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# Serial abdominal radiographs do not significantly increase accuracy of diagnosis of gastrointestinal mechanical obstruction due to occult foreign bodies in dogs and cats

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## Abstract

Abdominal radiographs are commonly used in dogs and cats that present with gastrointestinal signs. When initial abdominal radiographs are equivocal for the presence or absence of gastrointestinal mechanical obstruction, follow-up abdominal radiographs may be recommended. Based on our review of the literature, no published study has been performed to evaluate the clinical utility of serial abdominal radiographs in such cases. The purpose of this study is to determine whether follow-up abdominal radiographs increase diagnostic accuracy for mechanical obstruction. A prospective cohort study was performed on client-owned dogs and cats with clinical concern for gastrointestinal mechanical obstruction and initial abdominal radiographs inconclusive for the presence of obstruction. Follow-up abdominal radiographs were performed between 7 and 28 h of the initial radiographs; an abdominal ultrasound performed within 3 h of the follow-up study served as the gold standard. A total of 57 patients (40 dogs and 17 cats) were recruited; 19 of 57 cases (11 dogs; 8 cats) were mechanically obstructed, all with nonradiopaque foreign bodies. Four blinded reviewers (2 radiologists, 1 radiology resident, 1 criticalist) separately assessed the initial and the combined initial/follow-up radiographic studies for diagnosis of mechanical obstruction; for each observer, there was no significant change in accuracy ($P = .058$-$.87$) for the diagnosis of mechanical obstruction. Given the lack of significant increase in diagnostic accuracy using follow-up radiographs in cases of occult gastrointestinal mechanical obstruction, other diagnostic options (eg, abdominal ultrasonography) could be considered when survey abdominal radiographs are inconclusive for the diagnosis of mechanical obstruction in dogs and cats.

KEYWORDS

canine, feline, foreign body, mechanical ileus, serial radiographs

## 1 | INTRODUCTION

Survey abdominal radiographs are frequently used as the initial diagnostic modality in dogs and cats with clinical signs associated with gastrointestinal mechanical obstruction. Radiographic diagnosis of mechanical obstruction has been based on identification of radiopaque or nonradiopaque foreign material; segmental small intestinal dilation with fluid or gas; characteristics of small intestinal location, orientation, and margination such as stacking, plication, and bunching of intestinal segments; or abnormally shaped small intestinal luminal

Abbreviations: AUC, area under the curve; ROC, receiver operator characteristic.

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gas opacities.[1-4] Accuracy of subjective assessment of abdominal radiographs to diagnose gastrointestinal mechanical obstruction has been reported to vary between 61% and 80.7-89.1%.[5,6] This wide range has been attributed to variable radiographic changes associated with this disease process that can complicate the confidence of the diagnosis, such as lack of small intestinal dilation and poor abdominal serosal detail.[5,7,8]

Ultrasound has a greater accuracy in the diagnosis of mechanical obstruction with less equivocal results when compared to abdominal radiographs in vomiting dogs, though accuracy is dependent on the ultrasonographer's skills and experience.[5] In addition, availability of ultrasound may be limited depending on location, time of day, and financial constraints of the owner.

Other techniques used to diagnose mechanical obstruction include gastrointestinal tract contrast studies, though they are often not pursued due to the time-consuming nature of the procedure that can delay time to surgery, the increased stress to the patient, the contraindication in patients with concern for gastrointestinal perforation (if barium is used as the contrast agent), and the potential to be a nondiagnostic study if the patient vomits the contrast agent.[4,9] Therefore, survey abdominal radiography remains a mainstay for diagnosing mechanical obstruction due to wide availability of radiographic equipment in small animal practices. In cases where initial abdominal radiographs are inconclusive for the presence or absence of mechanical obstruction, serial abdominal radiographs over a period of time of 24 h have been recommended.[4] However, based on our review of the literature no published study has been performed to evaluate the clinical utility of serial abdominal radiographs in the diagnosis of mechanical obstruction in small animals. Therefore, the purpose of this study was to compare the accuracy of initial radiographs versus combined assessment of initial and follow-up radiographs for the diagnosis of mechanical obstruction in dogs and cats that present with a clinical concern for gastrointestinal obstruction and in which the initial abdominal radiographic study was considered inconclusive. Our hypothesis was that assessment of the combined set of radiographs would improve the accuracy of radiography.

## 2 | MATERIALS AND METHODS

### 2.1 | Subjects

This prospective cohort study was approved by and conducted in accordance with the Institutional Animal Care and Use Committee at the University of Pennsylvania. Client-owned dogs and cats were recruited from June 2008 to August 2015 at the Matthew J. Ryan Veterinary Hospital of the University of Pennsylvania. Inclusion criteria for recruitment were dogs or cats with a clinical suspicion of mechanical obstruction and orthogonal abdominal radiographs (ventrodorsal or dorsoventral view and left lateral or right lateral views) that were considered inconclusive for the presence or absence of gastrointestinal mechanical obstruction by the radiologist or radiology-resident on-duty. Patients were excluded if all of the inclusion criteria were not met, or if follow-up imaging was not performed according to the prescribed procedure. Information gathered from the medical record included species, breed, age, presenting complaint/clinical signs, duration of clinical signs, ultrasound reports, surgical, endoscopic, or necropsy reports, if applicable, as well as differential diagnoses for cases that were not obstructed. Data collection was performed by two of the authors (E.B.E. and H.B.), both of which were radiology residents during the study period.

### 2.2 | Imaging procedures

Patients that met the inclusion criteria had a second set of abdominal radiographs acquired between 7 and 36 h after the initial abdominal radiographs. This radiographic study will be referred to as the "follow-up study" from herein. During the interim, medical management was provided in hospital or at home at the discretion of the attending clinician.

An abdominal ultrasound was performed on all included cases within 3 h of the follow-up abdominal radiographic study by a board-certified radiologist or a radiology resident under direct supervision of a board-certified radiologist (from 2008 to February 2013: GE Medical LOGIQ 9 Ultrasound Imaging System, General Electric Medical Systems, Milwaukee, WI; after February 2013: GE Logiq S8 Vet, Sound-Eklin, Carlsbad, CA). The gold standard for the diagnosis of small intestinal mechanical obstruction was determined by retrospectively reviewing the ultrasound reports. In the case of potential partial gastrointestinal mechanical obstructions, available static ultrasound images and cine loops for the case were reviewed by one of the authors (E.B.E.) and classified as either obstructed (referring to either suspected complete or partial gastrointestinal mechanical obstructions) versus not obstructed.

### 2.3 | Radiographic interpretation

Radiographs were subjectively assessed for the diagnosis of small intestinal mechanical obstruction; no universal definition or objective parameter for the diagnosis of obstruction was applied. Reviewers were asked to record their diagnosis on a Likert scale with five categories: (a) not obstructed, (b) probably not obstructed, (c) unsure, (d) probably obstructed, or (e) obstructed. Assessment was performed individually by four reviewers: two board-certified radiologists with 16 years (diplomate of the American College of Veterinary Radiology and the European College of Veterinary Diagnostic Imaging [W.M.]) and 10 years of experience (diplomate of the American College of Veterinary Radiology and the American College of Veterinary Internal Medicine [J.A.R.]), one board-certified emergency and critical care specialist (diplomate of the American College of Veterinary Emergency and Critical Care [V.T.]) with 2 years of experience, and one first-year radiology resident (with 6 years of veterinary experience prior to residency, including a 1 year diagnostic imaging specialty internship [E.B.E]). Reviewers were aware of the study goals, but were blinded

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to all clinical information other than the initial clinical concern for mechanical obstruction.

Abdominal radiographs were reviewed in two phases. During phase 1, the initial and follow-up radiographs were evaluated separately for each patient, evaluation of follow-up radiographs in isolation were included in this phase to decrease the potential for recall bias. Phase 1 was divided into two parts, 1A and 1B. Radiographs were randomly assigned to either phase 1A or phase 1B, such that both phases included one set of radiographs, either the initial or follow-up radiographs, for each patient. After completion of phase 1A, reviewers were asked to wait at least 1 week prior to starting phase 1B. Phase 2 started no earlier than 1 month after the completion of both parts 1A and 1B of phase 1. Phase 2 involved reviewing the initial and follow-up radiographs in concert for each patient (henceforth referred to as "combined assessment").

## 2.4 | Statistical analysis

For data analysis, a positive radiographic diagnosis for mechanical obstruction included the Likert scale categories of probably obstructed and obstructed. Associations between a final diagnosis of obstruction and time interval between the initial and follow-up radiographs were tested for using a logistic regression analysis. Assessment of the initial abdominal radiographs were compared to the combined assessment. Using ultrasound as a gold standard, sensitivity, specificity, and percent accuracy of radiography were calculated for each reviewer at each radiographic assessment step (initial radiographic study and combined assessment of the two radiographic studies). Receiver operator characteristic (ROC) curves were computed for each reviewer at each radiographic assessment step. The area under the curve (AUC) of the ROC curves for the initial and combined radiographic assessments were compared between reviewers. Within each reviewer, the AUC of the ROC curve for the initial radiographic assessment was compared to that of the combined assessment. Interobserver and intraobserver agreement was measured using Cohen's Kappa with values below 0.20 considered as poor agreement, 0.21-0.40 as fair agreement, 0.41-0.60 as moderate agreement, 0.61-0.80 as good agreement, and >0.81 as excellent agreement.[10] Statistical analyses were performed by two authors (W.M. and J.S.) with a PhD in biomedical engineering and core medical imaging and with a certification in clinical research using commercially available software (Stata/IC 12.1 for Windows, College Station, TX); $P < .05$ was considered significant.

# 3 | RESULTS

Fifty-seven dogs and cats were included in the study, of which 19 were ultimately diagnosed with a gastrointestinal obstruction; 40 of 57 (70.2%) were dogs and 17 of 57 (29.8%) were cats. Of the 40 dogs, there were five intact females, nine neutered females, eight intact males, and 18 neutered males. The median age of dogs was 2.5 ± 3.4 years (range: 3 months to 13 years). Canine breeds represented included: mixed breeds (7), American Pit Bull Terrier (7), Labrador Retriever (7), Golden Retriever (5), Beagle (2), Jack Russell Terrier (2), Standard Poodle (2), and one each of Cavalier King Charles Spaniel, Dachshund, French Bulldog, English Bulldog, Papillon, Pekinese, Portuguese Waterdog, and Yorkshire Terrier. Of the 17 cats, there were eight neutered females and nine neutered males. The median age of cats was 4.2 ± 3.8 years (range: 4 months to 13 years). Feline breeds represented included: domestic short hair (10), domestic long hair (3), and one each of Abyssinian, Himalayan, Maine Coon, and Ragdoll.

Patients had various clinical signs with vomiting being the most common. Duration of clinical signs ranged from <24 h to 3 weeks.

The mean time elapsed between acquisition of the initial and follow-up abdominal radiographic studies was 13 h 50 min ± 4 h 10 min (range: 7 h to 28 h 10 min), rounding to the nearest 10 min, with 21 of 57 (36.8%) cases having 12 or less hours between studies. Of the 19 obstructed cases in this study, six had <12 h between radiographic studies. The mean time between the acquisition of the follow-up abdominal radiographic study and the abdominal ultrasound was 40 ± 30 min (range: <10 min to 2 h), rounding to the nearest 10 min.

All cases had orthogonal radiographs available for the initial study. Of these, 49 of 57 (85.9%) cases had ventrodorsal and left lateral views, seven of 57 (12.3%) cases had ventrodorsal and right lateral views, and one of 57 (1.75%) cases had a dorsoventral and left lateral views. For the follow-up study, 55 of 57 (96.5%) cases had orthogonal radiographs of the abdomen, all of which were ventrodorsal and left lateral views, one dog (1/57, 1.75%) had a single left lateral view, and one dog (1/57, 1.75%) had three views of the abdomen that included ventrodorsal, right lateral and left lateral views.

Small intestinal mechanical obstruction was diagnosed on the abdominal ultrasound exam in 19 of 57 cases (33.3%; 11 dogs, 8 cats). Mechanical obstruction was caused by foreign bodies in 19 of 19 (100%) cases, all of which were not readily identifiable on the radiographs (non-radiopaque foreign bodies). Surgery was performed in 16 of 19 (84%) cases diagnosed with obstruction via ultrasound; surgery reports were not available for two patients that had surgery performed at the referring veterinary practice. Endoscopy for proximal duodenal material was performed in 1 of 19 (5.3%) cases. One cat (1/19, 5.3%) was euthanized without exploratory surgery and a necropsy was not performed. One dog (1/19, 5.3%) was diagnosed with a partial obstruction based on ultrasound; a second ultrasound performed 24 h after the follow-up radiographs confirmed resolution with medical management. For statistical purposes, this dog was considered obstructed based on the ultrasound performed at the study time-point. Retrieved foreign material included: trichobezoar (6 cats, of which one was endoscopically removed from the proximal duodenum), linear foreign body (5 dogs), non-specified small intestinal foreign body (3 dogs, 2 cats), squeaker toy (1 dog), and rubber (1 dog). Concurrent foreign material within the stomach, either extension from the small intestine foreign material or material separate from the above listed small intestinal obstructive material was present in four of 11 (36.4%) dogs and one of eight (12.5%) cats.

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There were a total of 38 of 57 (66.7%) patients that were not obstructed based on the ultrasound studies. Final diagnosis for these patients as determined by the ultrasound study included: gastroenteritis (22/38), enteritis (5/38), non-obstructive foreign material (4/57), possible ulceration of the stomach or duodenum (4/38), gastritis and duodenitis (2/38), intestinal inflammatory bowel disease versus small cell lymphoma (2/38), pancreatitis (2/38), unknown (2/38), gastroenterocolitis (1/38), colitis (1/38), protein losing enteropathy (1/38), or a combination thereof. Presence or absence of an obstruction was not associated with time interval between the initial and follow-up radiographic studies ($P = .85$).

Sensitivity, specificity, and accuracy for each observer are summarized in Table 1. Observers' sensitivity for the initial assessment ranged from 36.8% to 89.5% and for the combined assessment ranged from 26.3% to 84.2%. Of the four observers, the two board-certified radiologists had an increase in their sensitivity in the combined assessment as compared to the initial study assessment, whereas the first-year radiology resident and the board-certified emergency and critical care specialist had a decrease in their sensitivity in the combined assessment. Observers' specificity values for the initial assessment ranged from 71.1% to 94.7% and for combined assessment from 73.7% to 97.4%. Three of the reviewers increased their specificity in the combined assessment. One radiologist had a very high specificity (94.7%) on the initial assessment, which decreased for the combined assessment. Percent accuracy for the initial radiographic study ranged from 66.7% to 80.7% and for the combined assessment from 70.2% to 89.5%. Three of the four reviewers increased their percent accuracy in the combined assessment as compared to the initial assessment.

Accuracy as measured by the AUC of the ROCs for the initial assessment of the individual observers ranged from AUC 0.59 to 0.80 and for the combined assessment from AUC 0.61 to 0.87 (Figure 1). Accuracy increased for three of the four observers in the combined assessment as compared to the initial assessment; however, the differences in AUC were not statistically significant for any observer ($P = .058$-.87), although a possible trend toward significance was present for one of four observers ($P = .058$). Intraobserver agreement between the initial and combined assessment for each observer ranged from $\kappa = 0.15$-0.53 with one of the four observers having poor intraobserver agreement ($P = .12$) and three of four observers having moderate agreement, $\kappa = 0.41$-0.53 ($P < .0001$-.0006). Intraobserver agreement is summarized in Table 1.

The AUCs of the ROC curves were statistically significantly different between the four observers, both when comparing the initial assessments ($P = .034$) and the combined assessments ($P < .0001$) (Figure 2). When comparing the AUCs between only the board-certified radiologists, there was no significant difference for the initial assessments ($P = 1.0$) and for the combined assessments ($P = .83$). Interobserver agreement for the initial assessment was fair ($\kappa = 0.36$, $P \leq .0001$) and for the combined assessment was moderate ($\kappa = 0.53$, $P \leq .0001$).

## 4 | DISCUSSION

In dogs and cats that presented with a clinical concern for gastrointestinal mechanical obstruction and had initial abdominal radiographs equivocal for the diagnosis of obstruction, follow-up abdominal radiographs did not significantly increase the diagnostic accuracy in this study. This lack of statistical significance was present regardless of the reviewer's level of experience.

The recommendation to repeat abdominal radiographs in cases equivocal for mechanical obstruction in clinical practice is a common and well-accepted diagnostic plan; the results of this study were therefore unanticipated. One would expect that the time elapsed between the initial abdominal radiographs and the follow-up radiographs would allow for an increase in small intestinal and gastric distension in cases with mechanical obstruction. As gastrointestinal dilation is one of the main findings in the diagnosis of mechanical obstruction, this would facilitate radiographic detection of the distended segments, and the diagnosis of obstruction. A possible explanation for the lack of increased diagnostic accuracy in this study may be due to the timing between radiographic studies. Experimentally induced obstruction of the ileum in dogs has previously shown changes in gas and fluid distension with time. In early obstructions, that is, 12-36 h, the small intestine contained predominately gas, but with time, there was increased secretion of water and cations into the lumen orad to the obstruction.[11] Within 12 h of the experimentally induced obstruction, the ileum orad to the obstruction continued to secrete water at a normal rate but stopped absorbing water. However, after 48 h, the rate of water secretion was significantly greater, and the rate of cation secretion correlated with the movement of water. Together, the accumulation of gas, cations, and water would explain the dilation observed within the gastrointestinal tract with mechanical obstruction. Of the 19 obstructed cases in this study, six had less than 12 h between radiographic studies and all obstructed cases had less than 48 h between radiographic studies, with the greatest amount of time between studies being just over 28 h. Comparing these results to the experimentally induced obstructed dogs, the amount of time between the initial and follow-up studies may not have been enough for significant intestinal secretion to have developed and to result in radiographically discernible dilation. However, given the nature of this clinically based study, the amount of time between the moment of obstruction and the initial and follow-up radiographs cannot be determined.

There may be additional factors that were not analyzed in this study that could be contributing to the lack of significant increase in accuracy. One factor is selection bias for cases in which a diagnosis of mechanical obstruction or lack of obstruction was inherently more challenging. All initial radiographs were determined to be "equivocal" for the diagnosis of mechanical obstruction by a radiology resident or radiologist as part of the inclusion criteria. All of the included cases had occult (non-radiopaque) foreign bodies causing the mechanical obstruction that likely contributed to making these cases more difficult to diagnosis compared to cases in which a radiopaque foreign

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**TABLE 1** Sensitivity, specificity, and percent accuracy of each reviewer and intraobserver agreement between initial and combined assessment for each reviewer

| | Sensitivity | | Specificity | | Percent Accuracy | | Intraobserver agreement | |
|---|---|---|---|---|---|---|---|---|
| | Initial | Combined | Initial | Combined | Initial | Combined | Kappa | Agreement |
| Radiologist 1 | 63.16% | 73.68% | 84.21% | 97.37% | 77.2% | 89.5% | 0.53[a] | Moderate |
| Radiologist 2 | 52.63% | 84.21% | 94.74% | 89.47% | 80.7% | 87.7% | 0.41[a] | Moderate |
| Resident | 89.47% | 63.16 % | 71.05% | 73.68% | 77.2% | 70.2% | 0.44[a] | Moderate |
| Emergency and critical care specialist | 36.84% | 26.32% | 81.58% | 94.74% | 66.7% | 71.9% | 0.15 | Poor |

[a]* $P < .05$.

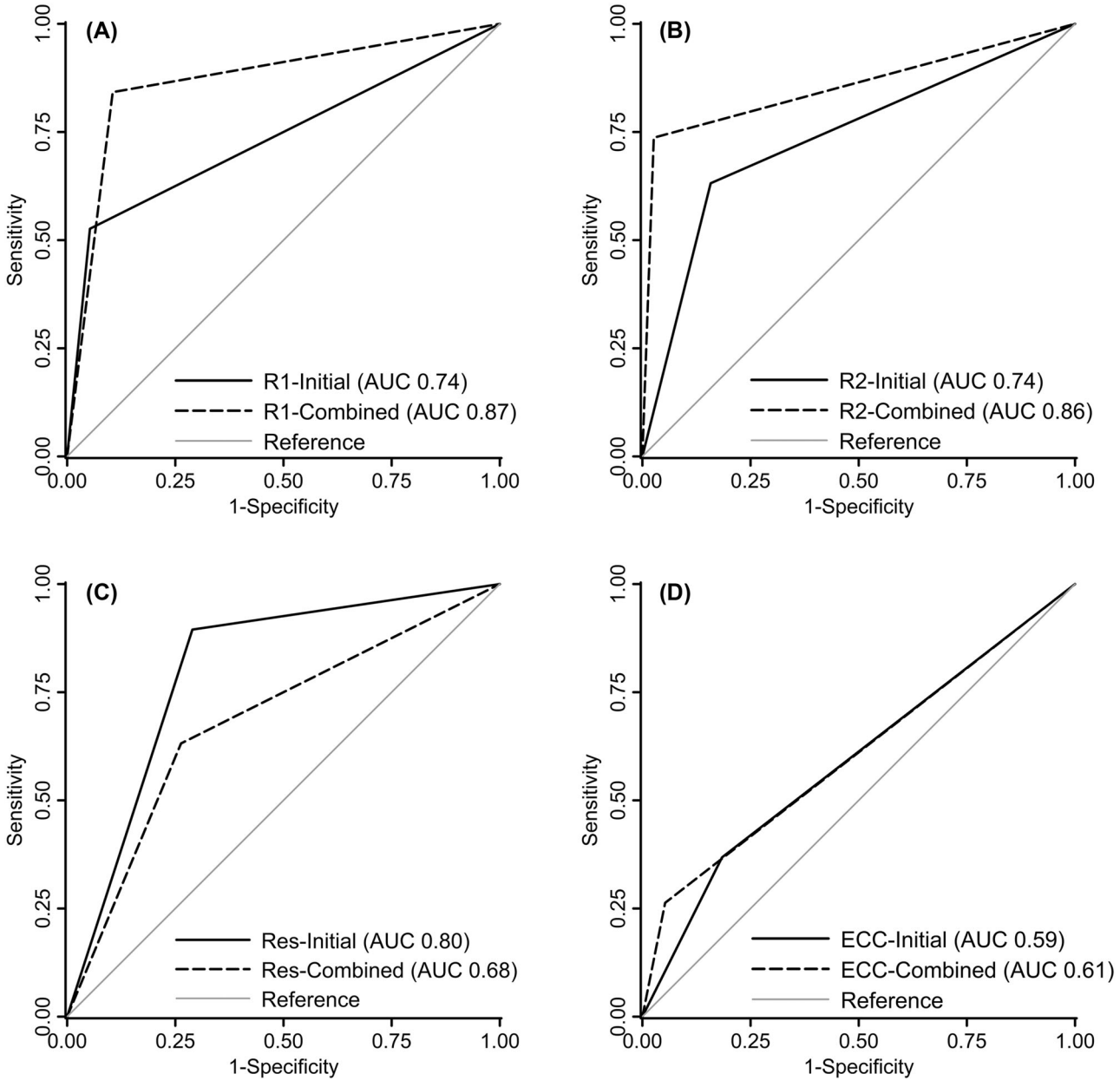



**FIGURE 1** Receiver operator characteristic curves for the initial assessment and the combined assessment for the radiologists (A, B), radiology resident (C), and emergency and critical care specialist (D). Accuracy was not significantly different between the initial and combined assessment for any observer. Radiologist 1 (R1), $P = .06$; Radiologist 2 (R2), $P = .08$; Resident (Res), $P = .08$; Emergency and critical care specialist (ECC), $P = .87$

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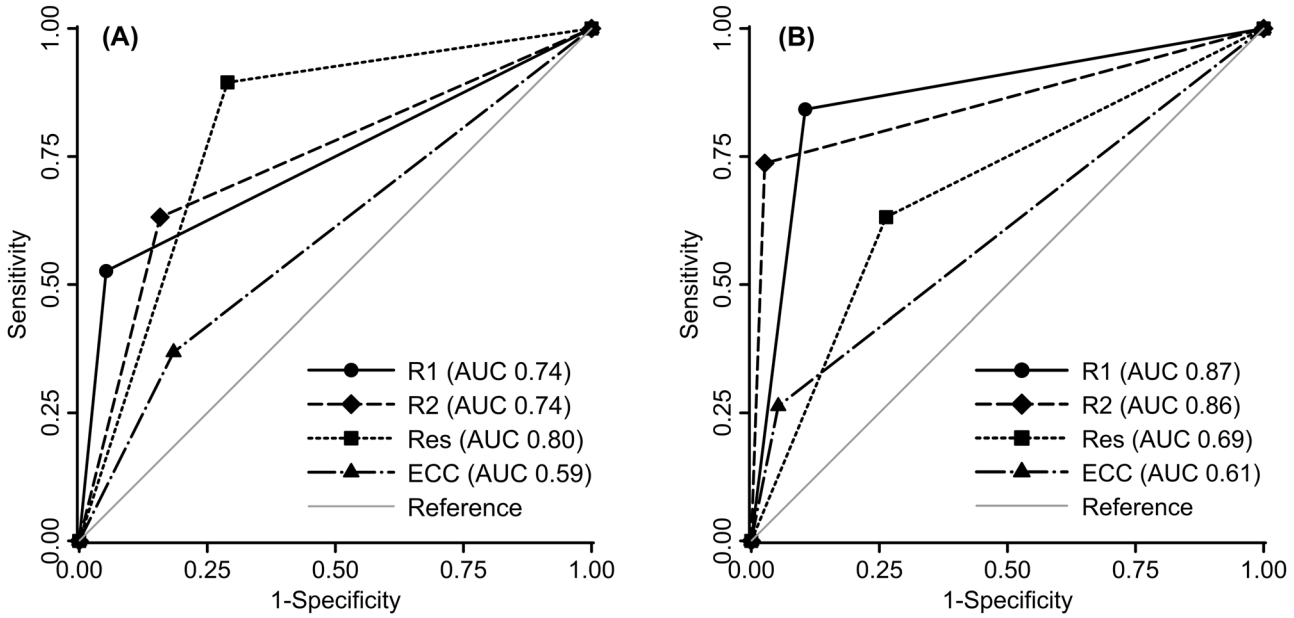



**FIGURE 2** Comparison of the receiver operator characteristic curves between reviewers for the initial assessment (A) and the combined assessment (B) for all reviewers. There were significant differences in accuracy between all observers in the initial assessment ($P = .034$) and in the combined assessment ($P = .0001$)

body is radiographically identified. Another factor includes that some patients may have been partially obstructed that allowed for some gas and fluid to pass around the obstruction and therefore precluded radiographically discernable intestinal dilation. An additional factor that could contribute includes patient hydration status, as dehydrated patients may not secrete as much fluid into the small intestines orad to the obstruction. Finally, decreased abdominal serosal detail, either due to a patient's lean body condition or the presence of peritoneal effusion or peritonitis, may potentially hinder the ability to identify dilated fluid filled intestinal segments.

Several clinical studies in dogs and cats that evaluated the accuracy of abdominal radiographs for the diagnosis of mechanical obstruction or that described the radiographic characteristics of mechanical obstruction showed that there were a small number of cases that were obstructed that did not have radiographically identifiable small intestinal dilation.[2,5,8,12,13,14] In one of these prior studies, eight of the 27 (29.6%) obstructed dogs did not have evidence of small intestinal dilation, with half of these due to linear foreign bodies.[5] Of the 19 obstructed cases in this study, there were five that were diagnosed with a linear foreign body and all of them were in dogs. Since linear foreign bodies do not always have small intestinal dilation, repeating radiographs with the expectation of identifying progressive intestinal dilation to help diagnose the patient would render this diagnostic choice unrewarding. Several published references have described a subset of mechanically obstructed cases that may not have small intestinal dilation as the result of the proximal location of the obstruction within the small intestine.[4,15,16,17] In the current study, there were two cats with a nonlinear foreign body involving the duodenum There was a total of 12 of 19 nonlinear foreign body cases involving material within the jejunum, and based on surgery reports, two of 12 were located in the proximal jejunum (one dog and one cat), two of 12 were located in the mid jejunum (one dog and one cat), and one of 12 was located in the distal jejunum to proximal ileum (one dog), whereas seven of 12 (four cats and three dogs) did not have a description of where the foreign body was located in the jejunum based on the surgery reports. Collectively, more than half of the obstructed animals in this study (9/19) had either a linear foreign body or a proximal intestinal nonlinear foreign body and this could have contributed to the lack of significant difference between combined assessment and initial radiographic assessment observed herein. Figure 3 is an example of a dog diagnosed with ultrasound as having a linear foreign body and secondary mechanical obstruction in which the initial and combined assessments did not generally yield a positive diagnosis for mechanical obstruction.

Lack of pertinent clinical information or history regarding each patient prior to or between radiographic acquisitions could affect the decision-making process of the reviewers and may have contributed to the lack of significant increase in accuracy in the combined assessment. Though all the reviewers were aware that the primary clinician had a clinical concern for mechanical obstruction, individualized clinical information that may aid in a more accurate analysis of the radiographic study was not available to the reviewers, such as if the patient vomited before acquisition of the follow-up abdominal radiographic study. In such a case, an obstructed patient could have evacuated the majority of the fluid in the stomach and/or small intestine rendering the gastrointestinal tract relatively empty or less dilated, which has been described in prior studies, particularly for more proximally located gastrointestinal obstructions.[4,5,12] Though lack of pertinent clinical information or history is not uncommon in imaging requests and may therefore reflect real-life scenarios, this laboratory bias could have affected

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**FIGURE 3** Initial (A, left lateral and B, ventrodorsal) and follow-up (C, left lateral and D, ventrodorsal) radiographs of a dog diagnosed with ultrasound as having linear foreign body and a secondary mechanical obstruction. On the initial radiographic assessment, one of four reviewers provided a diagnosis of probably obstructed (radiology resident; Likert score 4/5), two of four reviewers provided an unsure diagnosis for the presence or absence of mechanical obstruction (both radiologists; Likert score 3/5), and one of four reviewers provided a false negative diagnoses of probably not obstructed (criticalist; Likert score 2/5). On the combined assessment of this case, three of four reviewers provided an unsure diagnosis for the presence or absence of mechanical obstruction (both radiologists and the criticalist; Likert score 3/5) and one of four reviewers provided a false negative diagnosis of probably not obstructed (radiology resident; Likert score 2/5). (On the follow-up radiographs, C and D, metal marker beads are present on the dog's nipples.)

imaging interpretation in our study. In the above example, if a patient vomits prior to the follow-up radiographs, this could have resulted in the perception of non-progressive dilation such as with a functional ileus or even decreased gastrointestinal dilation between the initial and follow-up radiographic studies.

The lack of a significant increase in accuracy in the evaluation of serial abdominal radiographs in patients with clinical concern for mechanical obstruction places in question the effectiveness of this recommendation in clinical patients. This would suggest that in cases where the initial radiographs are equivocal for the diagnosis of mechanical obstruction, an alternate diagnostic plan should be considered, such as abdominal ultrasonography, especially as a prior study has shown that abdominal ultrasound is more accurate in the diagnosis of mechanical obstruction than abdominal radiographs in acutely vomiting dogs.[5] Despite this, in the hands of experienced radiologists, we observed an increased sensitivity (ie, decrease in false negative results for the diagnosis of obstruction) of the combined assessment compared to the initial assessment, and an increase in specificity (ie, decrease in the false positive results) for one of the two radiologists; therefore, this clinical recommendation may still have usefulness, particularly when access to ultrasound is limited but accessibility to radiologists' assessment is increasing via teleradiology. Examples of cases with an initial false positive diagnosis for mechanical obstruction and initial false negative diagnosis for mechanical obstruction in which the combined assessment facilitated the correct diagnosis are provided in Figures 4 and 5, respectively. Although intraobserver accuracy did increase in both radiologists, a statistical difference was not found between the initial and combined assessments; although a trend toward significance was seen in one of the two radiologists. Additional studies with a greater number of experienced radiologists are needed to further elucidate the possible trend toward a significant increase in accuracy when evaluating initial and follow-up abdominal radiographs in dogs and cats with clinical concern for mechanical obstruction due to foreign material.

There are several limitations to this study. First, all of the mechanically obstructed cases recruited in this study were obstructed secondary to a non-radiopaque foreign body and therefore, the foreign bodies were not readily detectable on the radiographic studies. Other causes for mechanical obstruction, such as intussusception, mural masses, and strictures, were not identified in the recruited patient population contributing to laboratory bias; therefore, the results reflected in this study should be taken into context of patients with mechanical obstruction due to occult foreign bodies. The second limitation is the low number of patients included in this study and selection bias for cases in which the clinician was willing to wait for follow-up radiographs to be performed. It was challenging to

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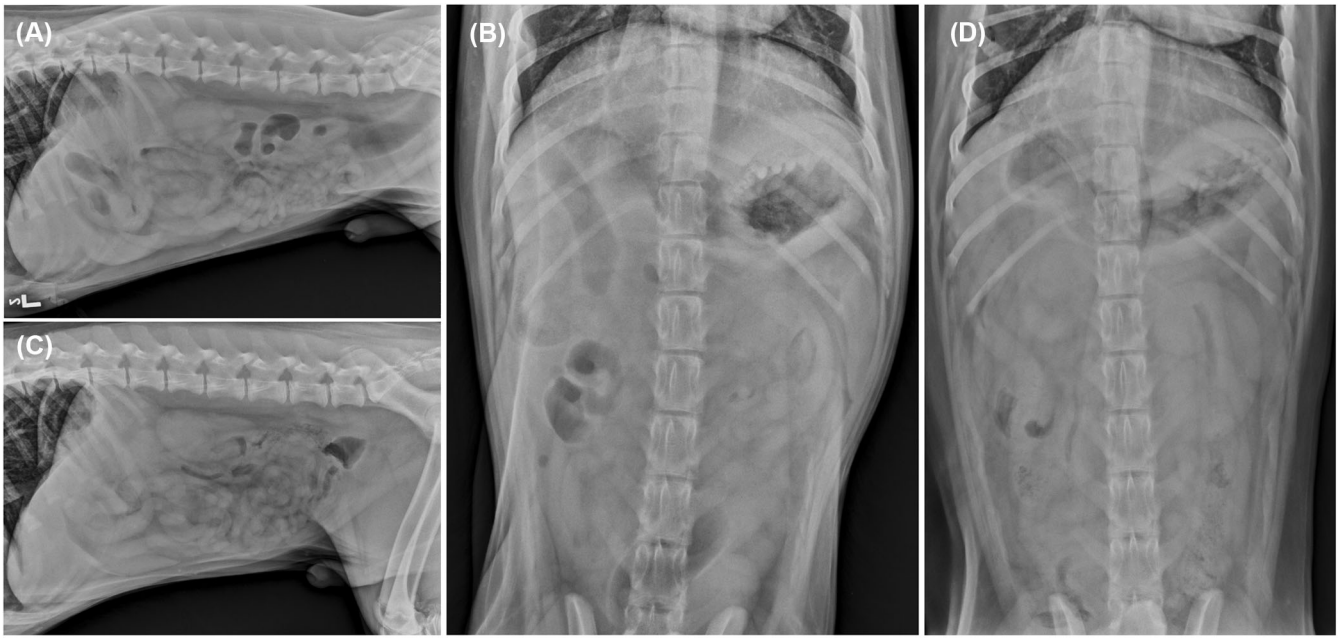



**FIGURE 4** Initial (A, left lateral and B, ventrodorsal) and follow up (C, left lateral and D, ventrodorsal radiographs) of a dog that did not have a mechanical obstruction based on ultrasound findings. On the initial radiographic assessment, three of four reviewers (both radiologists and the radiology resident) provided a false positive diagnosis of probably obstructed (Likert score 4/5) and one of four reviewers (criticalist) reported an unsure diagnosis for the presence or absence of mechanical obstruction (Likert score 3/5). On the combined assessment of this case, the resident and criticalist did not change their diagnosis (Likert score of 4/5 and 3/5, respectively); however, the radiologists changed their diagnosis to not obstructed and probably not obstructed (Likert score of 1/5 and 2/5, respectively)

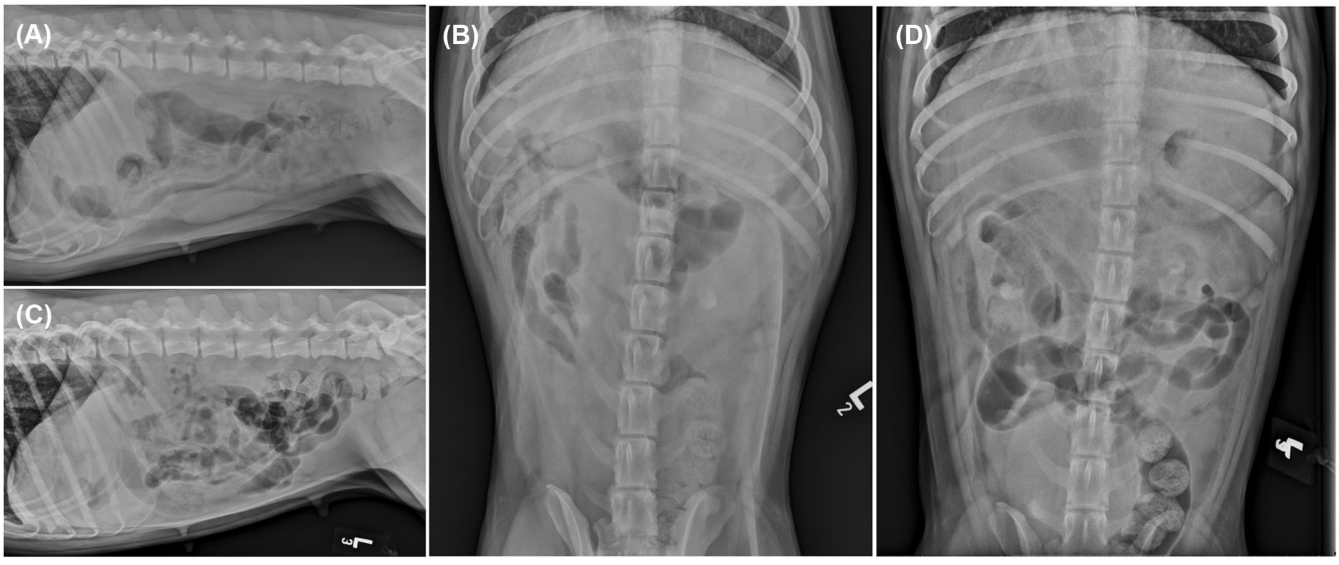



**FIGURE 5** Initial (A, left lateral and B, ventrodorsal) and follow-up (C, left lateral and D, ventrodorsal) radiographs of a dog with a jejunal foreign body and a secondary mechanical obstruction diagnosed with ultrasound. On the initial radiographic assessment, reviewers provided a false negative diagnoses of not obstructed (1 radiologist; Likert score 1/5), probably not obstructed (radiology resident and criticalist; Likert score 2/5), and an unsure diagnosis for the presence or absence of mechanical obstruction (1 radiologist; Likert score 3/5). On the combined assessment of this case, two of four reviewers changed their diagnosis to obstructed (both radiologist; Likert score 5/5), one of four reviewers changed their diagnosis to probably obstructed (criticalist; Likert score 4/5), and one of four reviewers changed to an unsure diagnosis for the presence of absence of mechanical obstruction (radiology resident Likert score 3/5)

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recruit patients as clinicians were more likely to request an abdominal ultrasound in cases with equivocal radiographs since in this hospital setting, ultrasound is readily accessible at all hours of the day, allowing clinicians the ability to get a more timely and accurate diagnosis as opposed to waiting for follow-up radiographs. This may have caused a selection bias toward patients that were more clinically stable or perhaps had a lower clinical concern for mechanical obstruction. There was also selection bias for cases in which a diagnosis of mechanical obstruction or lack of obstruction was inherently more challenging. All initial radiographs were determined to be "equivocal" for the diagnosis of mechanical obstruction by a radiology resident or radiologist as part of the inclusion criteria. Recruited cases also gravitated to having fewer hours between the radiographic studies. Although this study allowed for 7-36 h between radiographic studies, all radiographic study intervals were <28 h with 21 of 57 (36.8%) cases having ≤12 h between studies. This may be in part related to patients being recruited at presentation in the evenings or overnight and then receiving further imaging the following business day. Additionally, a sample size estimate was not generated; therefore, the power of this study may be limited.

In summary, in dogs and cats that presented with a clinical concern for gastrointestinal mechanical obstruction and initial abdominal radiographs were inconclusive for this diagnosis, follow-up abdominal radiographs between 7 and 28 h did not provide a more accurate diagnosis for non-obstruction versus the presence of mechanical obstruction due to occult foreign material regardless of reviewer experience. Based on these results, in dogs and cats that present with similar clinical concern and then have an inconclusive abdominal radiographic diagnosis for mechanical obstruction, other diagnostic options, besides repeating abdominal radiographs, should be considered, such as an abdominal ultrasound. Future studies that include retrospective and multi-institutional data may allow for greater patient numbers which could overcome several limitations of this study. Additionally, future studies could explore how a greater time interval between initial and follow-up abdominal radiographic studies could affect the accuracy of diagnosis.

## LIST OF AUTHOR CONTRIBUTIONS

### Category 1

(a) Conception and Design: Bagshaw, Mai, Suran, Reetz, Elser

(b) Acquisition of Data: Bagshaw, Mai, Suran, Reetz, Elser, Thawley

(c) Analysis and interpretation of Data: Mai, Suran, Elser

### Category 2

(a) Drafting the Article: Elser, Suran

(b) Revising the Article for Intellectual Content: Mai, Suran, Reetz, Elser, Thawley, Bagshaw

### Category 3

(a) Final Approval of the Completed Article: Mai, Suran, Reetz, Elser, Thawley, Bagshaw

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## CONFLICT OF INTEREST DISCLOSURE

Authors had no relevant financial interest, arrangement or affiliation with any company or organization.

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