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Evaluation of GI tract in horses by the ultrasound images to compare between normal healthy and disorder gastrointestinal tract

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Abstract
To evaluate and compare the ultrasound images of gastrointestinal tract between normal healthy and gastrointestinal disorder horses. Five normal healthy horses and five gastrointestinal disorder horses were imaged using a 3.5 MHz convex probe and an ultrasound machine. In normal healthy horses, ultrasound images were found in normal sites. The ultrasound images of horses with gastrointestinal disorder, stomach, colon, and caecum were distended with gas. Distended stomach was found between 8th to 14th intercostal spaces, and the curved hyperechoic line was over the gastrosplenic vein. The distended caecum, the depth of sacculation was lower and the motility was slower than that of normal. The colic type of horses with gastrointestinal disorder was flatulent colic. The utilization of ultrasonographic images in this study may aid physicians in determining the most suitable imaging positions for gastrointestinal organs during the interpretation of ultrasonographic images in clinical scenarios, with a specific focus on colic horses.

Keywords: Ultrasound, colic, gastrointestinal tract, horses

1. Introduction
Colic, abdominal disorder is severe gastrointestinal pain. Pain, which is regarded as the leading cause of mortality in horses and donkeys, is a frequent, major disease condition (Radostits *et al*., 2009) [32]. Colic in the horse can be caused manifest itself in many forms and by a plethora of pathological processes (Tinker *et al*., 1997; Ireland *et al.*, 2011) [42, 19] such as tympanic, impaction, displacement, and spasmodic (James and Moore, 2014) [20].
Abdominal ultrasonography is a highly effective and noninvasive diagnostic instrument (Klohnen, 2012) [23] that can differentiate between soft tissues of varying echogenicity. It enables identification based on their position in the body, size, anatomical features, luminal contents, and gastrointestinal tract motility (Williams *et al.*, 2014) [44]. Ultrasonography also permits the accurate evaluation of the digestive tract's location, appearance, and thickness (Freeman *et al*., 2001; Pease *et al*., 2004 and Beccati *et al*., 2011) [14, 29, 3]. Although ultrasonographic examination of the abdominal organs in various horse breeds has been observed by a number of researchers, no foal has yet been observed in Myanmar horses.
The stomach occupies the space between the left 11th and 13th intercostal compartments at shoulder level in healthy horses (Canon and Andrew, 1995) [7]. When the stomach is vacant, only the dorsal area of the greater curvature is visible, the lumen is typically filled with gas, and the stomach's contents are frequently not visible. A distinct gas–fluid interface may be visible in the lumen if gastric fluid is present ventrally (Barton, 2011; Williams *et al*., 2014) [44, 2]. The spleen is visible from the left ventral eighth intercostal space to the paralumbar vertebrae, immediately adjacent to the body wall. Left kidney and 1st to 3rd lumbar vertebrae are located between the 16th and 17th intercostal spaces, deep to the spleen (Kiper *et al*., 1990; Hoffman *et al*., 1995) [17, 22].
The left ventral colon was located ventromedial to the spleen, due to the sluggish motility of the sacculated wall.

The left dorsal colon was also located dorsal or even ventral to the left ventral colon and is not confined to sacculated. In the colon, gas creates a hyperechoic wall and luminal border was not distinct. The identification of the contents and the medial walls was prohibited by intraluminal acoustic shadowing. In healthy horses, small intestine is not easy to visualize except that movement of fluid contents in small intestine produces a transient peristaltic wave. In the left inguinal area of spleen, jejunum is typically found. Rhythmic contractions produced by peristaltic waves are the most visible motility of small intestine (Barton, 2011) [2].

The liver can be found between the diaphragm and the right dorsal colon and the 6th to the 14th intercostal spaces. In the liver, only a small portion of the right side can be seen (Rantanen, 1986) [33]. The liver can be found beyond the 15th intercostal space or in the same transverse plane as the right kidney, unless at the most rostral aspect of the kidney (Reef, 1998) [34]. Immediately caudal to the liver and duodenum there is no sacculated right dorsal colon. Adjacent to the liver, frequently appeared the right dorsal colon by its hyperechoic curved line. When the transducer moves from the right dorsal colon to the ventral, the junction of the right dorsal and ventral colon is commonly recognized. There is sacculation on the right ventral colon (Barton, 2011; Williams *et al.*, 2014; Siwinska *et al.*, 2017) [44, 2, 39]. The caecum can be located between under the right paralumbar vertebrae and the ventral midline. The wall of cecum is sacculated and motility of caecum is often more evident than that of the colon (Barton, 2011) [2].

Ultrasonographic verification in equine colic patients, distended stomach is attributed to small intestinal lesions by the most frequently primary to secondary and occasionally in disorders of large intestine. Impaction and neoplasia of stomach, such as carcinoma of squamous cell infrequently caused primary disorders of stomach (Taylor *et al.*, 2009) [40]. Displacement of the stomach wall to dorsal and caudal is deemed ultrasonography confirmation of distension of the stomach. Nasogastric intubation and decompression can be used to guess the volume of stomach (Lores *et al.*, 2007) [25]. Gastric feed impaction in horses, the contents of stomach are not classically visible, but fluid contents of the stomach increased and may be seen. The radius of curvature is enlarged and may also be observed (le Jeune and Whitcomb, 2014) [24].

Before palpated by rectum, distension of small intestine can be seen on ultrasonography with transcutaneous methods (Cavalleri *et al.*, 2013) [8]. Primary large intestine abnormalities in horses can be revealed that distention of small intestine (le Jeune and Whitcomb, 2014) [24]. In foals and rarely in adult horses, small intestinal intussusceptions can occasionally be identified (Fontaine-Rodgerson and Rodgerson, 2001) [13]. Acute colic in horses can be caused by the large colon displacement, which is left dorsal or entrapment of the large colon with nephrosplenic. The colon is located laterally to the spleen into the nephrosplenic space and can be palpated by rectum. To confirm the diagnosis by ultrasonographic examination of transcutaneous method (le Jeune and Whitcomb, 2014) [24]. The large colon displacement to left dorsal can be diagnose a high specificity with a lower sensitivity by ultrasound (Santschi *et al.*, 1993) [35]. When the ultrasonographic examination of with right dorsal displacement associated finding on the right side of the abdomen is dilated mesenteric vessels (Grenager and Durham, 2011) [16]. Abnormally distended vessels are the most frequently found between the right 10th and 12th ICS and are situated parallel to the ribs. In horses, the large colon torsion is a common cause of severe colic and ultrasound can be utilized to determine the appropriate diagnosis and treatment plan. The identification of large colon with no sacculation in the left ventral part of the abdomen, ultrasound can be used to diagnose the situation of the volvulus and degree of volvulus (Abutarbush, 2006) [1]. Ultrasound cannot be imaged adequately in sand deposits within the large colon and acute small bowel obstruction, but abdominal radiographs can be typically diagnosed. However, ultrasonographic image showed as a hyperechoic line when the ventral phase of sand deposits (le Jeune and Whitcomb, 2014) [24]. Lymphoma and adenocarcinoma are the most common intestinal tumors (Taylor *et al.*, 2006) [41]. Affected loops of intestine are often obvious on the related abdominal floor (le Jeune and Whitcomb, 2014) [24]. An orbicular structure including echogenic fluid contents and a distinct shell is found in classic appearance for abscessation (Pusterla *et al.*, 2007) [31].

2. Materials and methods

This research was conducted at the Department of Surgery and Theriogenology, University of Veterinary Science, and Military Veterinary Hospital of Honorable Riding Company, Nay Pyi Taw, during October 2021 to November 2022. Thirty-five horses reared at the Veterinary Hospital of Honorable Riding Company, Nay Pyi Taw, were primarily collected. Health status of all horses were checked up by physical, clinical, haematological, urinary, faecal and ultrasonographic examination. Only healthy animals were used as normal helathy (NH) horses. Five horses presented to Military Veterinary Hospital with symptoms of colic were used as gastrointestinal disorder (GID) horses.

The ultrasonographic examination of GI tract was performed by an ultrasound machine with 3.5 MHz probe (Z5 Vet Diagnostic Ultrasound, Mindray Bio-Medical Electronics Co. Ltd, Germany). To conduct the ultrasonographic examination of GI tract, hair in the abdominal area was cut off and the skin was scrubbed with water. The probe was scanned on the left and right sides of abdomen from dorsal to ventral and then cranial to caudal. Careful interest was paid to the longitudinal correlation of the viscera because this was the major to distinguish normal and abnormal findings (Rantanen, 1986; Barton, 2011) [2, 33]. The locations of parts of GI tract of healthy horses were imaged according to Colin *et al.*, (2005) [9], Williams *et al.*, (2014) [44] and Farroq *et al.*, (2016). In horses with colic, the locations for performing a rapid focused abdominal ultrasound were imaged according to Freeman, (2002) [12], Pease *et al.* (2004) [29] and Cook and Hassel (2014) [10]. In normal healthy horses, the ultrasound imaging was performed in detail by the method of Williams *et al.* (2014) [44]. There were ten different imaging sites on the abdomen (each flank in four and the ventral abdomen in two) as anatomical landmarks. In flank sites there were defined dorsally as a bent line encompassing from the tuber coxae along the sub lumbar muscular structure and the line of lungs to the 6th intercostal space, ventrally as a straight line from the olecranon process to the stifle joint. Each flank is intersected cranial to caudal and dorsal to ventral, creating four sites such as craniodorsal, cranioventral, caudodorsal and caudoventral flank.

The ultrasound imaging of the horses with GI tract disorder were performed at the sites of GI tract only for the examination of stomach, colon, caecum, and small intestine. The five imaging sites were selected by the results of the first stage to image major abdominal organs (kidneys, spleen,

liver, small intestine, caecum and large intestine). These sites were left caudal and dorsal flank (best imaging site for left kidney and spleen), right caudal and dorsal flank (best imaging site for duodenum, right kidney and caecum), right cranial and dorsal flank (best imaging site for non-sacculated large intestine and liver), cranial and ventral, and caudal and ventral abdomen (imaging sites for ventral colon, and for diseased small intestine).

3. Results

The ultrasound images of normal healthy horses, NH in left side, the stomach, spleen, left kidney, colon, small intestines were found in the left caudodistal flank site. The stomach was found immersed in the spleen between the 9th and 13th intercostal spaces at about the shoulder level. The stomach with the wall of the greater curvature was seen in this site, it was identified as a bent hyperechoic line near to the spleen and the gastrosplenic vein (Figure 1). Caudal from the stomach and nearby to the body wall it can be found spleen and from the left ventral eighth intercostal space to the paralumbar fossa (Figure 2). Immersed in the spleen and between the 16th and 17th intercostal spaces, the left kidney can be found (Figure 3). The left ventral colon can be identified by its sacculated wall and sluggish motility and discovered entero-medial to the spleen (figure 4.).

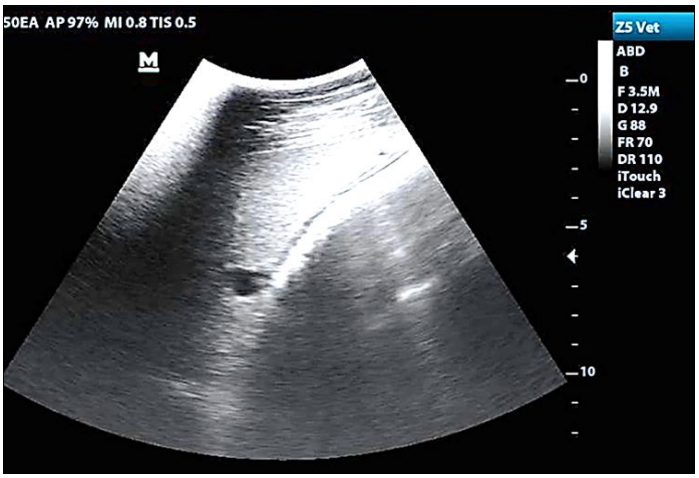

Fig 1: The ultrasound image of spleen and stomach in healthy horse

Fig 2: The ultrasound image of spleen in healthy horse

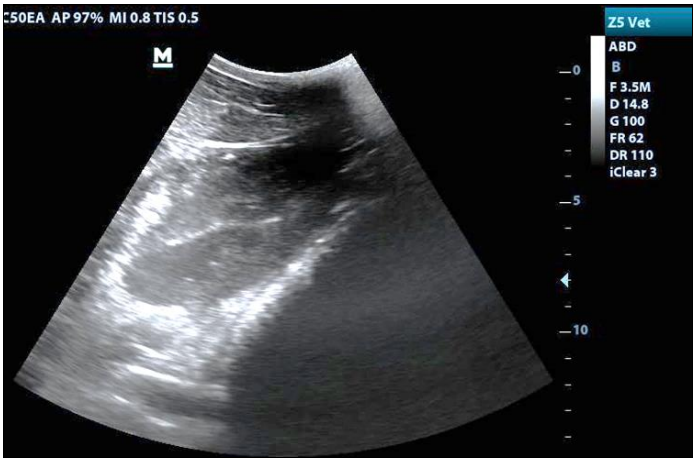

Fig 3: The ultrasound image of left kidney in healthy horse

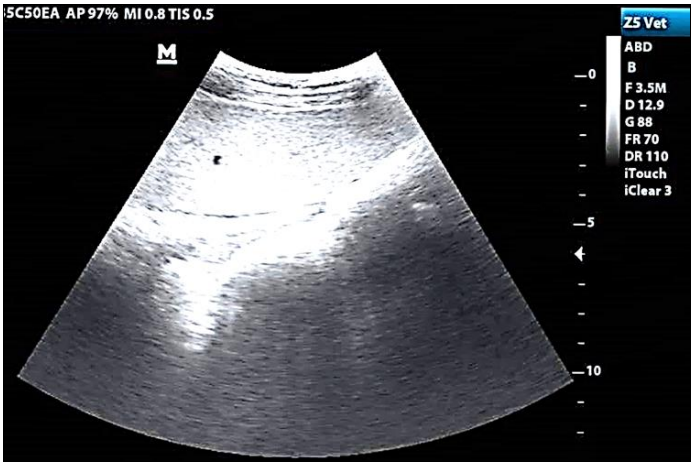

Fig 4: The ultrasound image of spleen and left ventral colon healthy horse

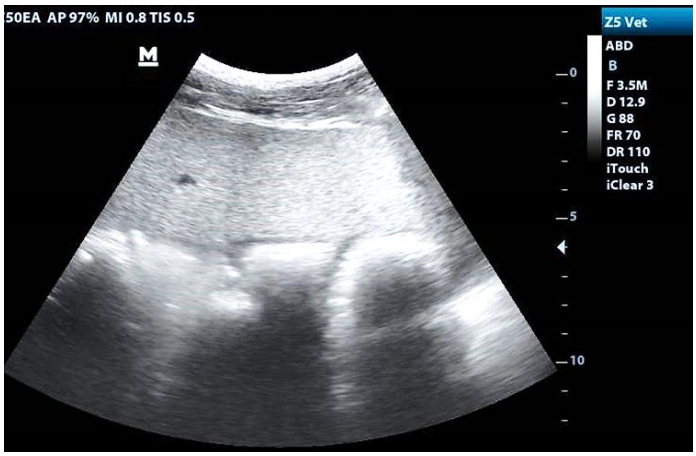

Fig 5: The ultrasound image of spleen and small intestine in healthy horse

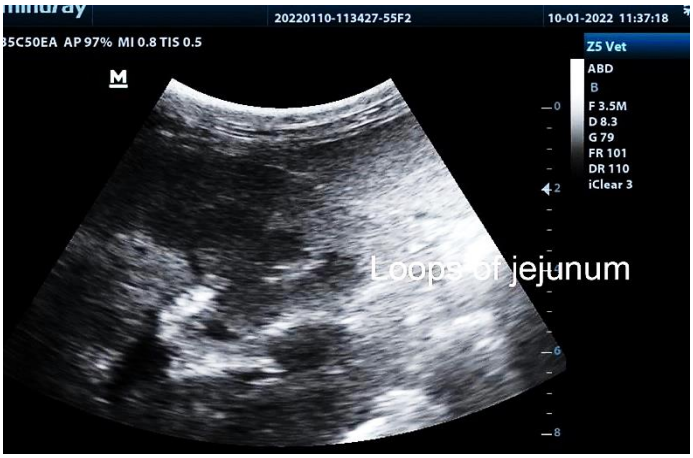

Fig 6: The ultrasound image of loops of jejunum in healthy horse

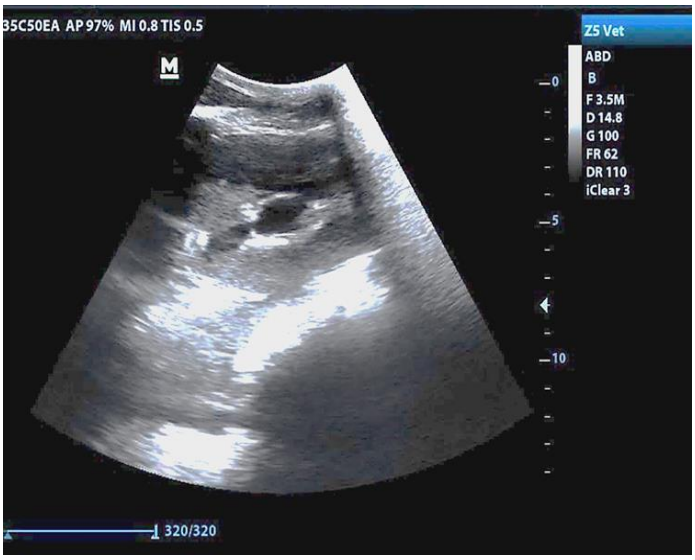

Fig 7: The ultrasound image of duodenum in healthy horse

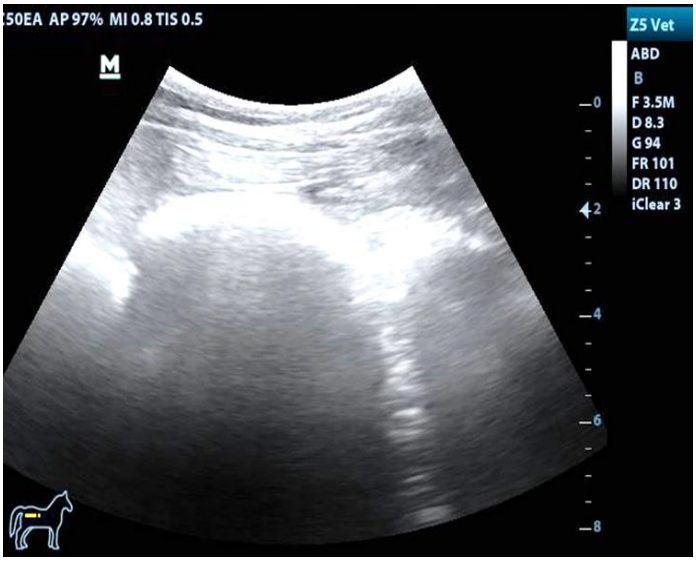

Fig 8: The ultrasound image of right dorsal colon and right ventral colon with junction in healthy horse

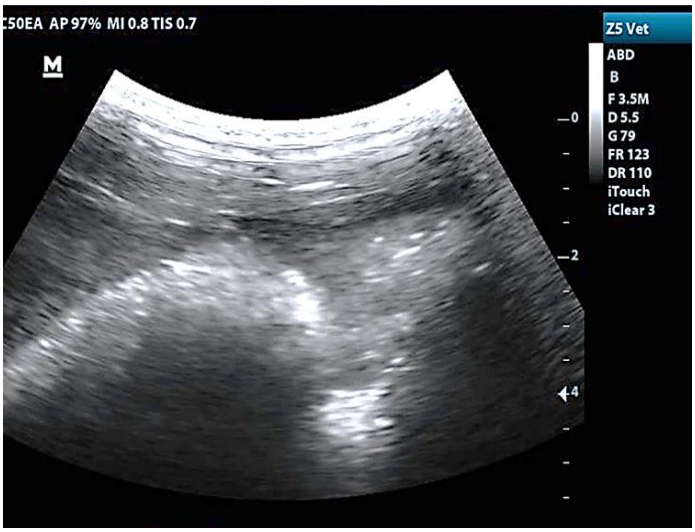

Fig 9: The ultrasound image of caecum with distinct sacculation in healthy horse

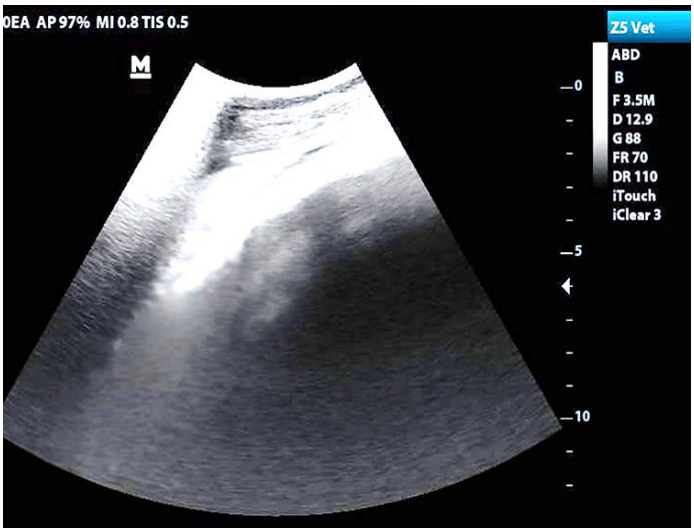

Fig 10: The ultrasonographic image of gastric distention stomach in the horses with gastrointestinal disorder (GID) horse

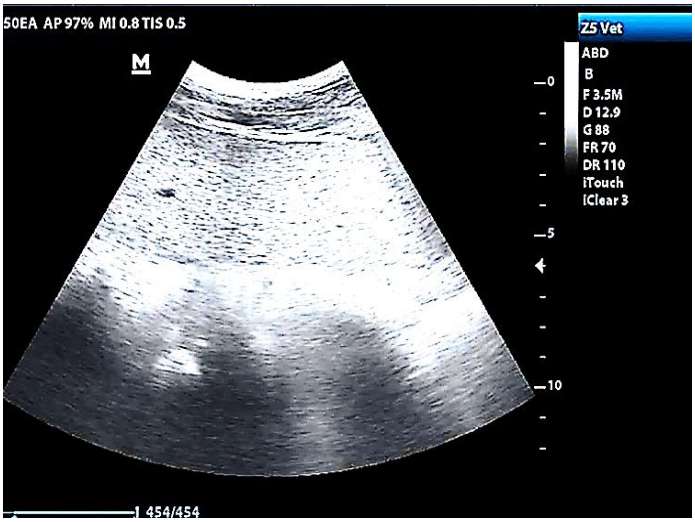

Fig 11: The ultrasound image of spleen and small intestine in GID horse

Fig 12: Gas filled right dorsal colon bellow duodenum in GID horse

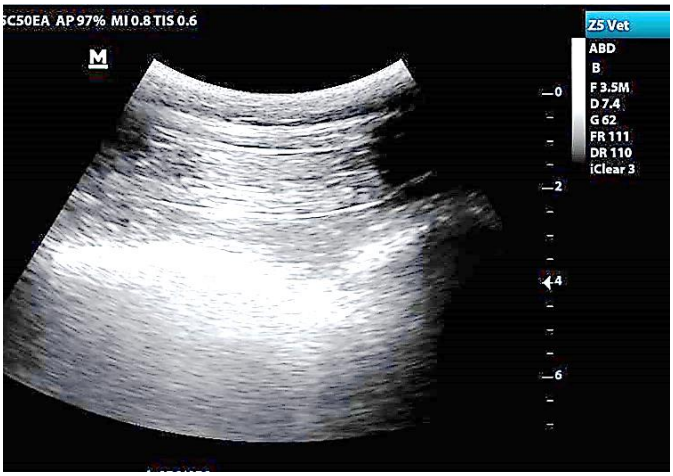

Fig 13: The ultrasonographic image of caecum with no distinct sacculation in GID horses

The small intestine was found in the left side of paralumbar fossa, medial or ventral to the spleen (Figure 5). The jejunum was found in the caudoventral site, in left side of inguinal area, medial to the spleen and the left ventral colon (Figure 6). The ultrasound images of normal healthy horses on the right side, the duodenum was found descending the right central abdomen at about the shoulder level and was found between the liver and the right dorsal colon (Figure 7). The right dorsal colon, which had no sacculation was located posterior to the liver and duodenum. The right dorsal colon was found and moves the probe ventrally, the junction between the right dorsal and ventral colon was observed. The cecum was extended from the right paralumbar fossa to the ventral midline (Figure 8). In the right caudal region, dorsal quadrant and bordering to the body wall, the cecum was found (Figure 9) and was sacculated, and its motility was more visible than that of the colon.

When ultrasound evaluation of GID horses, the stomach, colon, and caecum were distended with gas. Gastric distention was more obvious than normal and found between ninth to fourteenth intercostal spaces, and the curved hyperechoic line was over gastrosplenic vein (Figure 10). The ultrasonographic image of spleen and gas filled small intestine in GID were found (Figure 11). In GID horses, the right dorsal colon was filled with gas and found below duodenum (Figure 12). The caecum was distended with gas, the depth of sacculation was lower than that of normal and the motility of it was slower than that of normal (Figure 13). The horses with GI tract disorder were found as the type of flatulent colic (gas colic).

4. Discussions

Between 13th to 14th intercostal spaces of left side was the best observation site for stomach (Pessoa *et al.,* 2023) [30]. The ultrasound images of stomach can be found on varied from the 10th to 13th left intercostal spaces in normal horses. The stomach was positioned immersed to the spleen between the 9th and 13th intercostal areas at about the shoulder level. It was seen as a bent hyperechoic line near to the spleen and the gastrosplenic vein in the left rostral abdomen (Canon and Andrews, 1995; Barton, 2011) [7, 2]. In this research, the ultrasonographic image of stomach obviously extended beyond the 14th intercostal space and it was possible due to gastric distension stomach with the hyperechoic resonance of gas from the mucosal surface of stomach in GID horses. The results agreed with the report by Trachsel *et al.* (2010) [43], Barton, (2011) [2] and Pessoa *et al.* (2023) [30] who stated that the gastric distention was extended beyond 14th intercostal spaces in colic horses.

Many authors pointed out that inflammation of colon especially right dorsal colon inflammation is a common involvement among equine veterinarians and thickening of colon consistent with inflammation of colon can be found throughout the colon. However, thickening of colon is rarely segregated to the right dorsal colon (le Jeune and Whitcomb, 2014) [24]. In this research ultrasonographic feature of the right dorsal colon was found to be inflammatory colitis without thickening. In horses, for imaging of ventral colon and disordered small intestine, the best imaging sites are the cranioventral and caudoventral abdomen (Williams *et al.*, 2014) [44]. The colon with sacculation was recognized more commonly in the right craniodorsal flank region and occasionally identified in dorsal flank site. In agreement with the previous findings, it was found that the left ventral colon with sacculation was greatly larger in diameter and extended into back regions without increases in wall thickness in this research. This is related to the distension degree and different regions of the colon or destination of the places. Transabdominal ultrasound imaging is useful for identifying changes in colon wall thickness caused by right dorsal colitis, large colon volvulus and intestinal lymphoma (Sheats *et al.*, 2008; Sheats *et al.*, 2010) [37-38]. The colon increased in size and wall thickness caused by oedema and inflammation could resolved more rapidly and would associate with a higher survival rate at the percentage of 68 without complications (Hughes and Slone 1988) [18].

The best place for ultrasound imaging of right kidney and caecum is the right caudodistal flank but the best imaging site for large intestine without sacculation and liver is the right craniodorsal flank. Caecum is located within the right caudal abdomen and extended from under the right para lumbar vertebrae to the central line of ventral abdomen. It is occulated with less than 4 mm wall thickness (Nasr *et al.*, 2014) [18]. In this research the caecum was found in the right caudal abdomen. However, it was distended with gas and the sacculation was lower than that of normal image. Therefore, it was confirmed that gastrointestinal tract disorder was observed in horses as the type of flatulent colic. It was caused by different inflammation or infectious diseases that making etiology was different to determine (Biscoe *et al.*, 2018; Manso-Diaz, 2021) [6, 26].

5. Conclusion

The ultrasonographic findings of this research could help clinicians to decide on the best imaging sites for different organs in abdominal cavity when clarifying ultrasonographic imagines in experimental cases especially in colic horses.

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