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Reliability of Two Dimensional B-mode Ultrasonographic Imaging for the Detection of Intra-Abdominal Pathologies in Dogs

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ABSTRACT

The study was conducted to understand the overall usefulness and to assess the efficacy of two dimensional B-mode ultrasonography in the diagnosis of clinical and intra-abdominal pathological conditions in dogs. The medical records of all the dogs referred for or presented with clinical signs related to intra-abdominal pathological conditions were retrospectively analyzed. The cases where an ultrasonographic diagnosis was made using a real time two dimensional B-mode scanner with 3.5 MHz convex transducer and a definitive diagnosis was later obtained using either invasive and/or minimally invasive alternative diagnostic techniques were selected for the study. In those cases where a confirmatory diagnosis could be achieved through the alternative diagnostic techniques, the results obtained were compared with the ultrasonographic findings to assess the efficacy, accuracy and reliability of ultrasonographic diagnosis. Among 348 dogs suspected of intra-abdominal pathologies, 236 dogs were diagnosed positive and 112 were diagnosed negative. Among the 236 cases diagnosed positive for intra-abdominal pathologies by ultrasound, 233 cases were found to be true positive and three were false positive. Among the 112 cases diagnosed negative for abdominal pathologies, 102 cases were true negative and 10 cases were found to be false negative using alternative techniques. The sensitivity, specificity, positive predictive value, negative predictive value and accuracy of ultrasonography in the diagnosis of intra-abdominal pathologies were estimated as 95.88%, 97.14%, 98.73%, 91.07% and 96.26% respectively. The findings suggested that ultrasonography could be used as a reliable tool for the diagnosis of intra-abdominal pathological conditions in dogs.

HIGHLIGHTS

- The two dimensional B-mode ultrasonography was found to be a reliable tool for the diagnosis of intra-abdominal pathological conditions in dogs.
- The sensitivity and specificity of two dimensional B-mode ultrasonography were 95.88% and 97.14% respectively.

Keywords: Two dimensional, B-mode, ultrasonography, intra-abdominal, pathology

Ultrasonography has evolved as a useful tool for the examination of vital structures and the diagnosis of many disease conditions in animals. The dogs presented with the chief complaint of vomiting, abdominal distention or any other clinical signs related to intra-abdominal pathological conditions are often subjected to imaging of entire abdomen (Leib *et al*., 2010). Being non-invasive, B-mode ultrasonography has been widely employed for the detection of various intra-abdominal pathologies and

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was helpful in identifying the type of intra-abdominal masses like cysts, tumors, abscesses and foreign bodies (Ballegeer *et al*., 2007; Aras *et al*., 2010; Patsikas *et al*., 2014). Many researchers have studied the utility of two dimensional B-mode ultrasonography in diagnosing the conditions involving a specific organ or an organ system (Sharma *et al*., 2011; Cridge *et al*., 2020) or a specific type of condition involving any organ such as neoplasia (Book *et al*., 2011). Few literatures on the efficacy of ultrasonography in the diagnosis of certain diseases in veterinary practice in comparison with radiography, computed tomography and magnetic resonance imaging are also available (Sharma *et al*., 2011; Fields *et al*., 2012; Shanaman *et al*., 2013; Anderson *et al*., 2015). However, literatures on the overall usefulness of ultrasonography in identifying a wide range of abdominal pathologies are scarce. The present retrospective study was performed to evaluate the efficacy, reliability and accuracy of the two dimensional B-mode ultrasonography in the diagnosis of a wide range of abdominal pathological conditions rather than focussing on a specific organ or organ system.

MATERIALS AND METHODS

Selection criteria

The medical records of all the dogs referred for or presented at the District Veterinary Centre, Kannur, Kerala, India during the period from January 2020 to December 2021 with clinical signs related to any kind of intra-abdominal pathological conditions was retrospectively analyzed. The cases where an ultrasonographic diagnosis was made using a real time B-mode scanner (Mindray Biomedical Electronics Co. Ltd. Shenzhen, China) with 3.5 - MHz convex transducer and a definitive diagnosis was later made using alternative diagnostic techniques were selected for the study.

Ultrasonographic diagnosis of abdominal pathologies

In all the cases, the longitudinal and transverse slices of the abdominal organs were visualised. The compact organs like liver, spleen, kidneys, prostrate and abdominal lymph nodes were examined for non-uniform echogenicities of parenchyma, differences in comparative echogenicity, abnormal acoustic enhancement or shadowing, increase or decrease in size and distinctness of demarcation between different structures within the organ. Hollow organs like stomach, intestines, gall bladder, urinary bladder and uterus were examined for increased or decreased wall thickness, luminal contents, intra-mural masses and intra-luminal masses. In all the cases, the ultrasonographic examination was performed by the same veterinarian.

Alternative diagnostic techniques

The alternative diagnostic techniques used to obtain a definitive diagnosis were either invasive and/or minimally invasive which included radiography, fine needle aspiration cytology (FNAC), haemato-biochemical analysis, urinalysis, histopathology, exploratory laparotomy and direct visualisation of affected site during surgery. Post-mortem examination was done in case of death or humane euthanasia to reach at a confirmatory diagnosis.

Assessment of efficacy, reliability and accuracy

In those cases where a confirmatory diagnosis could be achieved through the alternative diagnostic techniques, the results obtained were compared with the ultrasonographic findings to assess the reliability of ultrasonographic diagnosis. By means of a contingency 2 × 2 table, the sensitivity and specificity was calculated (Parikh *et al*., 2008) to determine the efficacy of ultrasonography by using the equations, Sensitivity = 100 × [True positive / (True positive + False negative)] and Specificity = 100 × [True negative / (True negative + False positive)]. The positive predictive value (PPV) and the negative predictive value (NPV) were also calculated (Parikh *et al*., 2008) to determine the reliability of test using the equations, PPV = 100 × [True positive / Test positive] and NPV = 100 × [True negative / Test negative]. To determine the correctness in ultrasonographic diagnosis of intra-abdominal masses, the accuracy of ultrasonography (Parikh *et al*., 2008) was calculated by using the equation, Accuracy = 100 × [True positive + True negative] / [Test positive + Test negative].

RESULTS AND DISCUSSION

Among 348 dogs that underwent ultrasonography, 236 dogs were diagnosed positive and 112 were diagnosed negative for various types of intra-abdominal pathological conditions. The abdominal pathologies detected by

ultrasonography were associated with the uterus (54), urinary bladder (48), intestines (48), kidneys (44), spleen (32), lymph nodes (4), urethra (4) and testicles (2). The various pathological conditions associated with the organs were identified as pyometra (Fig. 1A and 1B), uterine mass (Fig. 1C, 1D and 1E), cystic calculi (Fig. 1F and 1G), cystitis (Fig. 1H, 1I and 1J), urinary bladder mass (Fig. 1K and 1L), gastro-intestinal foreign body (Fig. 2A, 2B, 2C and 2D), intussusception (Fig. 2E and 2F), fecolith (Fig. 2G and 2H), chronic kidney disease, splenomegaly (Fig 3A), splenic mass (Fig. 3B, 3C and 3D), lymphomatous lymph nodes (Fig. 3E and 3F), urethral calculi and retained testicle (Fig. 3G and 3H) respectively. Among the 236 cases diagnosed to have intra-abdominal pathologies by ultrasonography, 233 cases were found true positive and three cases were found false positive by alternative diagnostic techniques. The falsely diagnosed cases included three cases of fecolith misinterpreted as gastro-intestinal foreign body. Among 112 cases diagnosed negative for any intra-abdominal pathological conditions by ultrasonography, 102 were true negative and 10 cases were confirmed to be false negative. This included 8 cases of chronic kidney disease and one case each of intestinal foreign body and urethral calculi. The different

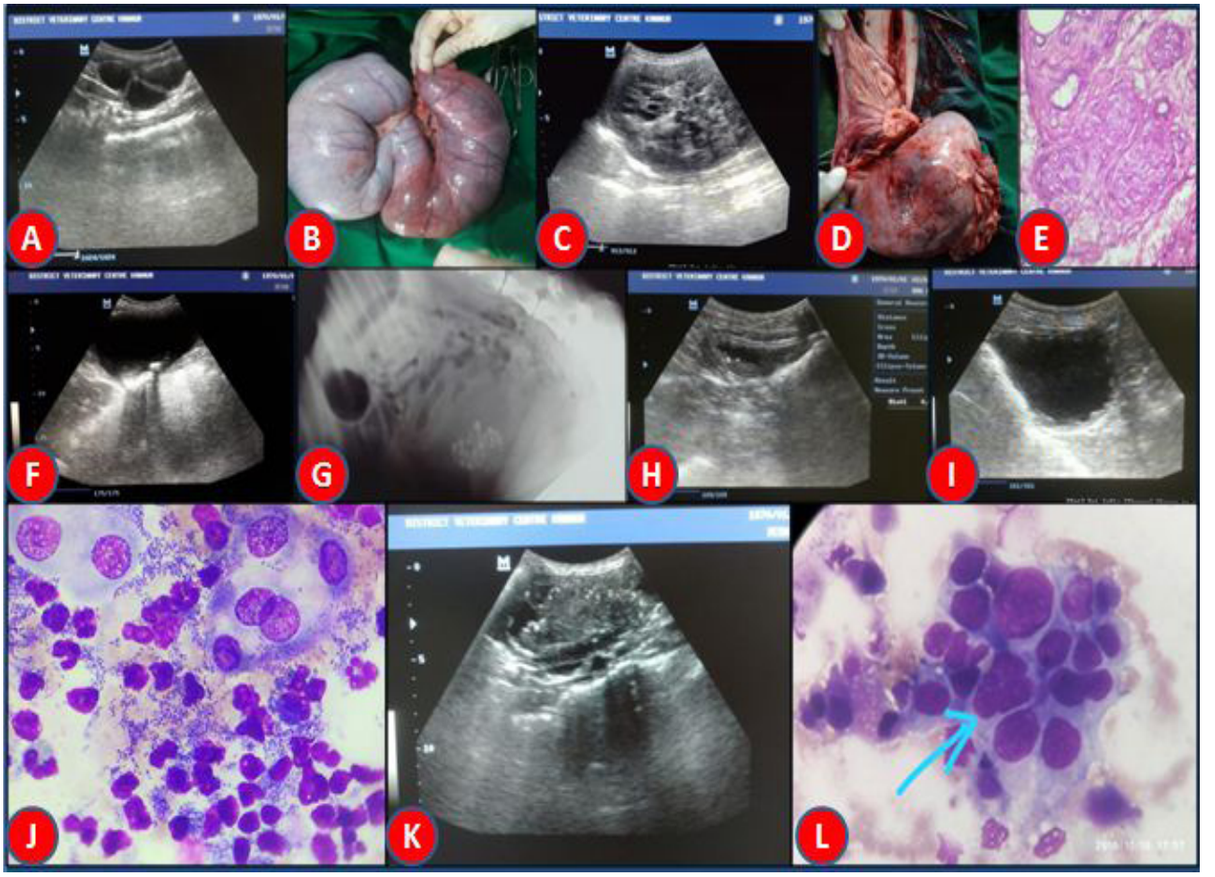

Fig. 1: Anechoic sacculations dorsal to urinary bladder in a dog with pyometra **(A)** confirmed during laparotomy **(B)**; Complex mass with mixed echogenicity dorsal to the urinary bladder **(C)** in a dog with uterine leiomyoma **(D)** confirmed by histopathological examination **(E)** Cystic calculi seen as focal echogenicities with distal shadowing **(F)** confirmed by radiography **(G)** Thickened non-distended bladder wall >3 mm **(H)** and blood clots seen as hyperechoic non-shadowing echogenicities adherent to the wall **(I)** in cystitis. The cytological evaluation confirmed it as bacterial cystitis **(J)**; Irregular echogenic mass extending into the bladder lumen **(K)** in a dog with transitional cell carcinoma. The presence of neoplastic cells in urine smear **(L)** and histoplathological examination confirmed the diagnosis

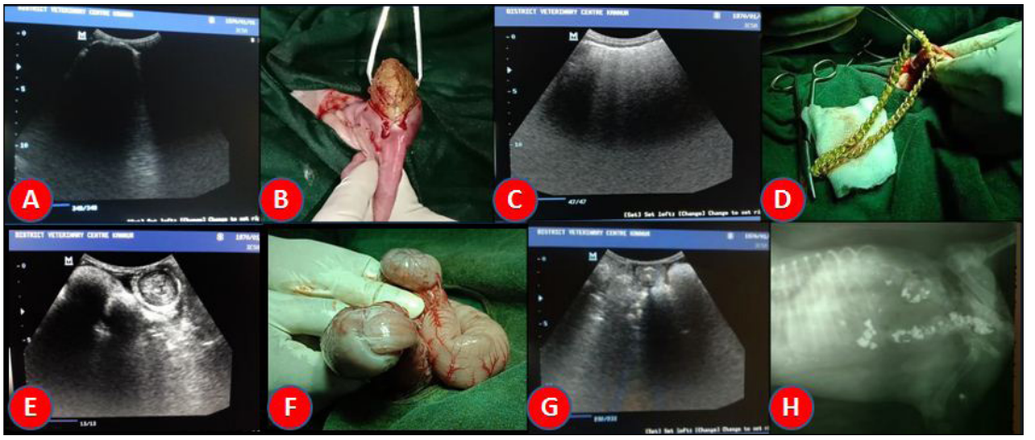

Fig. 2: Bright interface with distal clean shadowing **(A)** in a non-metallic **(B)** and bright interface with distal reverberation **(C)** in a metallic **(D)** GI foreign body confirmed by laparotomy; "Bull's eye" appearance of intestinal segments **(E)** indicating intussusception, confirmed by laparotomy **(F)** Faecolith visualized as bright echogenicities with distal shadowing **(G)** and confirmed by radiography **(H)**

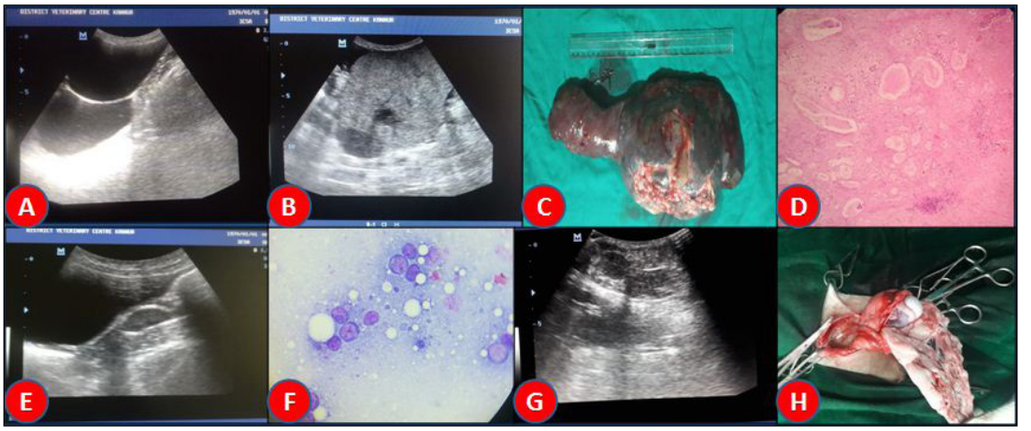

Fig. 3: Diffusely enlarged spleen extending up to the bladder in splenomegaly **(A)** Enlarged spleen with focal anechoic areas and overall changes in parenchymal echo texture **(B)** in splenic hemangiosarcoma. Splenectomy was performed **(C)** and histopathological evaluation **(D)** confirmed the diagnosis; Enlarged lymphomatous sub-lumbar lymphnodes with thin echogenic capsule and distal enhancement **(E)** confirmed by FNAC **(F)** Round homogenous structure with central focal echo in the mid-transverse plain indicating retained testicle **(G)** in an inguinal hernial sac **(H)**

pathological conditions associated with each organ as diagnosed by ultrasound and confirmed by alternative diagnostic methods are shown in table 1.

Based on the results obtained, a 2 × 2 contingency table was prepared as shown in table 2. From the table, the sensitivity, specificity, positive predictive value and negative predictive value of two dimensional B-mode ultrasonography in the diagnosis of intra-abdominal masses were estimated as 95.88%, 97.14%, 98.73% and 91.07% respectively. The accuracy of the technique was calculated to be 96.26%.

Diagnostic ultrasound is commonly used in veterinary clinical practice to identify the abdominal and thoracic pathological conditions such as masses, foreign bodies, trauma etc (Léveillé, 1998; Ballegeer *et al*., 2007; Patsikas *et al*., 2014). Ultrasonography gives the information

Table 1: Pathologies associated with each organ as diagnosed by ultrasound and alternative diagnostic methods

Sl. No.	Organ involved	Pathology	Number	Total*	**	
					TP#	FP##
1	Spleen	Splenomegaly	28	32	28[a,b]	-
		Splenic mass	4		4[c,i,j,l]	-
2	Kidney	CKD	44	44	44[f,g]	-
3	Urinary bladder	Bladder mass	4	48	4[h,i,k]	-
		Cystitis	26		26[g,h]	-
		Cystic calculi	18		18[a,e]	-
4	GI tract	GI Foreign body	29	48	26[a,c]	3[c]
		Fecolith	13		13[a,c]	-
		Intussusception	6		6[c]	-
5	Abdominal lymph node	Lymphomatous lymph nodes	4	4	4[j]	-
6	Uterus	Pyometra	49	54	49[d]	-
		Uterine mass	5		5[d,i]	-
7	Urethra	Urethral calculi	4	4	4[a]	-
8	Testicle	Retained testicle	2	2	2[c]	-
Total			**236**	**236**	**233**	**3**

*Diagnosis made by ultrasound, **Diagnosis made by alternative diagnostic methods, #True positive, ##False positive, [a]Radiography, [b]Blood smear examination and PCR, [c]Exploratory laparotomy, [d]Ovariohysterectomy, [e]Cystotomy, [f]Hemato-biochemical analysis, [g]Urinalysis, [h]Cytology, [i]Histopathological examination, [j]FNAC, [k]Euthanasia, post-mortem and histopathological examination, [l]Splenectomy.

Table 2: Contingency 2 × 2 table prepared to determine the sensitivity and specificity of ultrasonography

+ / –		+	–	Total
Test Result	+	233 True positive (a)	3 False positive (b)	236 Diagnosed positive by ultrasound (a + b)
	–	10 False negative (c)	102 True negative (d)	112 Diagnosed negative by ultrasound (c + d)
Total		243 (a + c) Diagnosed positive by alternate method	105 (b + d) Diagnosed negative by alternate method	348 (a + b + c + d) Total cases

about changes in the shape, size and architecture of solid organs and the changes in wall structure and lumen contents of hollow organs (de Souza *et al*., 2017). The appearance of an organ as visualized by the two dimensional ultrasonography is based on the acoustic impedance mismatch between various soft tissues (Goss *et al*., 1980). However, ultrasonography does not render any information regarding the mechanical properties of the tissue which includes the tissue stiffness or elasticity (Holdsworth *et al*., 2014). Hence, this technique has its limitations in distinguishing different types of pathological conditions such as tumours, abscess, hematoma etc. Being non-invasive and safe, ultrasonography has surmounted the limitations and has been used widely as a primary tool for the diagnosis and clinical evaluation of abdominal pathological conditions in dogs. In contrast to the previous studies where the utility of ultrasonography in diagnosing the conditions involving a specific organ or an organ system or a specific type of condition involving any organ (Book *et al.*, 2011; Cridge *et al.,* 2020) was evaluated,

the present study emphasised on the overall usefulness of ultrasonography in identifying a wide range of abdominal pathological conditions in dogs. The results of the study showed ultrasound to be efficacious, reliable and accurate in the diagnosis of intra-abdominal pathologies in dogs with high values of sensitivity, specificity, positive predictive value, negative predictive value and accuracy.

Ultrasonography has been routinely used in identifying the degenerative diseases such as chronic kidney disease (CKD) in dogs (Bartges, 2012). Although different ultrasonographic changes such as increased cortical echogenicity, abnormal cortico-medullary junction, pyelectasia have been described in dogs affected with CKD (Bragato *et al.,* 2017), published reports regarding the sensitivity of the two dimensional ultrasonography in identifying early degenerative changes of kidney are unavailable. Even, the sensitivity of ultrasonographic parameters such as resistive index calculated by pulsed wave Doppler evaluation was estimated to be only 38% (Morrow *et al.,* 1996). In the present study, the renal ultrasonographic findings were compared with hemato-biochemical values in dogs presented with uremic symptoms and thereby 44 true positive cases of CKD and 8 false negatives were identified. In fact, falsely eliminated cases of CKD alone comprised 80% of all the false negatives in the study and they fell in the International Renal Interest Society (IRIS) stage I category of CKD based on the serum creatinine levels (Bartges, 2012; Elliot and Watson, 2014). Out of the 44 true positive cases, four dogs were in IRIS stage I, 12 in IRIS stage II and 28 in IRIS stage IV. This suggested that ultrasonography with a 3.5 MHz probe was less sensitive in identifying the early CKD, but renal architectural changes in advanced cases could be well appreciated.

The urinary bladder pathologies observed in the study were cystitis, cystic calculi and bladder mass. The ultrasonographic diagnosis of cystitis was made based on the increased thickness of the minimally distended bladder wall greater than 2.3 mm with reduced echogenicity (Geisse *et al.,* 1997). Curvilinear focal echogenicities with distal acoustic shadowing was consistently observed in dogs with cystic calculi (Léveillé, 1998). Plain radiography was employed as the alternative diagnostic technique for detecting the presence of radiopaque cystic calculi and the radiolucent stones were observed during cystotomy. One case of urethral calculi was falsely eliminated by ultrasonography and was later identified by radiography. Few researchers have calculated a false negative rate of 3.5% for sonographic detection of uroliths, much lower than radiography which had a false negative rate of 15% (Weichselbaum *et al.,* 1999). On the contrary, the sensitivity of ultrasound in identifying urethral calculi was reviewed to be 77% and the same augmented to 90% when ultrasonography and radiography were used in combination (Langston *et al.,* 2008). Bladder tumours in ultrasonography were characterized by irregular echogenic appearance of the masses attached to the bladder wall which extended into the lumen. Though these features were described in transitional cell carcinoma (Kim *et al.,* 2017), similar findings were observed in blood clots adherent to the bladder wall also (Léveillé, 1998). In a previous study, the sensitivity and specificity was observed to be 93% and 92% respectively for ultrasonographic diagnosis of bladder wall tumours (Hanazono *et al.,* 2014). In the present study, the bladder masses occupied the trigone in all the cases and resulted in obstruction, backflow of urine and subsequent hydronephrosis. Urine cytology of all the dogs with bladder neoplasms revealed clusters of cohesive cells with basophilic cytoplasm, high nucleus:cytoplasm ratio, anisocytosis and anisokaryosis as previously observed (Renshaw and Gould, 2018). Although bladder masses were appreciated ultrasonographically, a diagnosis of bladder neoplasm could be made by urine cytolological examination and the differentiation of neoplasm as transitional cell carcinoma could be achieved solely by histopathological evaluation.

The ultrasonography has a high sensitivity in identifying uterine pathological conditions (Russo *et al.,* 2021). As observed in the study, the anechoic sacculations were typical for pyometra and the uterine neoplasms were visualised as huge heterogenous masses with anechoic cyst-like cavities. Similar ultrasonographic findings in uterine neoplasms have been reported previously (Patsikas *et al.,* 2014). Though uterine granulomas have a close ultrasonographic resemblance to uterine tumors (Feeney and Johnston, 2007), the histopathological evaluation following ovariohysterectomy (OHE) confirmed the uterine masses to be leiomyomas. The splenic neoplasms in the study appeared either as multifocal or as single discrete hypoechoic mass in splenic parenchyma with heterogenous echo texture. Although the ultrasonographic appearances of the masses were different, ultrasonography

was useful in identifying the solid lesion irrespective of its type. In a study to assess the ultrasonographic appearance of splenic lesions in dogs (Ballegeer *et al.,* 2007), multiple discrete masses on spleen were related to malignancy. The splenic masses in our study had similar characteristics and were later confirmed as hemangiosarcomas in 3 dogs and mast cell tumour in one dog by FNAC or histopathology following splenectomy. A moderate sensitivity of 63% for ultrasonography in the diagnosis of splenic masses was previously reported (Pastore *et al.,* 2007). Generalised splenomegaly was observed sonographically as an enlarged spleen that extended up to the level of urinary bladder or as a curved spleen that extended towards the right side without any obvious changes in the splenic echogenicity or echo texture. Survey radiographs also showed splenomegaly. The concurrent presence of parasites in blood smears and positive polymerase chain reaction results led to the assumption of extra vascular haemolysis as a cause of splenic enlargement. Histopathological examination was not performed to confirm haemolysis or to rule out any neoplasia as the cause for splenomegaly. We could not overcome such limitations due to ethical concerns.

Many authors have suggested ultrasonography as a superior diagnostic modality to radiography in identifying gastro-intestinal (GI) foreign bodies along with their exact location and to understand other associated changes in GI wall thickness and peristaltic movements, and abdominal lymphadenopathy (Aras *et al.*, 2010). A sensitivity of 100% and specificity of 87.5% was observed for the diagnosis of Intestinal obstructions by ultrasonography in a previous study (Garcia *et al.,* 2011). In another study, an accuracy of 94% has been estimated for both radiography and ultrasonography in identifying the surgical conditions of abdominal cavity (Shanaman *et al.,* 2013). On contrary, a very low sensitivity of 64% for ultrasonography when compared to exploratory laparotomy was also reported (Pastore *et al.,* 2007). Such wide variations may be attributed to the vast sample sizes and the different alternative diagnostic techniques used. Furthermore, diagnostic accuracy of ultrasonography or any diagnostic tool was not tested in a group of animals with foreign bodies of similar shape, size or mechanical properties. Also, the site and completeness of obstruction may vary from patient to patient. In other words, the cases selected by different researchers were of widely variable diagnostic challenge and the variation differed within the sample as well as between samples which might have contributed to the wide discrepancies in accuracy of ultrasonography. In our study, the metallic foreign body had bright reflective surface with distal reverberation artefacts and non-metallic foreign bodies were visualized as hyperechoic structures with distal acoustic shadowing as previously described. However, three cases of faecoliths were falsely diagnosed as foreign bodies by ultrasound and one case of foreign body which could not be identified by ultrasonography was later diagnosed by radiography and confirmed by laparotomy. This might be due to the presence of large gas collections in the intestine as a result of complete mechanical obstruction which obscured the foreign body. Ultrasonographically, the retained testicles appeared as a small, round homogenous structure with a central focal echo in the mid-transverse plain located between the caudal pole of kidney and inguinal area in one dog and as an inguinal hernial content in another dog. The testicles were surgically removed. The sensitivity of ultrasound in identifying retained testicles has been observed to be 100% (Felumlee *et al.,* 2012). The lymphomatous sub-lumbar lymph nodes were visualised in ultrasound as an enlarged and homogenous peanut shaped structure with thin echogenic capsule and distal enhancement.

CONCLUSION

The study attempted to test the reliability of the two dimensional B-mode ultrasonography in diagnosing a wide range of abdominal pathological conditions rather than focussing on a specific organ or system. Consequently, numerous alternative diagnostic tools with variable diagnostic accuracy were used to confirm the ultrasonographic diagnosis. Alternative diagnostic tools were used on test negatives only when there was no correlation between the ultrasonographic diagnosis and clinical signs. However, alternative tools were used on test positives to a greater extent. Alternative diagnosis was also obtained by exploratory laparotomy, splenectomy and OHE which were basically treatment modalities rather than merely being tools for diagnosis. Moreover, animals were not randomly selected but were included based on the suspicion of intra-abdominal pathology during physical examination. Hence the probability of occurrence of a test positive was relatively higher compared to that of a test negative. Less number of test negatives and thereby true negatives must have resulted in a low negative predictive

value. These were some sources of bias which could not be eliminated considering the ethical concerns in a clinical study. Nevertheless, the investigation was conducted in a large population of 348 animals and two dimensional B-mode ultrasonography was observed to be a reliable tool in diagnosing the intra-abdominal pathologies.

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