0.946
Body surface area (per m^2)	0.03	0.00	0.838
Breed group [d]			
Medium	0.43	0.19	<0.001
Large	-0.35	0.12	0.008
Giant	-0.04	0.00	0.762
Breed [e]			
Boxer	-0.09	0.00	0.505
English springer spaniel	-0.61	0.37	<0.001
Labrador retriever	-0.26	0.07	0.049
<u>Final multiple regression model</u>			

1			
Medium breed dogs	0.43	0.19	<0.001
Final multiple regression model 2			
English springer spaniel	-0.61	0.37	<0.001

[a] Classified as a binary variable: male = 1, female = 0. [b] Classified as a binary variable: neutered = 1, intact = 0. [c] Classified as a binary variable: overweight (BCS 6-9/9) = 1, ideal weight (BCS 4-5/9) = 0. [d] Each group classified as a binary variable, whereby: from that breed group = 1; not from that breed group = 0. [e] Classified as a binary variable: from that breed = 1; not from that breed = 0.

Figure legend

Figure 1: Transverse CT image slices. Sequential CT slices moving cranially from a) to c) illustrating identification of the pylorus (P). D = ascending duodenum and PA = pyloric antrum.

Figure 2: Dorsal CT image slice at the level of the most caudal aspect of R13 used to assign the z-axis coordinate for R13, R11, R10 and R9.

Figure 3: Transverse CT image slice used to calculate the clock face angle. The angle was measured from a line that intersected the centre of the pyloric canal (red) and the centre of the abdominal cavity (black circle), defined as the point half way along a vertical line from the dorsoventral axis of the vertebral body to the linea alba (green), relative to the sagittal plane.

Figure 4: Transverse CT image orientated in dorsal recumbency. The position of the pylorus in the dorsoventral plane was described using the clock-face analogy with the patient in dorsal recumbency to make the results surgically applicable.

Table 1: Position of the pylorus assembled into clock face units

Table 2: Median (range) absolute distance between the pylorus and RAW along the x-axis at predefined abdominal landmarks. Absolute values in columns with the same upper case letter are not significantly different at $P < 0.05$. Values in italics represent *[median net distance; range]*

Table 3: Median (range) absolute distance between the pylorus and RAW along the y-axis at predefined abdominal landmarks. Absolute values in rows with the same lower case Greek letter are not significantly different at $P<0.05$. Absolute values in columns with the same upper case letter are not significantly different at $P<0.05$. Values in italics represent *[median net distance; range]*.

Table 4: Median (range) absolute and net distances between the pylorus and RAW along the z-axis at predefined abdominal landmarks. Values in columns with the same upper case letter are not significantly different at $P<0.05$.

Table 5: Median (range) overall distance between the pylorus and RAW relative at predetermined abdominal locations. Values in columns with same upper case letter are not significantly different. Values in rows with same Greek letter are not significantly different at $P<0.05$.

Table 6. Simple and multiple linear regression analysis to determine factors affecting overall distance between the pylorus and RAW at the 10 o'clock position of the 10^{th} rib.