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Imaging of gastrointestinal foreign body obstructions in dogs and cats

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ABSTRACT

Partial or complete gastrointestinal foreign body (GI-FB) obstruction is a common syndrome in small animals, and prompt diagnosis is essential for appropriate treatment and prognosis. Although previous studies have described radiographic and ultrasonographic features and reported diagnostic performance, the true prevalence of this condition remains controversial. This study aimed to assess the prevalence of GI-FB obstruction and the sensitivity, specificity, and accuracy of radiography and ultrasonography in dogs and cats referred to a single institution over a 20-year period. The dog population included 73 males (5 neutered) and 37 females (15 neutered), with a median age of 3.3 years and a predominance of mixed breeds. The cat population consisted of 14 males (12 neutered) and 15 females (11 neutered), with domestic short-haired cats most represented. The prevalence of GI-FB obstruction was low in both dogs and cats (0.58% and 1%, respectively). In both species, affected animals were significantly younger than the reference population. Male dogs were overrepresented ($p < 0.002$), whereas neutered cats were more frequently affected ($p < 0.03$). Segmental intestinal dilatation was the most common radiographic sign, while ultrasonography most frequently demonstrated direct visualization of the foreign body and intestinal fluid dilatation. These findings support ultrasonography as the primary modality when gastrointestinal foreign body obstruction is suspected, although combining both techniques increased diagnostic sensitivity, specificity, and accuracy. Despite its perceived frequency, gastrointestinal obstruction by foreign bodies showed a low prevalence and was more common in young, male dogs and in young, neutered cats.

1. Introduction

Foreign body ingestion accounts for approximately 80% of all mechanical intestinal obstructions in dogs [1,2]. In addition to foreign body ingestion, mechanical gastrointestinal obstruction can result from intussusception, volvulus, intramural expansive lesions or extramural compressive/constrictive lesions [3]. In cases of gastrointestinal foreign bodies, the degree of obstruction is usually determined by the size and location of the foreign body. Small irregular or linear foreign bodies can cause partial obstruction, whereas complete obstruction may be attributable to large foreign bodies [1]. In both conditions, the main clinical sign is vomiting.

Usually, foreign bodies are classified as discrete (e.g. cloth, corn cobs, bones, rocks, small toys, etc.) and linear (e.g. thread, string, socks, etc.). Linear foreign bodies often produce only partial obstructions but pose a greater risk of intestinal necrosis and perforation [2].

It is well known that the presence of a foreign body in the intestinal lumen can induce a spasm of the wall that activates afferent neurons of both the intrinsic and extrinsic nervous system at the site of the foreign body and of the dilatation of the orad tracts [1,2]. When the spasm at the level of the foreign body and the dilatation of the orad tracts are severe enough to exceed systolic blood pressure, ischemia and, if the condition persists, necrosis and perforation of the affected gastrointestinal wall can occur [1,2]. Other than that, life-threatening complications are fluid, acid-base and electrolyte imbalances, hypovolemia, and toxaemia [1]. It is also demonstrated that chronic gastrointestinal obstruction is associated with increased risks of post-surgical complications [4–6].

Diagnostic imaging techniques are essential for establishing a definitive diagnosis in a vomiting dog or cat, and for determining whether the underlying condition requires surgical or conservative treatment. In the recent past, the only technique available, or at least considered suitable for the purpose, was radiography, which, in negative cases, was followed by an upper gastrointestinal contrast study or by an exploratory laparotomy [7–10]. This resulted in higher costs, longer

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Table 1 –
Reference population, subjects referred for a suspect gastrointestinal foreign body obstruction, true positive, false negative, true negative, false positive cases, and median age of cases referred at the Interdepartmental Veterinary Radiology Center in the period 2005–2025.

			Dogs		Cats	
Ref. pop.	TOTAL	M (NM)	18359	9525 (868)	2895	1482 (1032)
		F (NF)		8834 (3583)		1413 (917)
Susp. GI-FB obstr.	TOTAL	M (NM)	411	241 (11)	78	43 (33)
		F (NF)		170 (62)		35 (26)
True positive	TOTAL	M (NM)	105	68 (5) *	29	14 (12) #
		F (NF)		37(15) *		15 (11) #
False positive	TOTAL	M (NM)	4	2 (0)	-	-
		F (NF)		2 (1)		-
True negative	TOTAL	M (NM)	301	171 (6)	49	29 (21)
		F (NF)		130 (45)		20 (15)
False negative	TOTAL	M (NM)	1	-	-	-
		F (NF)		1 (1)		-
Total ref. pop. median age (min; max)			7 y (2 m; 20 y)		6 y (2 m; 24 y)	
Total true positive + false negative median age (min; max)			3.3 y (2 m; 17 y) ^		2 y (7 m; 12 y) §	

Legend: Ref. pop. = reference population; Susp. GI-FB obstr. = referred subjects with a suspect gastrointestinal foreign body obstruction; * significantly more males than females compared to the reference population ($P < 0.01$); # significantly more neutered cats compared to the reference population ($P < 0.03$); ^ significantly younger subjects compared to the reference population ($P < 0.01$); § significantly younger subjects compared to the reference population ($P < 0.001$).

Table 2 –
Radiographic signs.

	Dogs (n = 68)	Cats (n = 12)
Foreign body visualization	35	4
Gastric dilatation	6	-
Segmental small intestinal dilatation[1, 2]	58	3
Small intestinal plication	-	3
Small intestinal gathering	4	6
Crescent-shape gas bubbles	5	4
Reduced serosal detail	1	2

Legend: 1 = for dogs considering a L5 height/max intestinal diameter ratio > 1.6 (Graham et al., 1998); 2 = for cats considering a L2 height/max intestinal diameter ratio > 2 [28].

Table 3 –
Ultrasonographic signs.

	Dogs (n = 91)	Cats (n = 27)
Foreign body visualization	89	27
Gastric fluid dilatation	26	6
Small intestinal fluid dilatation	81	18
Peristaltic alterations	57	11
Pendular movement of luminal content	68	12
GI tract wall alterations	34	8
Corrugation/plication intestinal walls	27	16
Short intestinal intussusception	3	-
Peritoneal fluid effusion	4	1
Peritoneal fat alterations	3	1
Lymph nodes reactivity	3	1

diagnostic times, and, therefore, greater risks for the patient [11,12]. Ultrasonography, at the beginning of its application, was considered unsuitable for the study of the digestive tract due to its meteoric contents [13,14]. However, thanks to sonographers' increased experience and the technical evolution of devices, ultrasonography has been increasingly used to assess the gastrointestinal tract [12,14–17]. Indeed, ultrasonography permits the simultaneous evaluation of the contents, the gastrointestinal walls, and the peritoneal cavity [16]. Ultrasonography also allows real-time evaluation of peristalsis [12,16,18].

Since the popularity of gastrointestinal foreign body (GI-FB) obstructions, the literature contains many descriptions of either radiographic [19–21]or ultrasonographic [12,22–24]findings. Nevertheless, comprehensive and detailed studies on the true prevalence of GI-FB obstructions and their radiographic and ultrasonographic findings are still controversial. Therefore, this study aimed to assess the prevalence of GI-FB obstructions, the sensitivity, specificity, and accuracy of radiography and ultrasonography, and the related signs in a large sample of dogs and cats from the authors' urban area.

2. Material and methods

A retrospective study was conducted on the database of the Interdepartmental Veterinary Radiology Center (IVRC) of the University of Naples "Federico II" for the period January 2005– December 2025. Inclusion criteria were a radiographic and/or ultrasonographic diagnosis of GI-FB obstruction in client-owned dogs and cats, endoscopically/surgically confirmed or not.

For each radiographic study, left lateral, right lateral, and ventrodorsal projections were obtained, with patients positioned in left lateral, right lateral, and dorsal recumbency, respectively. All examinations were performed using either a computed radiography or direct digital radiography system (Agfa CR-30 and Agfa DR-14e, respectively; Agfa HealthCare, Mortsel, Belgium). Both systems employed the same focused Potter–Bucky grid and a standardized focus-to-film distance of 100 cm, with exposure parameters adjusted according to patient size. Abdominal radiographs encompassed the region extending from the diaphragm cranially to the pelvic inlet caudally. Patients were restrained either manually by owners wearing appropriate lead protection or with the use of positioning aids (e.g., sandbags), depending on patient temperament.

When deemed necessary, positive-contrast studies were performed following survey radiographs. A barium sulfate suspension (Prontobario H.D., 98.45 g, Bracco Imaging Italia, Milano, Italy; reconstituted to obtain a 60% w/w suspension, corresponding to 60 g of barium sulfate per 100 g of suspension) was administered orally at a dose of 8–12 mL/kg body weight for small- and medium-sized dogs, 5–7 mL/kg for large dogs, and 12–20 mL/kg for cats. Whenever possible, patients were allowed to ingest the contrast medium voluntarily; if this was not feasible, the contrast agent was carefully administered into the buccal fold using a syringe, taking care to avoid aspiration. In cases where oesophageal, gastric, or small intestinal perforation was suspected or considered possible, a water-soluble iodinated contrast medium (Gastromiro 61.2% solution, Bracco Imaging Italia, Milan, Italy) was administered at a dose of 10 mL/kg in both dogs and cats instead of barium suspension. Following contrast administration, right lateral and ventrodorsal radiographs were obtained immediately and at 15, 30, 45 and 60 min and at 4 h or until a diagnostic endpoint was reached. [10, 25]

Ultrasonographic examinations were performed with patients physically restrained in dorsal or right and left lateral recumbency, at the discretion of the ultrasonographer. Adequate transducer–skin contact was achieved by clipping the hair over the ventral abdomen and caudal thoracic region, followed by skin preparation with alcohol and application of acoustic coupling gel. Examinations were conducted using one of two ultrasound systems (MyLab Class C Vet or MyLab X9 Vet, Esaote, Genova, Italy), each equipped with multifrequency microconvex and linear array transducers. The gastrointestinal tract was evaluated ultrasonographically using a systematic scanning technique in sagittal and transverse planes. The stomach, pyloroduodenal junction, small

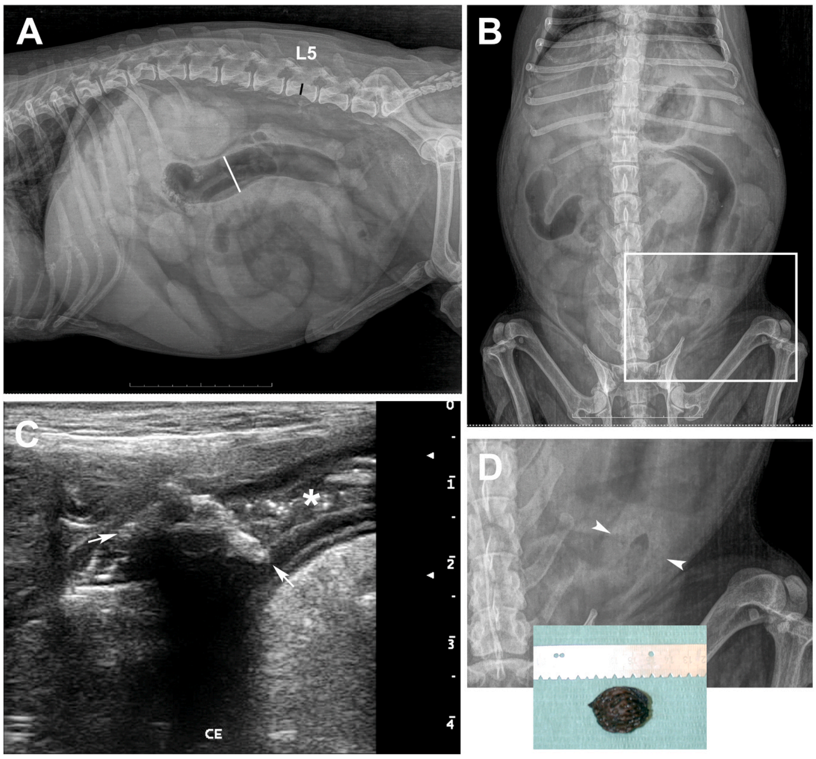

Fig. 1. – Jejunal foreign body in a 13-year-old neutered male Poodle dog. A) Right-Lateral and B) ventro-dorsal views of the abdomen. On the lateral view, there are fluid and gas dilated small intestinal loops a with a ratio between the maximum intestinal diameter (white line) and the height of L5 vertebral body (black line) equal to 3.4. On the ventro-dorsal view, in the left caudal abdomen, highlighted by the white box, a foreign body is visible. C) Ultrasonographic scan of a jejunal loop of the left caudal abdomen: a foreign body with a slightly irregular and convex hyperechoic profile (arrows) and a strong distal acoustic shadowing is visible into the intestinal lumen; note that the lumen orad to the foreign body is fluid-filled (asterisk). D) Closed view of the box in B): the foreign body (arrow heads) has an oval shape with an opaque cortex and a diamond-shaped central region filled by air. This is the typical radiographic appearance of a peach stone (shown in the photo).

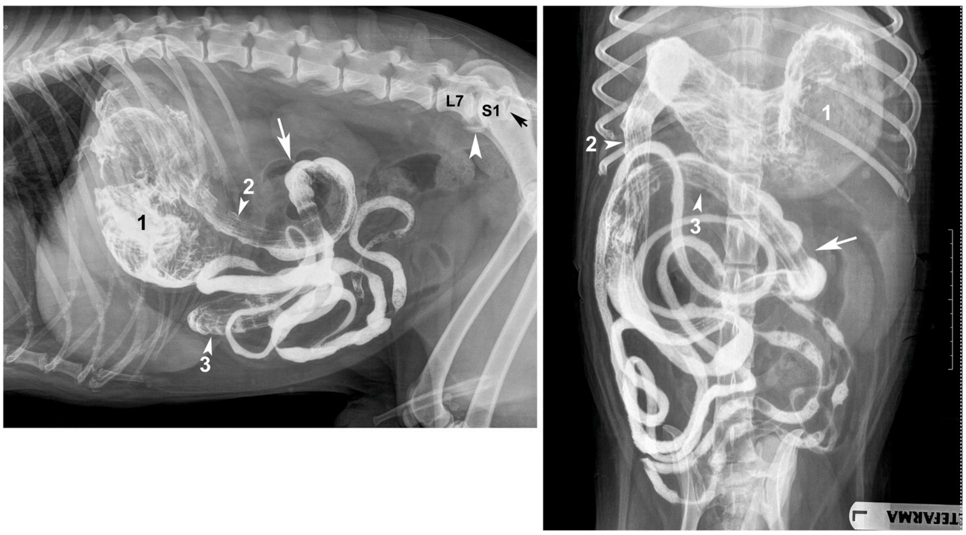

Fig. 2. – Gastric-duodenal-jejunal foreign bodies in a 10-year-old male English setter. A) and B) right-lateral and ventro-dorsal view of the abdomen after an upper gastrointestinal contrast study with barium sulphate suspension. The stomach, the duodenum and the first tract of the jejunum show an irregular emptying (“minus”), irregularly striated, caused by the presence of the foreign bodies (a sock and an underwear). The jejunal tract is partially corrugated, suggesting an initial pleating effect from a linear foreign body (arrow). Given the dog’s age, a lumbo-sacral spondylosis between L7 and S1 (arrowhead) is also visible. As an incidental finding, the first sacral vertebra (S1) is not completely fused with the second (S2) (black arrow). Legend: 1 = stomach; 2 = duodenum; 3 = first tract of jejunum.

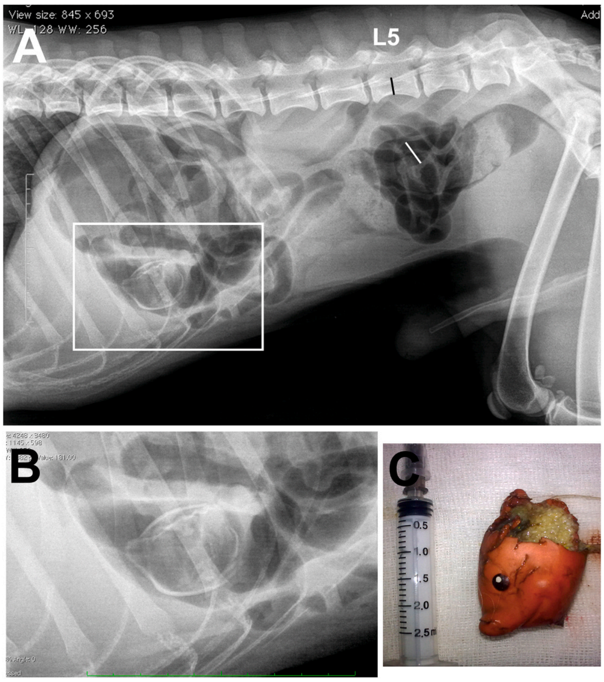

Fig. 3. – Gastric foreign body in a 5-year-old male English setter. A) left-lateral view of the abdomen with a discrete gastrointestinal gas dilatation compatible with a slight functional ileus or enteritis: in this case, the ratio between the maximum intestinal dilatation (white line) and the height of the L5 vertebral body (black line) is equal to 1.5. The box highlighted the antral region. B) Closed view of the box in A: a radiolucent foreign body with opaque profiles and surrounded by the air of the stomach is clearly visible. C) Photo of the foreign body in the stomach (a toy's head).

intestine, and colon were assessed for wall thickness, layering, luminal content, and motility, with probe rotation and repositioning as required to obtain complete visualisation. Particular attention was paid to the identification of intraluminal hyperechoic structures causing intestinal obstruction or sub-obstruction and/or abnormally fluid-distended intestinal loops consistent with a suspected gastrointestinal foreign body obstruction. [26] All examinations were recorded using short video clips and still images.

To assess the sensitivity, specificity, and accuracy of radiographic and/or ultrasonographic diagnosis, the database was also searched for all subjects referred with a clinical suspicion of GI-FB obstruction but diagnosed as negative at imaging and confirmed by clinical outcome or surgery. The species, breed, sex, age, and technique performed (only survey radiography, only ultrasonography, radiography and ultrasonography, or any contrast-enhanced exams) were recorded for all included subjects and descriptive statistics were generated for these variables.

The prevalence of GI-FB obstructions in dogs and cats was calculated by comparing the sample to the population of dogs and cats referred to IVRC during the same period for all kind of problem.

The distribution of the sample's subjects by sex, breed and age was compared with the overall reference population using the χ-squared test. Significance was set for $p < 0.05$. Sensitivity, specificity, and accuracy were obtained by comparing true-positive and true-negative cases with false-positive and false-negative cases.

All images were assessed by one of the authors (L.M.), a radiology professor with over 25 years of experience. The radiographic images were searched for the visualization of the foreign body, the presence of a gastric dilatation, gathering of the small intestinal loops, dilated intestinal loop, accordion-like pleating of small intestine and crescent C-shaped luminal meteoric bubbles; the degree of intestinal dilatation in dogs was assessed by measuring the ratio between the maximum diameter of the small intestine and the height of the L5 vertebral body [27] while in cats measuring the ratio between the maximum intestinal diameter and the height of cranial endplate of L2 [28]. Ultrasonographic images were assessed for the visualization of foreign body, dilatation of the stomach and/or intestinal loops, alterations in peristalsis, intestinal wall corrugation or intussusception, alterations in the gastrointestinal wall echo-structure, peritoneal effusion, lymph node and/or epiploic-mesenterial fat reactions. Finally, the type and localization of foreign bodies were recorded.

3. Results

The sample of subjects diagnosed with GI-FB obstruction consisted of 110 dogs and 29 cats. In the same period, the dogs referred with a suspect GI-FB obstruction were 411, while the cats were 78. In dogs, there were 105 true positive cases, 301 true negative cases, 4 false positive cases (3 functional ileus and 1 jejunal volvulus), and 1 false negative case (diagnosed as functional ileus but with a foreign body obstruction revealed at surgery). In dogs, the prevalence of GI-FB obstructions was 0.58% (106/18,359), while in cats, it was 1% (29/2895) (Table 1). In dogs, radiography and ultrasonography showed a sensitivity, specificity, and accuracy of 99.06%, 98.69%, and 98.78%, respectively. In cats, both imaging techniques showed 100% sensitivity, specificity, and accuracy, with no false-positive or false-negative cases.

The dog's group (true positives+ false negatives) consisted of 68 males (5 neutered) and 38 females (16 neutered); this sex distribution was significantly different from that of the reference population ($p < 0.002$), with more males than females. The cat's group consisted of 14 males (12 neutered) and 15 females (11 neutered), and this distribution was not significantly different from that of the reference population ($p = 0.4$). However, the prevalence of neutered subjects in the sample (23/29, 79%) was significantly higher than that of the reference population (67%) ($p < 0.03$) (Table 1).

The most frequent breed in the dog's group was mixed breed (31/106, 29%), while in the cat's group, most subjects were domestic shorthaired cats (25/29, 86%). Anyway, in both species, no significant differences were observed compared to the reference population of the same period.

The median age of the dog's group was 3.3 years (min. 2 months, max. 17 years); in the cat's group, the median age was 2 years (min. 7 months, max. 12 years); the age of the affected subjects was significantly lower than that of the reference population (dog: median 7 years; min. 1 month, max. 20 years; $p < 0.01$) (cat: median 6 years; min. 2 months, max. 24 years; $p < 0.001$) (Table 1).

Considering the techniques used, in the dog's group, survey radiography was performed on 19 subjects, ultrasonography on 42 subjects, and both survey radiography and ultrasonography on 48 subjects. On one dog, in addition to the survey radiography and ultrasonography, an upper gastrointestinal contrast study with barium sulphate was performed. In the cat's group, survey radiography was performed on 2 subjects, ultrasonography on 17, and both on 10.

Regarding the frequency of the radiographic and ultrasonographic signs, in dogs the most frequent radiographic sign was the segmental intestinal dilatation (58/68, 85%), while the most frequent ultrasonographic signs were the visualization of the foreign body (89/91, 98%) and the intestinal fluid dilatation with pendular movement of the content (81/91, 89%; 68/91, 75%; respectively) (Tables 2 and 3). In cats, the most frequent radiographic sign was the intestinal gathering (6/29, 21%), while the most frequent ultrasonographic signs were the visualization of the foreign body (27/29, 93%), the intestinal fluid dilatation (18/27, 62%) and the intestinal corrugation/plication (16/29, 55%) (Tables 2 and 3).

Considering the type of foreign body, in dogs, there were: 30 linear foreign bodies, in 9 cases represented by a clothes with a linear effect (e.

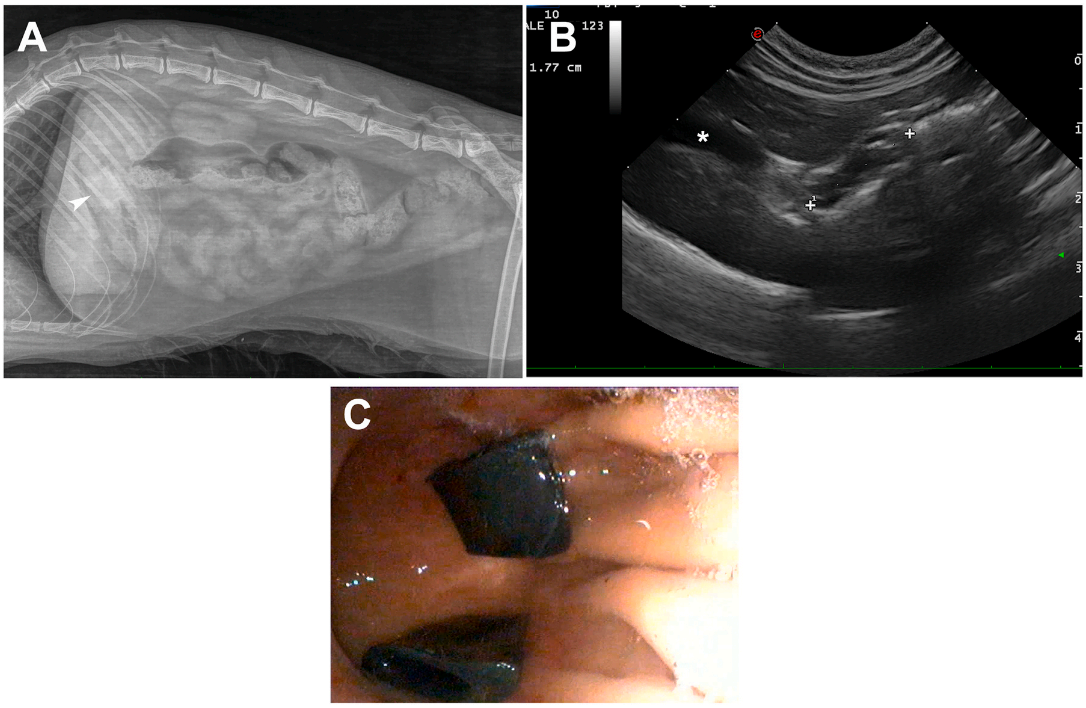

Fig. 4. – Gastric foreign bodies in a 1-year-old neutered female domestic short-haired cat. A) right-lateral view of the abdomen: on the region of the stomach, there is a hardly distinguishable rectangular opacity, possibly compatible with a foreign body. B) Longitudinal ultrasonographic scan of the antrum of the stomach (cranial is on the left): a rectangular hypoechoic foreign body is clearly visible (the diameter within the calipers is 1.77 cm). Cranially to the stomach and the foreign body, the gallbladder (asterisk), surrounded by the liver parenchyma, is visible. C) Endoscopic view of the stomach: two foreign bodies (rubber feet of an electric stove) are visible.

g. socks) and in 3 cases with the sewing needle; 19 vegetable foreign bodies: 14 peach stones, 2 corn cobs, 2 olives and 1 hazelnut; 16 balls; 12 pieces of toys; (including the false negative case); 8 cases of bone fragments; 7 clothes, generally underwear; 3 baby pacifier nipples; 3 skewer sticks; 2 corks; 2 sand agglomerates; 2 erasers; the remaining three cases were earplugs, a bulldog paper clip, and a fishing lead. In cats, there were: 18 linear foreign bodies (in 2 cases with a sewing needle); 4 trichobezoars; 3 balls; and, in the last four cases, an olive stone, a rubber cylinder, a rubber stopper, and the rubber feet of an electric stove.

Finally, regarding the localization, in dogs, 31 foreign bodies were found in the stomach, 6 in the stomach and duodenal tract, 9 in the stomach, duodenal and jejunal tract, 8 in the duodenum, 15 in the duodenal and jejunal tract, 32 in the jejunum, 2 in the ileo-colic valve (including the false negative case). In cats, the localization of foreign bodies was: 4 into the stomach; 1 into the stomach and duodenal tract; 8 into the stomach, duodenal and jejunal tract; 1 into the duodenum; 9 into the duodenal and jejunal tract; 4 into the jejunum; 2 at the ileo-colic valve. The linear foreign bodies were localized in more than one tract.

4. Discussion

Gastrointestinal mechanical obstructions secondary to foreign body ingestion are a typical example of an acute abdominal condition in which a successful surgical outcome depends on early diagnosis. Foreign body ingestion-related obstructions are considered relatively common in vomiting animals [5,21,29]. However, despite several reports on large samples, the prevalence of gastrointestinal foreign bodies was reported only for the dogs and never for the cats [29–31] with values ranging between 0.49% and 0.62%. Recently, an online journal that describes the caseload of a USA private clinic network [32] reported a prevalence of 11% in dogs and 3,2% in cats. Our results highlighted a lower prevalence, 0.58% in dogs and 1% in cats. However, the prevalence in dogs was similar to previous studies [29–31], but, surprisingly, the higher prevalence in cats was in contrast with what has been reported [1]. In one study, the lower frequency of GI-FB obstructions in cats was, albeit hypothetically, justified by the smaller number of cats compared to dogs [12]. The prevalence of GI-FB obstructions found in our sample could be linked to specific characteristics that were not clearly identifiable, given that the population to which our sample belonged was sufficiently large and distributed over 20 years. Obviously, larger samples could yield different results, although this type of statistical analysis would be better conducted on a multicentric study.

Among the dogs in our sample, males outnumber females, which may suggest a greater propensity for foreign bodies ingestion or increased exposure to risk factors. The underlying reason for this distribution remains unclear. One could hypothesise that males are much more curious and enterprising than females. Also, although all animals were client-owned, when not under direct owner control, they may still have access, both outdoors and within the domestic environment, to ingest garbage or inappropriate materials (i.e., dietary indiscretion), potentially increasing the risk of gastrointestinal mechanical obstruction. In our sample of cats, the sex distribution was not different compared to that of the reference population, but neutered subjects were more numerous than in the overall reference population. This could suggest that the domestic environment, in which most neutered cats live, exposes them to a greater risk of ingesting foreign bodies. Indeed, most of the foreign bodies found in our sample consisted of common sewing thread, sometimes with the needle. No differences were found between the breeds of dogs and cats in our sample and those in the reference population. Indeed, the greater prevalence of some breeds reflects their relative abundance among the dogs and cats in our geographical area.

In dogs, age appears to be a risk factor, as the median age in the sample (3.3 years) was significantly lower than that of the reference

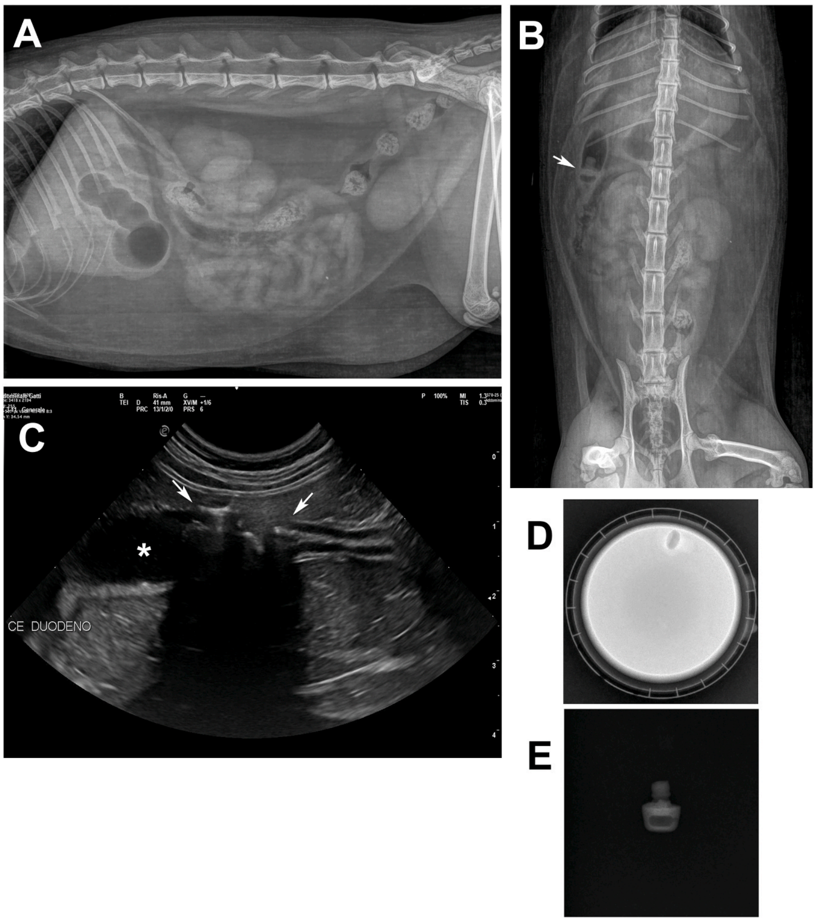

Fig. 5. – Duodenal foreign body in a 2-year-old neutered female Siberian cat. A) Left-lateral and B) ventro-dorsal views of the abdomen: on the lateral view, no foreign bodies are visible except a slight meteoric dilatation of the antral region of the stomach and of the proximal duodenum, while, on the ventro-dorsal view, a small foreign body, partially surrounded by air, is visible (arrow) in the lumen of the proximal duodenum. C) Longitudinal ultrasonographic scan of the duodenum (cranial is on the left): a foreign body with an irregular hyperechoic profile and a strong distal acoustic shadowing is visible inside the lumen of the duodenum (arrows). Note that, cranially, the lumen is fluid-filled (asterisk) instead of the caudal tract that has a regular mucous pattern. The foreign body, a rubber cap, radiographed in the water (D) and in the air (E): it is possible to note that when surrounded by the water, the foreign body is not easily detectable.

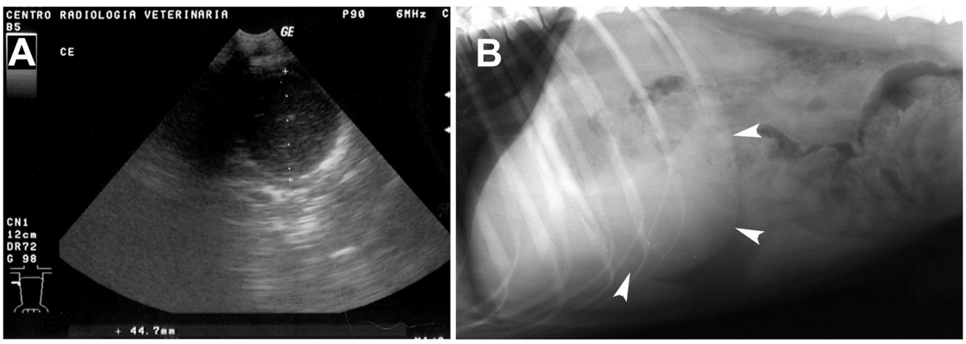

Fig. 6. – Gastric foreign body in a 1.5-year-old male Golden retriever. A) Longitudinal ultrasonographic scan of the antrum (cranial is on the left), a spheroidal foreign body (a solid rubber ball) is visible with the measured diameter within calipers. B) right-lateral view of the abdomen of the same dog: the antral region of the stomach is dilated by fluid (arrows), and no foreign body is visible.

population [4,5]. This finding is consistent with the common belief that puppies, driven by curiosity, are more likely to ingest a wide variety of objects [29]. However, even adult dogs can ingest a foreign body (in our sample, 50/106 subjects were over 4 years old), sometimes due to hunger, sometimes due to pica, or because they are attracted to the smell of food or to traces of it on the foreign body [33]. This means that in an adult vomiting dog, a GI-FB obstruction should not be ruled out a priori. Also, the cats in our sample had a median age significantly lower than that of the reference population, consistent with previously reported findings [19].

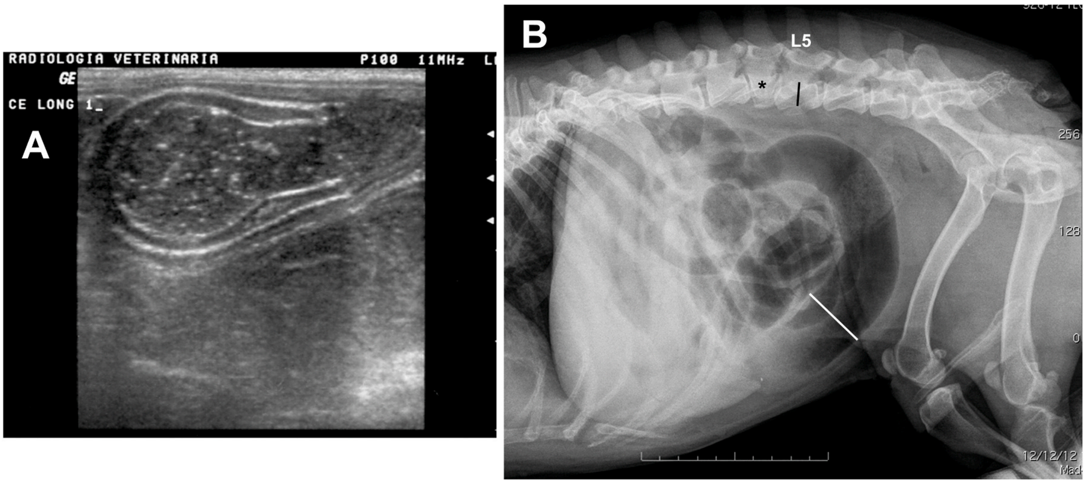

Fig. 7. – Jejunal foreign body in a 3-year-old male French bulldog. A) Ultrasonographic scan of a baby pacifier nipple inside a jejunal loop: the shape of the foreign body is easily recognised, and it is also evident that it is fluid-filled. B) right-lateral view of the abdomen of the same dog: except for the meteoric dilatation of jejunal loops - ratio between the maximum intestinal diameter (white line) and the height of L5 vertebral body (black line) is equal to 2.8 - the foreign body is not visible. The black asterisk marks the L4 vertebral body with a congenital malformation (hemivertebra). This type of malformation is very common in this breed.

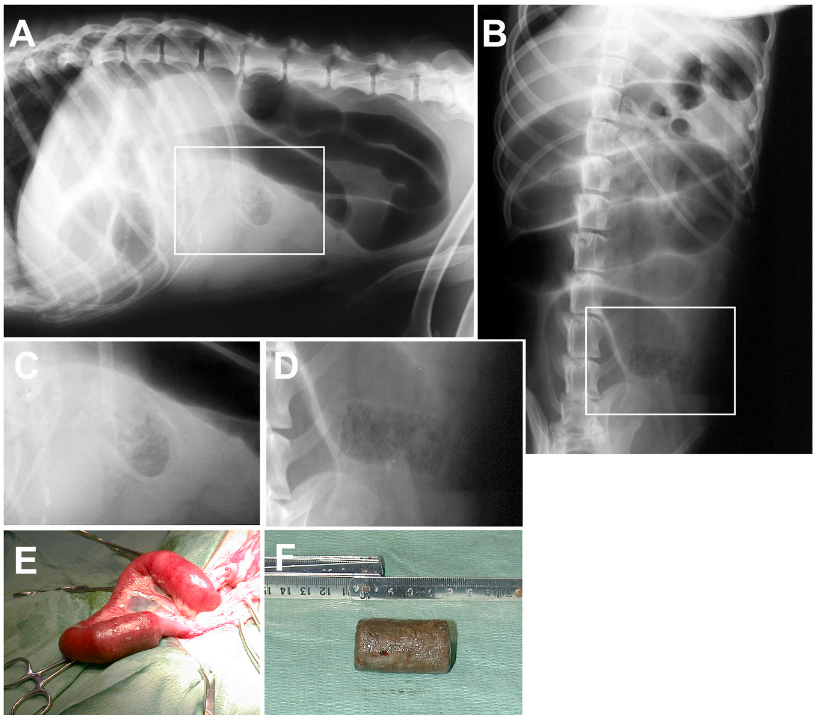

Fig. 8. – Jejunal foreign body in an old adult male Breton spaniel without a history (stray dog). A) right-lateral and B) ventro-dorsal views of the abdomen. C) Closed view of the box in A. D) Closed view of the box in B. E) Intraoperative aspect of the intestinal obstruction. F) Photo of the foreign body (a cork). In this dog, ultrasonography failed to identify the foreign body due to marked meteoric dilatation of the small intestinal loops. Radiographically, the foreign body, owing to its relative radiolucency, is clearly visible and, with the two orthogonal views, its shape and nature can be determined.

In our study, the two techniques used, radiography and ultrasonography of the abdomen, were performed on the same subjects in most cases. In humans, non-enhanced helical CT is considered the best technique for the acute abdomen [34,35]. Despite a few reports suggesting the same in small animals [36,37], survey radiography and B-mode ultrasonography are the most commonly used techniques. This is primarily due to higher costs, lower availability, and the frequent need for general anaesthesia during CT in most veterinary practices [38]. Recently, awake and minimally sedated CE-MDCT protocols have been used safely and successfully to evaluate canine and feline patients with acute abdomen [36]. However, the same authors acknowledge a significant reduction in image quality due to animal movements and breathing during the study. In another study performed on sedated or anaesthetised dogs [37], CT was found to be more accurate and faster than ultrasonography. However, only the time required to perform the study was considered, while the time needed for evaluation was not

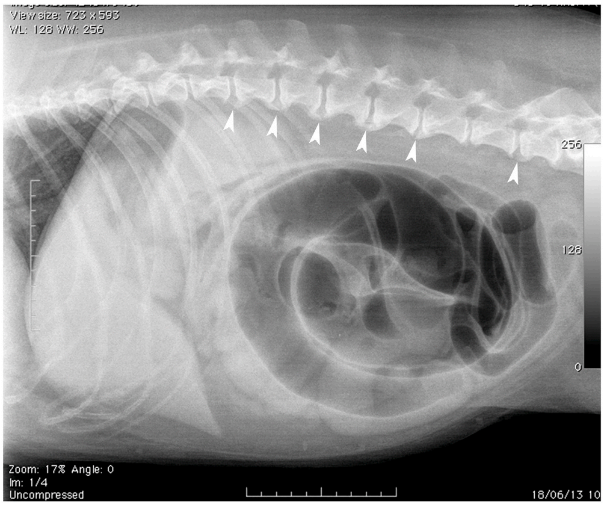

Fig. 9. – False negative case in an 11-year-old neutered female Labrador retriever. Right-lateral view of the abdomen. A marked and generalised meteoric and fluid dilatation of the small intestinal loops is visible. Despite the dilation exceeding the upper limit proposed by Graham et al. [25], given its generalised nature, it was erroneously diagnosed as a functional ileus. Since the dog is old, multiple foci of spondylosis deformans are present (arrowheads); this finding is quite common in large adult and older dogs.

included. On the other hand, another study revealed no substantial differences between radiography and CT in differentiating acute abdomen for treatment with or without a surgical approach [39]. Anyway, in our experience, ultrasonography and radiography showed a very high sensitivity, specificity and accuracy, especially in cats, and, nevertheless, we did not consider the two techniques separately, ultrasonography appeared to be more sensitive and specific than radiography in diagnosing GI-FB obstructions both directly, considering the percentage of visualization of the foreign bodies and of the dynamic alterations of gastrointestinal tract as previously reported [11,17,18], and indirectly, considering that two of the false positive cases in dogs had only a survey abdominal radiography. Therefore, at our institution, as already suggested [16], in cases referred for suspected GI-FB obstruction, the diagnostic pathway always includes ultrasonography as a first-line technique, possibly followed by a survey radiograph that can provide more information about the nature of the foreign body (Fig. 1). However, it must be remembered that the potential of ultrasonography is highly related to the experience of the observer [40] and to the meteoric condition of the gastrointestinal tract. At the moment, the need for an upper gastrointestinal contrast study is rare, and in our sample, it was performed in only one dog (Fig. 2).

As regards the detectable signs, radiographic examination confirms, as already reported in previous studies, its low sensitivity: in fact, the foreign body is not always visible (in dogs 35/68, 51%; in cats 4/12, 33%) and indirect signs of ileus (dilatation, gathering of intestinal loops, etc.) are not always present (Table 2), and, when the foreign body is not detectable, those signs can be referred also to other causes of gastrointestinal obstruction like intussusception, neoplasia, adhesions, and stricture [12]. It also notes that more recent studies have shown that the ratio of the maximum intestinal luminal diameter to the height of the L5 vertebral body (>1.6, proposed by Graham et al. [25]) has very low sensitivity and specificity [3,17,41]. The visibility of the GI-FB depends mainly on its radiopacity or radiolucency relative to the surrounding tissues and obviously on the object's shape (Figs. 3–6) [42]. Conversely, ultrasonography appears to be much more sensitive: in our sample, the foreign body was directly visualised in 89/91 (98%). The ultrasonographic appearance of foreign bodies is strictly related to the acoustic characteristics of their surfaces and of the medium they are made of [22,23] (Fig. 7). In the two cases in which ultrasonography did not allow direct visualization of the foreign body, one was correctly diagnosed as a GI-FB obstruction, since the foreign body (a cork) was visible radiographically (Fig. 8). The other one, due to generalised intestinal fluid and gaseous dilatation associated with pendular peristaltic activity, was incorrectly diagnosed as a functional ileus (Fig. 9). The fluid dilatation and pendular peristaltic activity are considered specific, although not pathognomonic, for gastrointestinal obstruction [18,43]. The fluid dilatation and pendular movement are present in 81/91 (89%) and 68/91 (75%) cases in dogs, and in 18/27 (67%) and 12/27 (44%) cases in cats (Table 3).

Linear foreign bodies need a separate discussion since their initial clinical signs are not specific, which makes diagnosis difficult and may result in a delay of treatment that can lead to severe lesions to the gastrointestinal tract, such as perforation and peritonitis (Figs. 10 and 11) [6,19,44,45]. Linear foreign bodies are common in both dogs and cats, but in the latter, according to the literature, they are the most common type [1,12,19,22,44]. In our sample, we observed radiographic evidence of a linear foreign body, i.e., small bowel gathering/plication, crescent C-shaped meteoric bubbles, and reduced serosal detail in only a few cases, both in dogs and cats, and this result agrees with what has been reported (Figs. 10–13) [9,20]. Ultrasonographically, in all cases of GI-FB obstruction due to a linear foreign body, the foreign body and the corrugation/plication ("accordion loops"), sometimes associated with inversions very similar to short intussusceptions, were easily detected

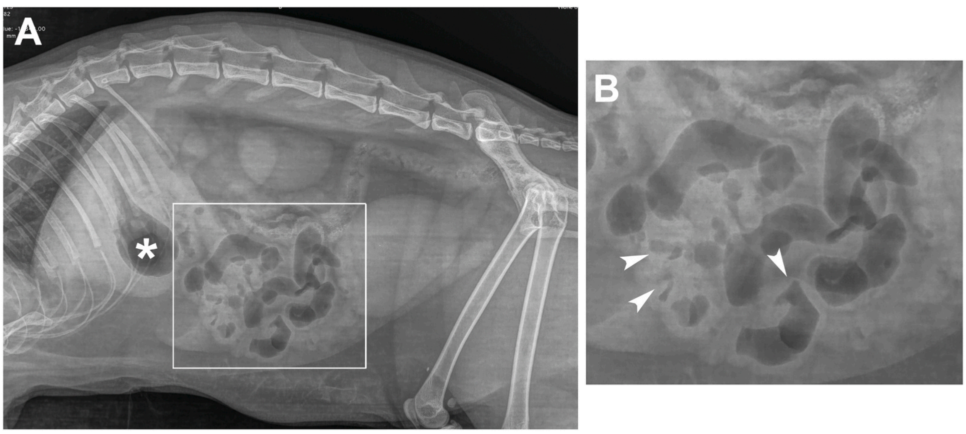

Fig. 10. – Linear foreign body in a 1-year-old neutered male domestic short-haired cat. A) Left-lateral view of the abdomen. The small intestine (box) is gathered and plicated, and the antrum of the stomach is dilated by air (asterisk). B) Closed view of the box in A: many irregular crescent C-shaped bubbles are visible.

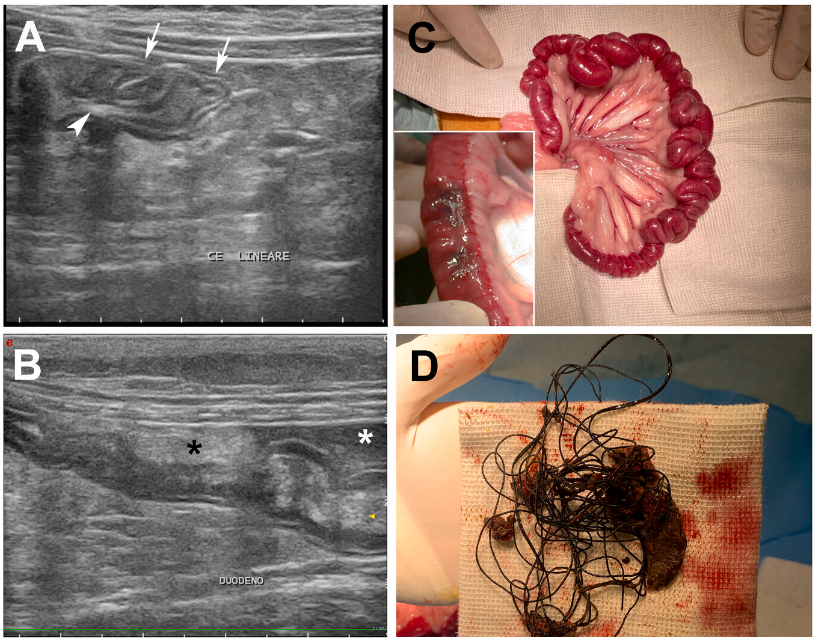

Fig. 11. Same cat as in Fig. 10. A) Longitudinal ultrasonographic scan of a severely pleated (“accordion loops”) jejunal tract (arrows), with a visible short tract of the linear foreign body (arrowhead) inside it. B) Longitudinal ultrasonographic scan of the duodenum (cranial is on the left): other than the corrugation of the duodenal walls, a hyperechoic mesenteric fat (black asterisk) and a small hypoechoic free peritoneal fluid effusion pocket (white asterisk) are visible. C) Intraoperative aspect of the pleated (“accordion loops”) and inflamed jejunal tract; in the box, a closed view of a jejunal tract with necrotic lesions. D) Photo of the foreign body: a fishing line.

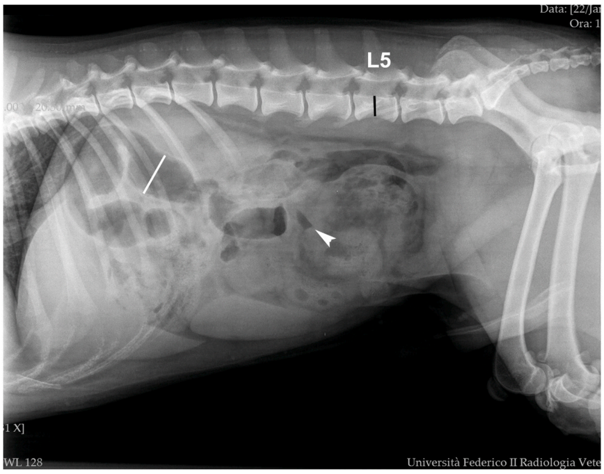

Fig. 12. – Linear foreign body in a 1-year-old male Bull terrier. Latero-lateral view of the abdomen: a segmental intestinal dilatation - ratio between the maximum intestinal diameter (white line) and the height of L5 vertebral body (black line) is equal to 2.2, and a crescent C-shaped gas bubble (arrowhead) is visible.

(Fig. 13). Furthermore, given that the diagnosis of GI-FB caused by linear foreign bodies is usually delayed, intestinal wall damage is often present, associated with lymph node, mesenterial, and epiploic reactions, and small, usually compartmentalized, peritoneal effusions (Fig. 11) [12].

Some foreign bodies, because of their shape (needles or steaks) or their chronicity (linear and discrete foreign bodies), can cause perforation of the gastrointestinal wall, leading to peritonitis, fluid effusion, and pneumoperitoneum (Fig. 14). Despite survey radiography being considered superior to ultrasonography in detecting pneumoperitoneum, ultrasonography is definitively superior in visualising other signs, such as small peritoneal effusion, peritoneal and mesenteric fat inflammation and necrosis, gastrointestinal wall alterations, and related lymph nodes reactivity (Fig. 11) [34–46].

Obstruction by bezoars, especially those composed of hair (trichobezoars), is a quite unique circumstance in the feline patient due to the excessive accumulation of hair ingested during grooming, a characteristic of this species [44]. Predisposing factors are considered long-hair coat, ageing, flea allergy dermatitis, inflammatory bowel disease, and ingestion of nondigestible plant material [47]. In dogs, phytobezoars (vegetable conglomerates) are more often seen [48,44]. In our sample, no bezoars were found in dogs, whereas in cats, 4 cases were identified, all of which were older than 8 years.

In conclusion, based on our sample of dogs and cats, it can be stated that GI-FB obstructions, contrary to common assumptions, are not as frequent, at least not as believed in our geographical area. Radiography, when it does not allow direct visualization of the foreign body, is poorly sensitive and specific. Ultrasonography is almost always able to visualize the foreign body directly and provides several other signs that can be considered specific for GI-FB obstruction. Therefore, in cases of suspected GI-FB obstruction in dogs and cats, abdominal ultrasonography should be considered the first-line technique; survey abdominal radiography may be used as a complementary exam to confirm ultrasonography or to better characterise the foreign body. CT or upper gastrointestinal contrast study should be used only when the two previous techniques have not given a definitive diagnosis.

Ethical approval

In this retrospective study, all procedures were performed at the Interdepartmental Veterinary Radiology Center, Department of Veterinary Medicine and Animal Productions, University of Naples “Federico II”, Italy solely for patients benefit and for standard diagnostic purposes. Previous informed written consent was obtained from all dog owners.

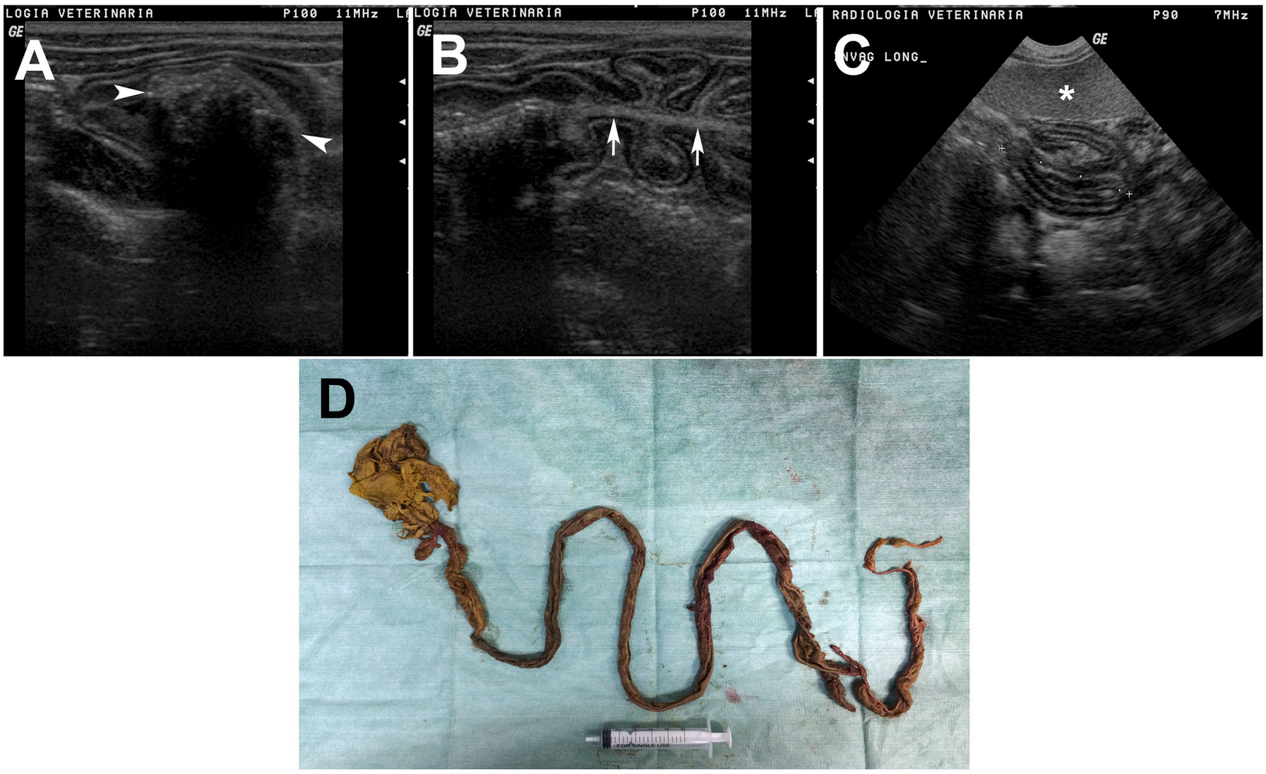

Fig. 13. – Same dog as in Fig. 12. A) Transversal ultrasonographic scan of the antrum: an amorphous hyperechoic foreign body with a shadowing is visible (arrowheads). B) Longitudinal ultrasonographic scan of a severely pleated (“accordion loops”) jejunal tract, and inside it, a linear foreign body (arrows) is visible (cranial is on the left). C) Ultrasonographic scan of a short jejunal intussusception (the length within the calipers is 3.2 cm) located dorsally to the spleen (asterisk). D) Photo of the foreign body (a sausage string): the largest portion on the left was in the antrum.

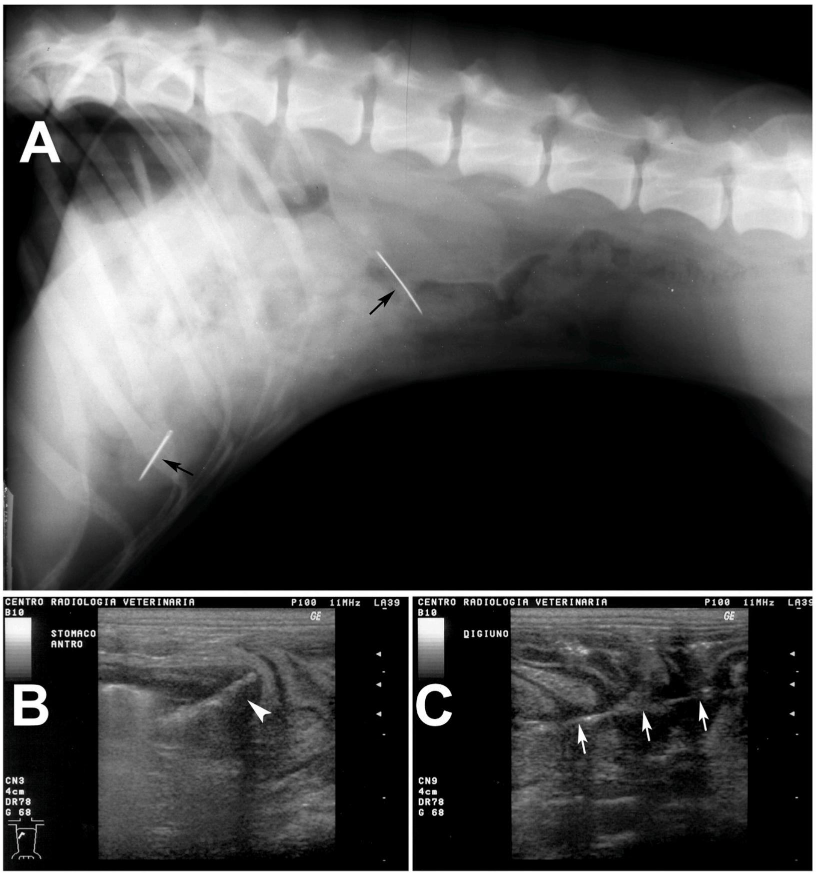

Fig. 14. – Penetrating and linear foreign bodies in a 4-year-old male Rottweiler. A) right-lateral view of the abdomen: two sewing needles are visible (arrows): the cranial one, on the region of the antrum; the caudal one, on the central abdomen. B) Transversal ultrasonographic scan of the antrum (cranial is on the left): a linear hyperechoic foreign body (the cranial sewing needle) is penetrating the wall of the antrum (arrowhead). C) Longitudinal ultrasonographic scan of a severely pleated ("accordion loops") jejunal tract, and inside it, a linear foreign body (arrows) is visible.

All the procedures performed complied with the European legislation "on the protection of animals used for scientific purposes" (Directive 2010/63/EU) and with the ethical requirement of the Italian law (Decreto Legislativo 04/03/2014, n. 26).

CRediT authorship contribution statement

Camilla Sangiuliano: Writing – review & editing, Visualization, Resources, Investigation. **Arianna Del Treste:** Writing – review & editing, Visualization, Resources, Investigation. **Nicole Damiano:** Writing – review & editing, Visualization, Resources, Investigation, Data curation. **Micheletino Matarazzo:** Writing – review & editing, Visualization, Investigation. **Adelaide Greco:** Writing – review & editing, Validation, Resources, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Dario Costanza:** Writing – review & editing, Visualization, Validation, Software, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Leonardo Meomartino:** Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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