# RADIOGRAPHIC DIAGNOSIS OF MECHANICAL OBSTRUCTION IN DOGS BASED ON RELATIVE SMALL INTESTINAL EXTERNAL DIAMETERS

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**Mechanical obstruction is a frequent cause of acute vomiting in dogs requiring prompt diagnosis to improve patient management and prognosis. The purpose of this retrospective study was to compare small intestinal radiographic characteristics in dogs with versus without mechanical intestinal obstruction. Fifty dogs with gastrointestinal clinical signs and abdominal radiographs were recruited from hospital record archives and assigned to groups (group 1, obstructive, $n = 25$; group 2, nonobstructive $n = 25$). Abdominal radiographs were randomized and independently interpreted by three examiners who were unaware of group status. Intestinal dilation was subjectively scored based on distribution (segmental, regional or diffuse), and severity (absent, mild, moderate or severe). Small intestinal maximal diameter ($SI_{max}$), L5 vertebral body height, small intestinal minimal diameter ($SI_{min}$), and an estimated average of small intestinal diameters ($SI_{ave}$) were measured and three ratios were calculated: $SI_{max}/L5$, $SI_{max}/SI_{min}$, and $SI_{max}/SI_{ave}$. Segmental dilation was more prevalent in obstructed dogs for all examiners ($P \leq 0.03$) and most nonobstructed dogs had no dilation ($P \leq 0.05$). All ratios were higher in obstructed dogs ($P < 0.002$). Subjective dilation scores and ratio measurements had low interobserver agreement (absent to fair, with kappa values between −0.06 and 0.57) and reproducibility (coefficients of 0.35–0.61). Findings indicated that dogs with $SI_{max}/L5 \leq 1.4$, $SI_{max}/SI_{min} \leq 2$, and $SI_{max}/SI_{ave} \leq 1.3$ values are very unlikely to be mechanically obstructed; dogs with $SI_{max}/L5 \geq 2.4$, $SI_{max}/SI_{min} \geq 3.4$ and $SI_{max}/SI_{ave} \geq 1.9$ are very likely obstructed, particularly if segmental dilation (less than 25% of the small intestine) is present. Dogs with ratios falling between these thresholds may need further testing unless other signs justify surgical exploration or endoscopy.** 

**Key words: dog, interobserver variability, obstruction, radiography, small intestinal diameters.**

## Introduction

MECHANICAL OBSTRUCTION is a frequent cause of acute vomiting in dogs requiring prompt diagnosis to improve patient management and prognosis.[1–3] While several studies have reported that ultrasonography provides superior accuracy for identifying intestinal obstruction,[4,5] this modality remains less available, more user-skill dependent, more expensive, and more time consuming when compared with radiography in general veterinary practice. Numerous studies have investigated the usefulness of radiography in dogs with mechanical ileus. Several of these focused on the use of anatomical landmarks, and particularly the height of L5 vertebral body, to predict intestinal obstruction requiring surgery. The published criterion for normal intestinal diameter in the dog is the ratio comparing the maximal small intestinal ($SI_{max}$) external diameter to the height of L5 vertebral body ($SI_{max}/L5$), which should not exceed 1.6 in the normal dog.[2,6–9] In these studies, ratios were determined based on measurements performed by a single observer and potential interobserver variations were not described. More recently,[10] when examiners of variable experience in radiology were asked to score the likelihood of small intestinal obstruction based on lateral abdominal radiographs in dogs, it was found that the additional use of the $SI_{max}/L5$ ratio did not result in increased diagnostic accuracy. In this recent study, a ratio of 1.7 was only 66% sensitive and specific for predicting intestinal obstruction. The value of this ratio, which remains widely used in practice,[7] was thus concluded to be questionable.

Focal, or segmental, small intestinal dilation orad to the level of obstruction has been reported to be more prevalent with mechanical ileus, although more diffuse distention may occur with chronic distal obstruction.[2,3,5,7,8,11] Yet, the patterns of intestinal dilation present with mechanical

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obstruction have not been specifically investigated. It has been proposed that a difference in diameter of greater than 50% between normal and distended bowel should indicate obstruction or diverticulum.[3,7] While the potential value of comparing intestinal diameters for predicting obstruction has been proposed, this has never been validated. The objectives of the current study were to (1) compare $SI_{max}/L5$ ratios, small intestinal relative diameter ratios and patterns of dilation for dogs with versus without mechanical obstruction; and (2) determine interobserver reproducibility for measurements and subjective scoring.

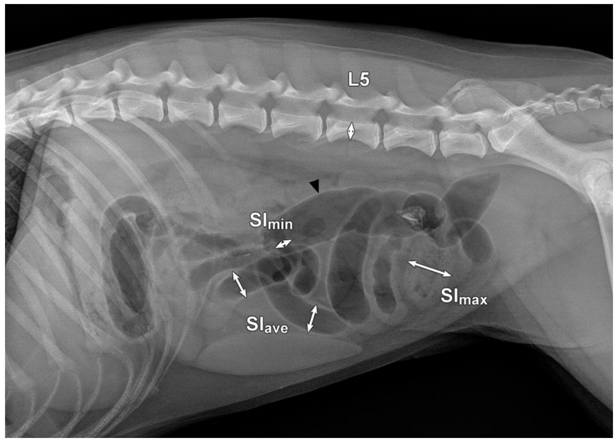


FIG. 1. Abdominal radiograph of a dog for which intestinal dilation was determined present and scored as regional by all examiners. Four intestinal diameter measurements are illustrated: $SI_{max}$, $SI_{min}$ and two loops representative of the average small intestinal diameter (further averaged as $SI_{ave}$). The height of L5 mid-vertebral body is also identified. All projections were available for review to help identify the colon (black arrowhead). The dog was diagnosed with an obstructive jejuno-ileal foreign body. This likely represents the luminal content at the level of the $SI_{max}$ measurement.

## Material and Methods

### *Patient Selection*

Medical records from the Centre Hospitalier Universitaire Vétérinaire of the Université de Montréal were searched for dogs presenting between 2006 and 2012 for acute or chronic clinical signs consistent with small intestinal obstruction (e.g. vomiting, diarrhea, anorexia, lethargy, and/or abdominal pain), and for which abdominal computerized radiographs were obtained (Agfa CR-DX® system, Toronto, ON, Canada). For study inclusion, dogs had to have diagnostic quality radiographs that included at least one lateral and one ventro-dorsal view of the entire gastrointestinal tract and had to have small intestinal external surfaces that were well visualized. Dogs with poor abdominal serosal detail were excluded. The first 25 dogs that met these inclusion criteria and that had intestinal obstruction confirmed by surgery or necropsy were assigned to the obstructed group (Group 1). Dogs were excluded if they had a gastric foreign body or a small intestinal foreign body that was naturally expulsed. Additional dogs were then recruited as needed until Group 1 totaled 25 dogs. The 25 dogs selected for the nonobstructed group (Group 2) had to meet the following criteria: intestinal obstruction was a clinical possibility; intestinal obstruction was proved to be absent based on surgery and/or endoscopy; and intestinal obstruction was proved to be absent based on clinical follow-up confirming a nonobstructive cause, and/or resolution of clinical signs without expulsion of foreign body. Dogs without follow-up were excluded and additional dogs recruited as needed until Group 2 totaled 25 dogs.

### *Data Collection*

For the 50 dogs meeting study inclusion criteria, abdominal radiographic series were randomized and independently reviewed by three observers unaware of dog group status. Observers were two board-certified radiologists (E1 and E2), and a second-year radiology resident (E3). All examiners used the same dedicated medical imaging processing software (Osirix, version 32 bits 4.0). All observers were aware of the objectives of the study and how groups were assigned. Except for E1, the other examiners were unaware of the proportion of dogs in each group.

Examiners were each asked to record the same set of findings for each study (Fig. 1). First, intestinal dilation was scored for presence (yes/no), distribution (segmental, regional or diffuse), and severity (mild, moderate or severe). The distribution of the dilation was arbitrarily defined as segmental when less than 25% of small intestinal loops were affected, regional when 25–50% of loops were affected, or diffuse when more than 50% of loops were involved. No further instruction was provided. Examiners were allowed to assess features based on all available radiographic projections. Then, examiners were asked to measure four intestinal diameters in the lateral projections, using the software's electronic calipers placed on the bowel outer edges and specific guidelines. Diameters measured were (1) maximum small intestinal diameter $SI_{max}$; (2) minimal small intestinal diameter ($SI_{min}$), excluding areas of peristaltic segmentation; and (3) and (4) two loops considered representative of the average small intestinal diameter, that is, in-between $SI_{max}$ and $SI_{min}$ values. These two average loop measurements were averaged and reported as $SI_{ave}$. Finally, the height of L5 mid-vertebral body was measured using the same lateral projection(s). Three ratios were then calculated from these measurements: $SI_{max}/L5$, $SI_{max}/SI_{min}$, and $SI_{max}/ SI_{ave}$.

### *Statistical Analysis*

Statistical analyses were performed by one of the authors (GB), a biostatistician at the University of Montréal.

A *t*-test for equal variances was used to compare the distribution of age and weight between the 2 groups, and a Chi-2 test was used to compare the distribution of sex between groups. An exact Chi-2 test was used to compare the distribution of intestinal dilation pattern (segmental, regional, and diffuse) between the two groups, whereas a *t*-test for unequal variances was used to compare all three ratios between groups. Receiver operating characteristic (ROC) curve analysis was used for each ratio to determine optimal thresholds. Optimal ratio threshold was defined as the value associated with highest sensitivity and specificity. Minimal and maximal thresholds for the diagnosis of mechanical obstruction, with 95% confidence intervals, were also determined using ROC analysis for the three ratios and for each examiner. Minimal threshold for a ratio was set when associated with a sensitivity exceeding 95% (under which only 5% of dogs with mechanical obstruction were included, that is to say that almost exclusively dogs without mechanical obstruction were present). Maximal threshold for a ratio was set when associated with a specificity exceeding 95% (over which only 5% of dogs without mechanical obstruction were included). Results of sensitivities and specificities were obtained with combinations of the three ratios (at optimal thresholds), and combinations of each ratio (at optimal threshold) with each pattern of intestinal dilation. When considering tests in parallel, a dog was considered to be positive for mechanical ileus if one condition or the second one was present. For serial tests, a dog was considered positive for mechanical ileus if one condition and the second one were present. The reproducibility of measurements among three examiners was tested using the method of intraclass correlation, determining a coefficient between 0 and 1. A coefficient approaching 1 indicated that measurements obtained by the examiners were nearly identical, and that all data variation was attributed to patient variations (i.e. exact reproducibility), whereas a coefficient approaching 0 indicated that measurement variations were more likely attributed to a variation between examiners rather than between patients. Interobserver agreement for the presence and distribution of dilation in both groups of dogs was tested with $\kappa$ values, and level of agreement was classified as excellent ($\kappa$ between 0.93 and 1.0), very good ($\kappa$ between 0.81 and 0.92), good ($\kappa$ between 0.61 and 0.80), fair ($\kappa$ between 0.41 and 0.60), slight ($\kappa$ between 0.21 and 0.40), poor ($\kappa$ between 0.01 and 0.20), or none ($K < 0.01$).[12] All analyses were performed with dedicated statistical software (SAS vs. 9.3, Cary, N.C.). For all analyses, a value of $P < 0.05$ was considered significant.

## Results

### *Dogs*

Fifty-eight dogs (29 in each group) were initially considered. However, in eight of these cases, small intestinal diameters could not be confidently assessed and measured due to insufficient abdominal contrast. Twenty-five dogs met inclusion criteria for each of the two groups. Mean age at presentation was 4.4 years (+/ −2.9) for obstructed dogs (group 1), and 5.6 years (+/−4.1) for nonobstructed dogs (group 2). Mean weight was 27.8 kg (+/−10.8) for group 1, and 27.1 kg (+/−11.8) for group 2. Group 1 was composed of 7 females and 18 males, and group 2 was composed of 12 females and 13 males. There was no significant difference for age, weight, and sex distribution between the 2 groups. A foreign body was responsible for mechanical obstruction in all dogs of group 1. Nonobstructive processes confirmed for group 2 dogs were parvovirus infection ($n = 3$), hypoadrenocorticism ($n = 2$), protein-losing enteropathy ($n = 1$), pyogranulomatous lymphangiectasia ($n = 1$), gastritis ($n = 5$), enteritis ($n = 2$), paralytic ileus ($n = 5$), pancreatitis ($n = 2$), clostridium infection ($n = 1$), abdominal liposarcoma ($n = 1$), abdominal necrotic lipoma ($n = 1$), adrenal mass with gastric ulcers, and jejunal artery thrombosis ($n = 1$).

### *Radiographic Patterns of Dilation*

Patterns of intestinal dilation that were scored by the three examiners are reported in Table 1. Segmental dilation was more prevalent in obstructed dogs for all examiners (E1 $P < 0.0001$, E2 $P < 0.008$, E3 $P = 0.03$) (Fig. 2A). Regional dilation was more prevalent in obstructed dogs for E3 ($P = 0.02$), whereas there was no difference between groups for this pattern for E1 ($P = 0.22$) and E2 ($P = 0.07$). Diffuse dilation was more prevalent in nonobstructed dogs for E1 ($P < 0.0001$), whereas there was no difference between groups for this pattern for the other two examiners (E2 $P = 1$, E3 $P = 0.051$). Absence of dilation was more prevalent in dogs without mechanical obstruction (E1 $P = 0.05$, E2 $P < 0.0001$, E3 $P = 0.005$) (Fig. 2B).

### *Small Intestinal Diameter Ratio Comparisons*

Mean $SI_{max}/L5$ value for the three observers was 2.71 (+/−0.69) for group 1, and 1.62 (+/−0.41) for group 2. Mean $SI_{max}/SI_{min}$ value for the three observers was 4.13 (+/−1.12) for group 1 and 2.52 (+/−0.75) for group 2. Mean $SI_{max}/SI_{ave}$ value for the three observers was 2.27 (+/−0.59) for group 1 and 1.51 (+/−0.30) for group 2. All three mean ratio values were higher for obstructed dogs for the three observers ($P < 0.0001$) (Table 2). These ratios were all significantly higher in dogs with small intestinal mechanical obstruction for all three examiners (E1 $P < 0.0001$, E2 $P \leq 0.0005$, E3 $P \leq 0.002$). Based on ROC analyses, the optimal, maximal, and minimal thresholds for diagnosing mechanical obstruction for each ratio and for each examiner are summarized in Table 3. When considering tests in parallel, for all

TABLE 1. Small Intestinal Dilation Patterns Recorded by Three Examiners for Obstructed and Nonobstructed Dogs

| | | GROUP 1 (obstructed) ($N = 25$) | | | | | | GROUP 2 (non-obstructed) ($N = 25$) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | E1* | | E2 | | E3 | | E1 | | E2 | | E3 | |
| Distribution | Severity | $n^{\ddagger}$ | Total (%) | $n$ | Total (%) | $n$ | Total (%) | $n$ | Total (%) | $n$ | Total (%) | $n$ | Total (%) |
| Segmental | Severe | 10 | | 9 | | 9 | | 0 | | 1 | | 1 | |
| | Moderate | 3 | | 1 | | 2 | | 0 | | 1 | | 1 | |
| | Mild | 1 | 14$^{\dagger}$ (56%) | 1 | 11$^{\dagger}$ (44%) | 0 | 11$^{\dagger}$ (44%) | 0 | 0$^{\dagger}$ (0%) | 0 | 2$^{\dagger}$ (8%) | 1 | 3$^{\dagger}$ (12%) |
| Regional | Severe | 5 | | 2 | | 4 | | 1 | | 0 | | 1 | |
| | Moderate | 5 | | 5 | | 5 | | 1 | | 1 | | 1 | |
| | Mild | 0 | 10 (40%) | 1 | 8 (32%) | 1 | 10$^{\dagger}$ (40%) | 3 | 5 (20%) | 1 | 2 (8%) | 0 | 2$^{\dagger}$ (8%) |
| Diffuse | Severe | 0 | | 1 | | 3 | | 0 | | 0 | | 0 | |
| | Moderate | 0 | | 2 | | 0 | | 0 | | 0 | | 6 | |
| | Mild | 1 | 1$^{\dagger}$ (4%) | 0 | 3 (12%) | 0 | 3 (12%) | 15 | 15$^{\dagger}$ (60%) | 2 | 2 (8%) | 4 | 10 (40%) |
| No dilation | | 0 | 0$^{\dagger}$ (0%) | 3 | 3$^{\dagger}$ (12%) | 1 | 1$^{\dagger}$ (4%) | 5 | 5$^{\dagger}$ (20%) | 19 | 19$^{\dagger}$ (76%) | 10 | 10$^{\dagger}$ (40%) |

*E1 examiner 1, E2 examiner 2, E3 examiner 3.
†Significantly different ($P < 0.05$) between groups.
‡$n$ = number of dogs with each score for a given dilation distribution, total = number of dogs with each dilation distribution.

observers, the sensitivity was increased, but the specificity was decreased. For serial tests, a dog was positive for mechanical ileus if one condition and the second one were present. For all observers, the specificity of serial testing was increased, but the sensitivity was decreased. Among results, the presence of $SI_{max}/L5>1.8$–2.4 or $SI_{max}/SI_{min}>2.3$–3, as well as $SI_{max}/L5>1.8$–2.4 or $SI_{max}/SI_{ave}>1.5$–1.7 increased the sensitivity up to 88–96%, but decreased the specificity to 44–74% depending on the observer. The specificity was itself increased up to 84–96% if $SI_{max}/L5>1.8$–2.4 and $SI_{max}/SI_{min}>2.3$–3, or $SI_{max}/L5>1.8$–2.4 and $SI_{max}/SI_{ave}>1.5$–1.7 were recognized, but the sensitivity was decreased to 64–76%. Overall, sensitivity and specificity values that were decreased were less affected for serial and parallel combinations of each ratio at optimal threshold, compared with tests combining a ratio at optimal threshold and a pattern of dilation. In fact, the association of any of the ratios at optimal threshold and a segmental pattern of dilation highly increased the specificity but drastically decreased the sensitivity. For instance, the specificity was increased up to 96–100% when $SI_{max}/L5>1.8$–2.4 and segmental dilation were recognized by any reader, but the sensitivity decreased to 44–52%.

*Reproducibility for Small Intestinal Diameter Ratio Measurements*

Coefficients of reproducibility for $SI_{max}/SI_{min}$ and $SI_{max}/SI_{ave}$ among all three examiners were 0.35 and 0.44, respectively, indicating that there were more variations between the examiners than between the subjects measured. The coefficient for $SI_{max}/L5$ was of 0.61, indicating that the variation between the observers for this ratio was notable, but less than for the other 2 ratios. Individually, $SI_{max}$ and $SI_{ave}$ measurements were associated with higher coefficients of reproducibility, that is, 0.69 and 0.73, respectively, indicating good reproducibility. The coefficient for $SI_{min}$ measurement was 0.33, indicating poor reproducibility. Conversely, the coefficient of reproducibility for L5 was 0.96, indicating excellent reproducibility.

*Interobserver agreement for subjective small intestinal scores (Fig 3.).* The agreement between E1 and E2 was fair for the presence of segmental ($K = 0.44$) and regional ($K = 0.53$) dilation, but poor when identifying diffuse dilation ($K = 0.05$) and absence of dilation ($K = 0.16$). Agreement between E1 and E3 was fair for the presence of diffuse ($K = 0.47$) dilation, slight for the presence of segmental ($K = 0.31$) dilation, and for absence of dilation ($K = 0.27$), but was absent when identifying regional dilation ($K = -0.06$). Fair agreement was found between E2 and E3 for an absence of dilation ($K = 0.57$), while agreement was slight for segmental ($K = 0.24$) and diffuse ($K = 0.22$) dilation, and poor for regional dilation ($K = 0.19$).

## Discussion

The previously reported radiographic criterion of intestinal luminal dilatation for small intestinal mechanical obstruction was supported in our study, as intestinal luminal dilatation was significantly more prevalent in obstructed dogs for all examiners (44–56%), and recognized with slight to fair agreement ($0.24 < K < 0.44$). Intestinal luminal dilatation has been established as a hallmark sign of ileus, and its extent and severity represent discriminating criteria that have been investigated in several studies.[3,7,8,10] For instance, segmental dilation is typically associated with mechanical obstruction.[3,5,7,13] Conversely, absence of dilation was

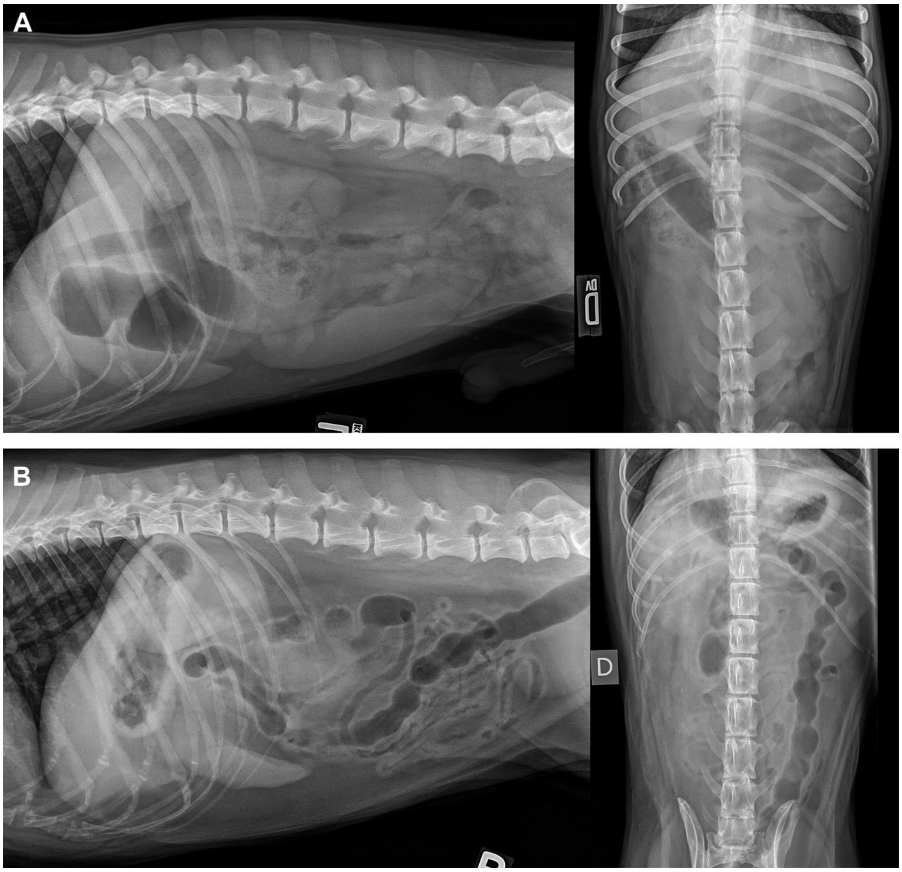


FIG. 2. (A) Abdominal radiograph of a dog for which all examiners scored the intestinal dilation as segmental. Mechanical obstruction was diagnosed and a jejunal foreign body (plastic bag) was removed at surgery. (B) Intestinal dilation was scored as absent in this nonobstructed dog by all examiners. The dog was diagnosed with pancreatitis that resolved with medical treatment.

TABLE 2. Mean Values for Three Small Intestinal Ratios Measured by Three Examiners for Obstructed and Nonobstructed Dogs

| | Mean value between E1-E2-E3* | | E1 | | E2 | | E3 | |
|---|---|---|---|---|---|---|---|---|
| Ratio | Group 1‡ | Group 2§ | Group 1 | Group 2 | Group 1 | Group 2 | Group 1 | Group 2 |
| $SI_{max}/L5$** | 2.71† ± 0.69 | 1.62† ± 0.41 | 2.67† ± 0.68 | 1.51† ± 0.40 | 3.04† ± 1.07 | 1.76† ± 0.72 | 2.43† ± 0.69 | 1.58† ± 0.54 |
| $SI_{max}/SI_{min}$†† | 4.13† ± 1.12 | 2.52† ± 0.75 | 3.58† ± 1.33 | 1.94† ± 0.71 | 4.28† ± 1.59 | 2.55† ± 1.06 | 4.54† ± 1.86 | 3.08† ± 1.52 |
| $SI_{max}/SI_{ave}$‡‡ | 2.27† ± 0.59 | 1.51† ± 0.30 | 2.18† ± 0.72 | 1.33† ± 0.24 | 2.32† ± 0.77 | 1.58† ± 0.62 | 2.31† ± 0.93 | 1.63† ± 0.45 |

*E1 examiner 1, E2 examiner 2, E3 examiner 3.
†Significantly different between groups ($P < 0.05$).
‡Group 1 obstructed.
§Group 2 nonobstructed.
**Maximum small intestinal diameter/height of 5th lumbar vertebra.
††Maximum small intestinal diameter/minimal small intestinal diameter.
‡‡Maximum small intestinal diameter/average small intestinal diameter.

significantly more prevalent in dogs of the current study without mechanical obstruction for all examiners (20–76%). Interobserver agreement was only poor to fair ($0.16 < K < 0.57$) for this category. The last two patterns of dilation, that is, regional and diffuse, were also associated with low and quite variable reading agreement ($-0.06 < K < 0.53$ and $0.05 < K < 0.47$, respectively). Interestingly, it appears that most of the reading discrepancy was linked to the fact that one radiologist scored mild diffuse dilation in the majority (15/25, 60%) of dogs without obstruction, while another radiologist considered intestinal diameter to be normal in 76% of them. In fact, when regrouping results in the categories of mild diffuse dilation and absence of dilation for these two readers, we realized that the vast majority of dogs without mechanical obstruction, that is, 20 or 21 out of 25, were scored in one of these two categories. The third reader scored 80% of dogs without mechanical obstruction with no intestinal dilation (10/25) or with mild or moderate diffuse intestinal dilation (10/25). When adding the results of the three readers, it appears that the absence

TABLE 3. Optimal Threshold Ranges Among Examiners for Each Small Intestinal Ratio

| Ratio | Se ≥ 95%* | Optimal threshold | Sp ≥ 95%† |
|---|---|---|---|
| $SI_{max}/L5$‡ | ≥ (1.4–1.6) | ≥ (1.8–2.4)<br>Se (74–92)%<br>Sp (74–84)% | ≥ (2.4–2.8) |
| $SI_{max}/SI_{min}$§ | ≥ (2.0–2.1) | ≥ (2.3–3.0)<br>Se (77–88)%<br>Sp (62–84)% | ≥ (3.4–6.2) |
| $SI_{max}/SI_{ave}$** | ≥ (1.3–1.4) | ≥ (1.5–1.7)<br>Se (72–80)%<br>Sp (69–80)% | ≥ (1.9–2.6) |

*Sensitivity.
†Specificity.
‡Maximum small intestinal diameter/height of 5th lumbar vertebra.
§Maximum small intestinal diameter/minimal small intestinal diameter.
**Maximum small intestinal diameter/average small intestinal diameter.

of dilation, or the presence of mild or moderate diffuse dilation, represent radiographic signs that are predominant among dogs without mechanical obstruction, and should therefore help excluding mechanical obstruction in most dogs.

Our results also indicated that the identification of mechanical obstruction based on radiographic intestinal dilation severity and pattern can be difficult, even for board-certified radiologists and radiology residents. Guidelines were provided to the readers for the extent of patterns of dilation, but not for the presence/absence of dilation per se, or its severity. The difficulty in subjectively assessing intestinal diameter justifies development of several quantification methods, most of which use other body landmarks to produce ratios that minimize effects of variable body sizes in dogs. Over the last two decades, most studies evaluating the capacity of radiography to detect small intestinal mechanical obstruction used the $SI_{max}/L5$ ratio.[4–6,9,10] In the present study, the lower threshold for $SI_{max}/L5$—ruling out mechanical obstruction almost certainly—was between 1.4 and 1.6. These threshold values supported previous reports describing 1.6 as the upper limit for normal small intestine in the dog (i.e. $SI_{max}/L5 \leq 1.6$).[6,7] In our study, the maximal threshold value for $SI_{max}/L5$, which should be considered as very high probability of mechanical obstruction, was 2.4–2.8 for the three examiners, which is higher than previously reported (i.e. 2.19).[6] This discrepancy might be related to the fact that our study design and statistical approach were different.

To the authors' knowledge, this is the first report describing comparisons of small intestinal ratios such as $SI_{max}/SI_{min}$ and $SI_{max}/SI_{ave}$, in dogs. In cats, the $SI_{max}/SI_{min}$ ratio did not allow discrimination of mechanical obstruction from nonobstructive ileus.[14] Conversely, in our study, this ratio as well as the $SI_{max}/L5$ and $SI_{max}/SI_{ave}$ ratios were all significantly higher in dogs with mechanical obstruction. Lower and upper thresholds for $SI_{max}/SI_{min}$ and $SI_{max}/SI_{ave}$ ratios (which target the highest possible true positive and true negative rates, respectively) were also established based on the three readers' measurements. Ratio values of $SI_{max}/SI_{min} \geq 2$–$2.1$ and $SI_{max}/SI_{ave} \geq 1.3$–$1.4$ justify a strong clinical concern of mechanical obstruction. While it had been stated that an increase of diameter of greater than 50% more than the remaining bowel is indicative of an obstruction (or diverticulum),[3,7] we found that an increase of diameter of greater than 100% of the minimal diameter, or greater than 30% of the average bowel should indicate mechanical obstruction. On the other hand,

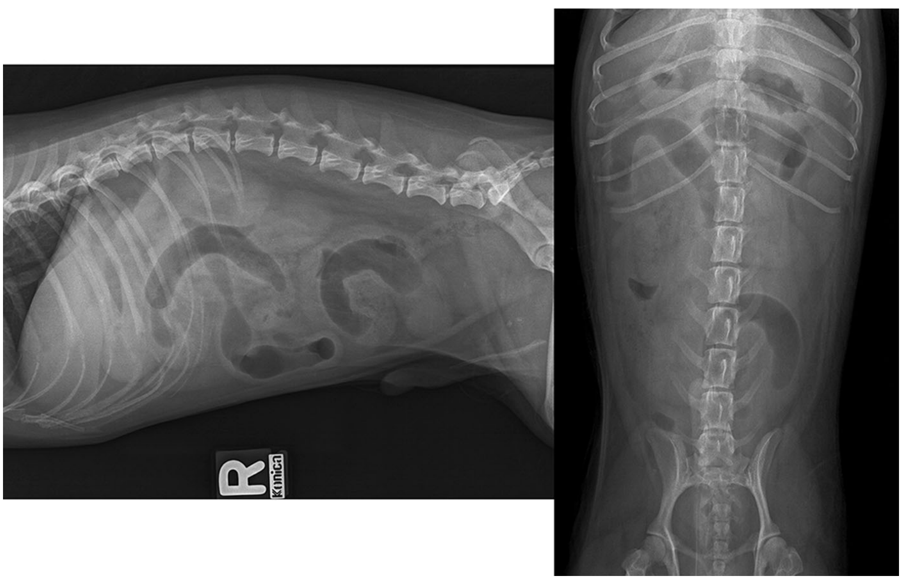


FIG. 3. Abdominal radiograph of a dog for which there was observer disagreement on the pattern of dilatation. In this dog with an ileo-caeco-colic obstructive foreign body, the dilatation pattern was scored by the three examiners as regional, diffuse, and segmental.

$SI_{max}/SI_{min} \geq 3.4–6.2$ and $SI_{max}/SI_{ave} \geq 1.9–2.6$ should strongly indicate small intestinal mechanical obstruction in most dogs. However, it must be pointed out that dogs with and without mechanical obstruction in the current study had ratios overlapping between lower and upper thresholds for mechanical obstruction.

Optimal thresholds ideally should be limited for both false negatives and false positives. Based on our results, optimal ratio thresholds with reasonably high sensitivity and specificity were 1.8–2.4 for $SI_{max}/L5$, 2.3–3.0 for $SI_{max}/SI_{min}$, and 1.5–1.7 for $SI_{max}/SI_{ave}$. A recent study reported $SI_{max}/L5$ ratio to be significantly increased in dogs with intestinal mechanical obstruction.[10] However, in this study, a ratio of 1.7 was only 66% sensitive and specific for the diagnosis of obstruction. In our study, depending on the examiners, sensitivity, and specificity at the optimal threshold for $SI_{max}/L5$ were between 74% and 92%, and 74% and 84% respectively, which seems more satisfactory. Both lateral and ventro-dorsal views were available to the readers, which might have allowed more precise determination of the maximally distended bowel segment compared with a lateral view only, and might explain the differences between our results and those of the recent study.[10] Using a combination of several ratios or combination of ratios and patterns of intestinal dilation did not result in an increase for both sensitivity and specificity. When the sensitivity was increased there was a drop in the specificity and vice versa. This was more pronounced when one ratio and intestinal pattern of dilation were examined. These combinations must thus be employed with caution and used in accordance with other clinical assessments.

Ratios using body landmarks are commonly used in veterinary imaging to improve detection of changes in organ size, while compensating for variations in body conformation. We often assume that these measurements are made with more consistency than when the assessment is purely subjective. Interestingly, a recent study concluded that the use of the $SI_{max}/L5$ ratio had no impact on the accuracy of radiographic diagnosis of intestinal obstruction in dogs when compared to subjective assessment only, regardless of the experience of the examiner.[10] Not only was the use of small intestinal ratio questioned by these authors, but they also highlighted the fact that certain measurements might be difficult to obtain if selection of landmarks is based on subjective interpretation. Our findings supported this conclusion as all diameters and ratios had some degree of interobserver variability. This was particularly noted for the $SI_{min}$ diameter measurement that had a reproducibility coefficient of 0.33. This finding indicated that differences between readers accounted for most of the differences in diameter measurements rather than actual differences between dogs. This was probably because of the difficulty in identifying the narrowest intestinal segment not constricted due to peristalsis. Measurements of $SI_{max}$ diameters were more consistent between readers (coefficient of 0.69), but still remained more variable than measurements of L5 diameters (coefficient of 0.96). This makes sense, as readers would be expected to more similarly measure a landmark that is anatomically constant and well defined. This likely explains why the $SI_{max}/L5$ ratio (coefficient of 0.61) was more reproducible than the other two ratios (0.35 and 0.44 for $SI_{max}/SI_{min}$ and $SI_{max}/SI_{ave}$, respectively).

Our findings supported the use of lower and upper thresholds for each small intestinal diameter ratio as one of the diagnostic criteria for making treatment decisions in dogs with suspected small intestinal mechanical obstruction. Dogs with a low clinical probability of mechanical obstruction could be discharged with medical management, whereas dogs with a high clinical probability of mechanical obstruction could be sent directly to surgery. When ratios fall in the gray zone, further diagnostic tests such as ultrasound may be required. Authors acknowledge that, in clinical practice, diagnosis and treatment decisions for dogs with suspected intestinal obstruction are usually based on a combination of several clinicopathologic features and that radiographic signs are only one of these. Radiographic reading variability may be even greater for clinicians with less experience in radiographic interpretation, justifying the inclusion of other radiographic criteria (such as luminal content and shape)[3,7,8,10,11] and other tests before sending dogs to surgery. Future studies may be warranted to assess the relative utility of all of these diagnostic criteria.

One of the limitations of the current study was that it was not possible to eliminate all reading bias, as foreign bodies were directly visible in radiographs of some of the obstructed dogs. This might have biased the choice of the maximal small intestinal diameter at the level of or just orad to the visible foreign body. Dogs with foreign bodies that were naturally evacuated were excluded from this study that focused on dogs with confirmed obstruction and that require surgery. We chose to exclude dogs with small intestinal obstruction due to other conditions such as infiltrative masses because we felt it would be difficult to confirm whether the ileus was truly mechanical in origin as opposed to functional. Similarly, dogs with endoscopically removed foreign bodies were excluded since we could not confirm if these foreign bodies were truly obstructive. Another limitation of the study design was the choice to use external intestinal margins for diameter measurements and to eliminate dogs with poor serosal detail.[15,16] This could have introduced a population bias due to exclusion of thin or young animals and animals with peritoneal effusion, which constituted 14% (4 out of 29 in each group) of the clinical cases initially considered for this study. Finally, the relative proportion of dogs with and without obstruction may not reflect the reality in practice, if we presume that mechanical obstruction is identified in less than 50% of all dogs presented with gastrointestinal signs.

In conclusion, findings from the current study indicated that the pattern of intestinal dilation and several intestinal ratios, considered alone or in combination, can help diagnose mechanical obstruction on abdominal radiographs in dogs. Instead of simply using cut-off values as the upper threshold of normal for these ratios, we recommend using the following flowchart approach based on probabilities of obstruction: (1) dogs with $SI_{max}/L5 \leq 1.4$, $SI_{max}/SI_{min} \leq 2$ and $SI_{max}/SI_{ave} \leq 1.3$ values are very unlikely to be mechanically obstructed and could be sent home with medical management, or further investigated for other conditions; (2) dogs with $SI_{max}/L5 \geq 2.4$, $SI_{max}/SI_{min} \geq 3.4$ and $SI_{max}/SI_{ave} \geq 1.9$, with or without segmental dilation, are very likely obstructed and could be sent directly to surgery if ultrasound is not available or declined; (3) dogs with ratios falling between these thresholds should be further investigated with other tools such as ultrasound or upper gastrointestinal series. It must however be kept in mind that reader variability can affect all radiographic parameters and they should therefore be used with caution.

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