DOES MEASUREMENT OF SMALL INTESTINAL DIAMETER INCREASE DIAGNOSTIC ACCURACY OF RADIOGRAPHY IN DOGS WITH SUSPECTED INTESTINAL OBSTRUCTION?

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The ratio between maximal small intestinal (SI) diameter and the height of the body of the fifth lumbar vertebra (L5) in radiographs has been reported as a diagnostic test in dogs with suspected intestinal obstruction. In order to assess the effect of the SI/L5 ratio on the accuracy of radiographic diagnosis of intestinal obstruction, lateral abdominal radiographs of 37 dogs with small intestinal obstruction and 48 nonobstructed dogs were mixed and examined independently by six observers who were unaware of the final diagnosis and who represented a range of experience. Observers first examined radiographs subjectively and stated the likelihood of obstruction (definitely not, probably not, equivocal, probably, definitely). Observers subsequently reexamined the radiographs, determined the SI/L5 ratio, and again stated the likelihood of obstruction. The most frequent cause of obstruction was foreign body (29/37, 78%). Dogs with SI obstruction had a significantly larger median SI/L5 ratio than nonobstructed dogs ($P = 0.0002$). Using an SI/L5 ratio of 1.7 for diagnosis of intestinal obstruction, sensitivity and specificity were 66%. Use of the SI/L5 ratio was not associated with increased accuracy of diagnosis for any observer, regardless of experience, hence this test may have no diagnostic impact.

Key words: dog, foreign bodies, intestinal obstruction, radiography, receiver operating characteristic.

Introduction

MECHANICAL OBSTRUCTION of the small intestine is a frequent cause of vomiting in dogs. Common causes include foreign body, neoplasia, and intussusception. In the acute phases of intestinal obstruction, hyperperistalsis promotes fluid and gas accumulation in intestinal loops orad to the obstruction and emptying of intestine aborad to the obstruction.[1] Swallowing of saliva and air, continued secretion into the gastrointestinal tract, and decreased absorption of fluid by distended intestine contribute to further fluid and gas accumulation.[1]

Survey radiographs are frequently obtained in dogs with suspected intestinal obstruction. Radiographic diagnosis of intestinal obstruction is based on signs including gastric and intestinal dilatation by gas and/or fluid, abnormal shape of intestinal loops (e.g., hairpin bends, stacked loops, pleating, or plication), foreign material, and the gravel sign.[2–5] Of these, localized dilation of the intestine is considered the key radiographic sign. However, the length of dilated intestine and degree of dilatation observed radiographically may vary depending on the site, duration, and completeness of an obstruction.[2,3,6,7] Dilatation of obstructed intestine may not occur if the obstruction is partial or intermittent, or if fluid is lost by vomiting. For example, a complete obstruction of the duodenum may cause minimal dilatation if most of the luminal fluid refluxes into the stomach and is removed by vomiting.[7] Furthermore, intestinal dilatation may also be observed with nonobstructive conditions, such as acute enteritis[8] and dysautonomia.[9]

Various quantitative radiographic criteria have been used to define the normal upper limit of intestinal dilatation.[7] For example, the diameter of a segment of the small intestine should not be more than 50% of the average diameter of the small intestine.[2] The ratio between maximal small intestinal (SI) diameter and the height of the body of the fifth lumbar vertebra (L5) does not normally exceed 1.6.[10] In the original study of the SI/L5 ratio, increasingly large values were associated with an increasing probability of intestinal obstruction: a value of 1.95 represented an 80% probability of obstruction, and a value of 2.07 represented a 90% probability of obstruction.[10] Hence, measures of intestinal dilatation, such as the SI/L5 ratio, may be considered as diagnostic aids in dogs with possible intestinal obstruction.

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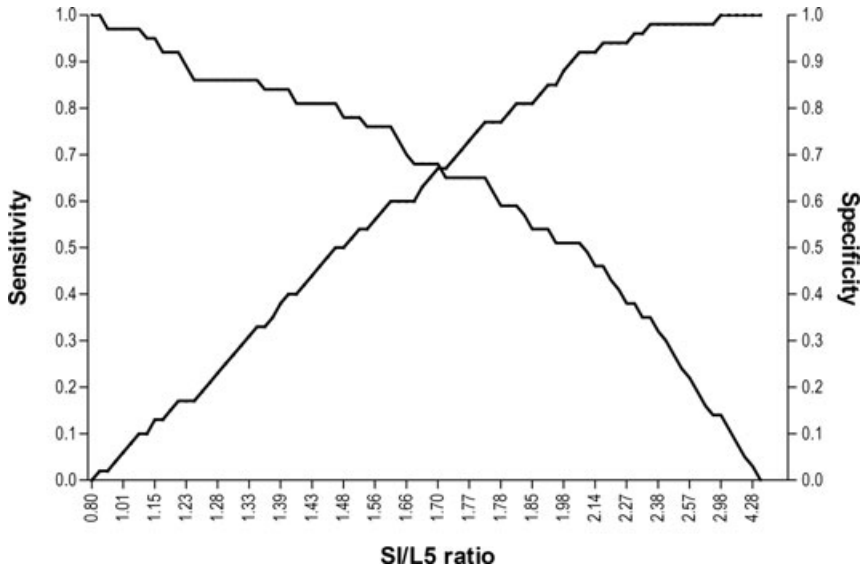

FIG. 1. Plot of sensitivity and specificity vs. SI/L5 ratio. Sensitivity and specificity are 0.66 (66%) at SI/L5 ratio = 1.7. SI, small intestinal maximal diameter; L5, height of the body of the 5th lumbar vertebra.

Although various radiographic measurements have been devised that tend to increase in patients with target conditions, the use of such measurements does not necessarily increase the diagnostic accuracy of observers compared to subjective assessment alone.[11] The aim of the present study was to determine if use of the SI/L5 ratio increased the accuracy of radiographic diagnosis of intestinal obstruction in dogs.

Material and Methods

Medical records at The Royal Veterinary College were searched backwards chronologically for dogs that had vomiting and abdominal radiographs, and either a surgical diagnosis of small intestinal obstruction during the same period of hospitalization or vomiting that resolved or was controlled medically. The median (range) elapsed time between radiography and exploratory surgery was 0 (0–1) days.

Assuming moderate accuracy of radiography for intestinal obstruction, moderate variability between observers, and approximately equal numbers of patients with and without the target condition, the minimum sample size for adequate statistical power was determined to be 78.[12] Digital lateral abdominal radiographs of obstructed and nonobstructed dogs with patient data removed were placed in a teaching file in case number order (which mixed obstructed and nonobstructed examples), and viewed using a 1.3 megapixel monitor (Flexscan S1910, Eizo Nanao Corporation, Japan). Radiographs were examined twice independently by six observers who were unaware of the final diagnosis and who represented a range of experience (two final year veterinary students, two residents, and two >12-year board-certified radiologists). At the first sitting, observers were instructed to first examine radiographs subjectively (without making measurements) and to state the likelihood of obstruction (definitely not, probably not, equivocal, probably, definitely), which was recorded by an investigator (T.C.). At the second sitting, which occurred a minimum of 3 days after the first sitting, observers reexamined the radiographs. On this occasion they were given a sheet containing information about the SI/L5 ratio, including Fig. 1B and Table 1 from the paper by Graham et al.[10], and were instructed in each case to measure the maximal SI diameter and the height of the body of the fifth lumbar vertebra (L5) directly from the radiographs. Measurements were made using a clear plastic ruler placed directly on the monitor screen. The SI/L5 ratio was calculated using the observer's measurements by the same investigator and the result communicated to the observer. Observers were then asked to again state the likelihoodof obstruction.

Statistical tests were done using commercially available software (SPSS Statistics 19, IBM Corporation, Hampshire, UK). The significance of differences between obstructed and nonobstructed dogs was tested using the Mann–Whitney test. Differences between observers' measurements of maximal SI diameter and L5 were tested using repeated measures ANOVA. Differences in the area under observers' paired receiver operating characteristic curves (AUC) were tested using multivariable analysis with sitting and level of experience as fixed effects. Differences of $P < 0.05$ were considered significant.

Results

A total of 85 dogs were included in the study. There were 37 dogs with small intestinal obstruction and

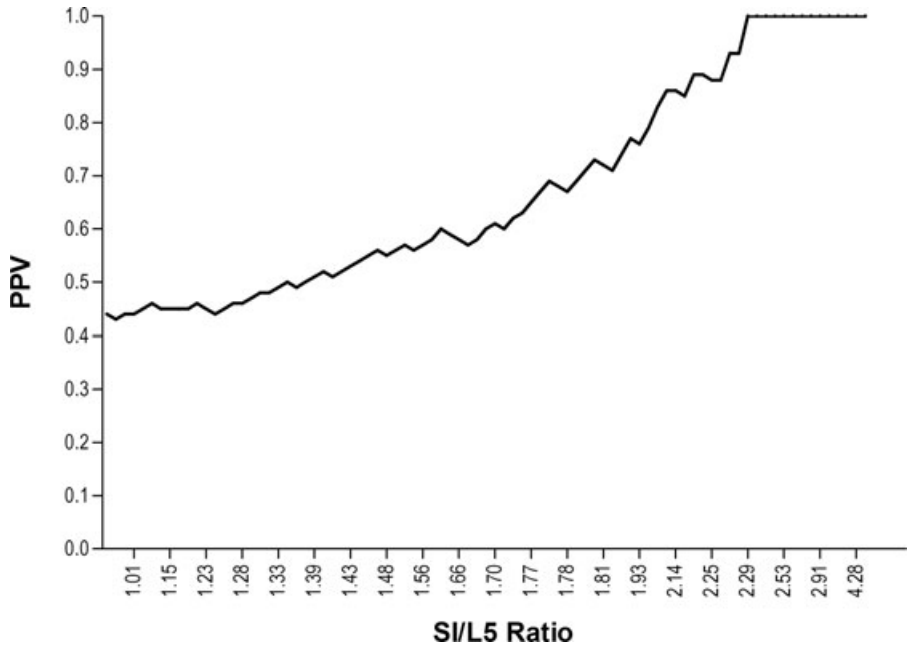

FIG. 2. Plot of positive predictive value (PPV) vs. SI/L5 ratio. The value at the *Y*-intercept (0.44) is equal to the prevalence of intestinal obstruction in this study (37/85, 44%).

48 nonobstructed dogs. The causes of obstruction were foreign body (29/37, 78%), intestinal neoplasia (5/37, 14%), and intussusception (3/37, 8%). Intestinal foreign bodies in two dogs were readily visible radiographically because they were more opaque than soft tissues; the remaining foreign bodies were nonradiopaque items. Male dogs (sum of entire and neutered) predominated in both obstructed (26/37, 70%) and nonobstructed (31/48, 65%) groups. Median ages of obstructed and nonobstructed dogs were 7.0 years and 5.0 years, respectively ($P = 0.2$). Median body weights of obstructed and non-obstructed dogs were 23.2 kg and 16.8 kg, respectively ($P = 0.7$).

Significant differences were found between observers' measurements of maximal SI diameter and height of L5 ($P = 0.0001$). The average difference in maximal SI diameters measured by observers was 3.0 mm, and the maximum likely difference was 6.9 mm. The average difference in heights of L5 measured by observers was 0.3 mm, and the maximum likely difference was 0.7 mm. For all observers, dogs with SI obstruction had a significantly larger median SI/L5 ratio than nonobstructed dogs ($P = 0.0002$). Using an SI/L5 ratio of 1.7 for diagnosis of intestinal obstruction, sensitivity and specificity were 66% (Fig. 1). The probability of SI obstruction increased with increasing SI/L5 ratio (Fig. 2).

Observers' sensitivity and specificity values for intestinal obstruction at the first sitting were in the ranges 22–49% and 63–94%, respectively, and at the second sitting were 14–51% and 67–88%, respectively. Observers stated a significantly different likelihood of obstruction at the second setting compared to the first (i.e., a change of at least two steps on the likelihood scale used) in 65/510 (13%) instances (Table 1). Observers changed their interpretation of the likelihood of obstruction at the second setting in similar numbers of obstructed or nonobstructed dogs (28 vs. 37, $P = 0.31$). The total number of cases in which observers were more correct at the second setting was almost balanced by the number of cases in which they were less correct (31 vs. 34, $P = 0.80$). There were no significant differences in paired AUC for any observers ($P = 0.9$) (Table 2). No effect of observer experience was found ($P = 0.2$).

Discussion

Dogs in the current study with small intestinal obstruction had a significantly larger median SI/L5 ratio than nonobstructed dogs and the positive predictive value of this test increased with increasing values for SI/L5 ratio, as previously reported.[10] Based on our data, an SI/L5 ratio value of 1.95 represents a 77% probability of obstruction, and a value of 2.07 represents an 86% probability of obstruction (Fig. 2). These results are comparable to previous results based on a similar sample of dogs.[10]

Many dogs found to be obstructed at surgery had no radiographically apparent small intestinal dilatation. This finding is compatible with another recent study in which dilated small intestine was observed in 6/11 (55%) of obstructed dogs.[13] Similarly, the low sensitivity of the SI/L5 ratio is compatible with another recent study in which an

TABLE 1. Observers' Interpretations of Likelihood of Small Intestinal Obstruction in 85 Dogs

Observer		Interpretation 0	1	2	3	4
First sitting: Subjective assessment						
1	Obstructed	1	12	6	15	3
	Nonobstructed	1	24	17	6	0
2	Obstructed	2	5	6	6	18
	Nonobstructed	6	18	6	14	4
3	Obstructed	4	10	5	5	13
	Nonobstructed	16	18	6	3	5
4	Obstructed	1	12	2	14	8
	Nonobstructed	7	31	7	3	0
5	Obstructed	1	4	6	11	15
	Nonobstructed	2	22	12	8	4
6	Obstructed	1	7	3	12	14
	Nonobstructed	11	26	6	4	1
Second sitting: Using SI/L5 ratio						
1	Obstructed	0	7	8	17	5
	Nonobstructed	0	22	10	15	1
2	Obstructed	4	9	4	7	13
	Nonobstructed	16	18	5	7	2
3	Obstructed	9	8	3	5	12
	Nonobstructed	26	13	3	2	4
4	Obstructed	5	9	2	10	11
	Nonobstructed	22	16	2	7	1
5	Obstructed	1	2	8	10	16
	Nonobstructed	2	19	14	9	4
6	Obstructed	3	4	4	7	19
	Nonobstructed	11	26	4	6	1

Note: SI/L5 = ratio of small intestine maximum diameter vs. height of the fifth lumbar vertebra on a lateral radiograph; 0, definitely not; 1, probably not; 2, equivocal; 3, probably; 4, definitely.

TABLE 2. Results of Receiver Operating Characteristic Analysis

Observer	Level of Experience	Area Under Curve (SE) First Sitting	Second Sitting
1	Student	0.66 (0.06)	0.68 (0.06)
2	Student	0.73 (0.06)	0.74 (0.05)
3	Resident	0.71 (0.06)	0.71 (0.06)
4	Resident	0.77 (0.05)	0.78 (0.05)
5	Radiologist	0.78 (0.05)	0.77 (0.05)
6	Radiologist	0.84 (0.04)	0.83 (0.05)

SE, standard error.

SI/L5 ratio >2 was observed in 55% obstructed dogs.[14] Overall, the SI/L5 ratio was not an accurate test for intestinal obstruction in the current study, and use of the SI/L5 ratio was not associated with increased accuracy of diagnosis for any observer, regardless of experience. Observers stated a significantly different likelihood of obstruction at the second setting compared to the first in only a small proportion of cases, and having considered the SI/L5 ratio they were equally likely to change a correct diagnosis to incorrect as vice versa. Because observers performed equally whether or not they determined the SI/L5 ratio, we conclude that this test has no diagnostic impact.

It is difficult to find examples of radiographic measurements that enable affected and unaffected patients to be accurately distinguished. Although measurements may complement the descriptive part of a radiology report, making measurements does not generally increase the accuracy of diagnosis because many affected patients fall within the normal size range.[11,15] Despite this, studies describing radiographic measurements of normal and abnormal patients are published frequently. There is continued interest in refining measurements of small intestinal diameter, as evidenced by a recent abstract.[16]

Relatively small (less than 1 mm) differences were found between observers' measurements for height of L5, reflecting the consistency with which the correct landmarks could be identified. Much larger differences (up to 7 mm) were found between observers' measurements of maximal SI diameter, which likely reflects greater variability in selection of the site of maximal dilatation and placement of a ruler on curved structures. Although radiographic measurements are sometimes recommended for use by inexperienced observers, these observers may have difficulty making the measurements if selection of landmarks relies heavily on subjective interpretation. This problem may contribute to the variability in maximal small intestinal diameter values observed in the present study.

It should be emphasized that the aim of this study was addressed by looking for differences in interpretation when a radiograph was viewed twice under different conditions (with and without measuring the SI/L5 ratio). To achieve this, there was no need to use more than one radiograph per dog. We elected to use only lateral radiographs because the SI/L5 ratio requires a lateral view for measurement of L5. In contrast, studies aiming to describe the accuracy of radiography for intestinal obstruction or to compare accuracy of radiography with other tests (such as ultrasonography) require complete imaging studies done consistently to an acceptable clinical standard.[14] Use of lateral radiographs only may have contributed to the low sensitivity for intestinal obstruction that was found in this study. Sensitivity of our most experienced observers was about 50%, compared with 19/27 (70%) in a recent study that used left and right lateral and ventrodorsal radiographs.[14] Potential disadvantages of omitting ventrodorsal radiographs include reduced sensitivity for foreign material (which could increase false negatives) and reduced ability to distinguish dilated small intestine from normal large intestine (which could increase false positives). However, it seems unlikely that omitting ventrodorsal radiographs could have confounded the comparison of observer accuracy with or without the SI/L5 ratio. Debatably, reduced sensitivity for foreign material could be considered advantageous for a study focused on intestinal dilatation as the key criterion of obstruction. Although the prevalence of intestinal foreign bodies in this study was high, it is realistic, particularly for first opinion or emergency clinics examining dogs with acute vomiting. Only two dogs had radiopaque foreign bodies that could be considered obvious to the inexperienced observers.

Radiography is sufficiently accurate for intestinal obstruction that it continues to be recommended as the initial imaging modality in both small animals[17] and humans.[18] However, in recent studies, abdominal ultrasonography has proved to be more accurate than radiography for the diagnosis of intestinal obstruction.[13,14,19,20] The choice of radiography or ultrasonography in any particular clinical setting will be influenced by multiple factors, such as tentative diagnosis, patient size, comorbidities, and clinician preference. Regardless of which modality is used first, it is important to determine the presence or absence of an intestinal obstruction as soon as possible because of the risk of intestinal wall ischemia and perforation if treatment is delayed.[1,21]

In conclusion, findings from the current study indicated that measuring the SI/L5 ratio from lateral radiographs has no diagnostic impact for dogs with suspected intestinal obstruction. If radiographs are made in patients with clinical signs suggestive of intestinal obstruction, subjective findings such as localized small intestinal dilatation and foreign material represent indications for exploratory surgery. Lack of intestinal dilatation in radiographs does not rule out intestinal obstruction, hence ultrasonography (or contrast radiography) should then be considered.

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