TRANSCUTANEOUS ULTRASONOGRAPHIC EVALUATION OF THE AIR-FILLED EQUINE STOMACH AND DUODENUM FOLLOWING GASTROSCOPY

David O. G. Kihurani, Ann Carstens, Montague N. Saulez, Cynthia M. B. Donnellan

Gastroscopy with air insufflation was performed in 10 ponies, after which a transcutaneous ultrasound examination of the stomach and duodenum was performed immediately and at 1, 2, and 4 h postgastroscopy, and 24 h after feeding. Stomach measurements included the dorsoventral and craniocaudal dimensions, as well as the stomach depth from the skin surface and stomach wall thickness at the different time periods. Gastric wall folding was observed in one pony, becoming most distinct 2–4 h postgastroscopy. An undulating stomach wall was noted in eight other ponies postgastroscopy. These observations appeared to be a response to the deflation of the stomach as the insufflated air was released gradually. Gas was detected in the duodenum after the gastroscopy. The parameters measured were noted to be useful to evaluate the extent of stomach distension due to air or feed. The ultrasonographic appearance of the stomach can, therefore, be altered by gastroscopy and this should be borne in mind when examining horses with suspected gastric disease. *Veterinary Radiology & Ultrasound, Vol. 50, No. 4, 2009, pp 429–435.*

Key words: equine, gastric wall folding, stomach measurements, ultrasonography.

Introduction

Transcutaneous ultrasonography is useful for evaluating horses and ponies with gastric disease.[1–7] Gastric distension with air is performed routinely during gastroscopy to facilitate viewing of the lumen of the stomach. We noticed that the ultrasonographic appearance of the stomach wall is sometimes undulated or folded after gastroscopy. It was not known whether this was a pathologic change or whether it was related to the gastroscopy. It was postulated that the introduction of air, or even the physical presence of the gastroscope, could have led to the gastric wall appearance, implying that even nasogastric intubation itself may cause this undulation.

Rugal folds of the stomach have also been observed in some horses undergoing food restriction, but the reason for this was not stated.[4] There was also no reference to this type of change following distension of the equine stomach with fluid.[5] It is important to know and document what happens to the ultrasonographic appearance of the stomach postintervention, in this instance gastroscopy, to determine what is normal or abnormal.

The purpose of this study, therefore, was to further evaluate the sonographic appearance of the stomach at different times after gastroscopy, and also describe the changes occurring to the stomach with regard to dimensions, wall thickness, and contractility. In addition, the duodenum was examined to see if the air introduced into the stomach during gastroscopy was released into the small intestine.

Materials and Methods

Ten adult Nooitgedacht ponies from the University of Pretoria Animal Unit were used for the study. They ranged in age from 4 to 14 years, weighing 362–462 kg and standing 142–149 cm at the withers. They had no recent history of gastrointestinal disease or clinical signs of gastrointestinal problems. The clinical parameters of the ponies were within the normal ranges. They had been dewormed 2 weeks before the study. During the study, the ponies were housed in the Equine Clinic stables of the Onderstepoort Veterinary Academic Hospital.

Before ultrasonographic and gastroscopic examination, feed was withheld for 10 h and water for 2 h to allow emptying of the stomach. At approximately 5 h postgastroscopy, grass and lucerne hay and water were given. No concentrates were provided during the study.

A pre-gastroscopic ultrasonographic exam after food withdrawal was performed to characterize the baseline appearance of the stomach and duodenum. Gastroscopy with air insufflation, as is routinely done, was performed to view the internal aspects of the stomach. Immediately after, the

From the Department of Companion Animal Clinical Studies, Faculty of Veterinary Science, University of Pretoria, Private Bag X04, Onderstepoort 0110, South Africa (Kihurani, Carstens, Saulez, Donnellan).

Address correspondence and reprint requests to David O. G. Kihurani, Clinical Studies Department, Faculty of Veterinary Medicine, University of Nairobi, PO Box 29053-00625, Nairobi, Kenya. E-mail: d.kihurani@cgiar.org

Received August 29, 2008; accepted for publication December 23, 2009.
doi: 10.1111/j.1740-8261.2009.01561.x

pony was examined, using ultrasonography to evaluate the distended stomach and duodenum. The examination was repeated after 1, 2, and 4 h, during which time deflation of the stomach was complete. The pony was then fed and a final ultrasonographic examination performed after 24 h.

Just before gastroscopy, the ponies were sedated with 200 mg of 2% Xylazine Hcl,* intravenously. This provided about 45 min of sedation to facilitate the examination. The ponies were restrained in stocks, where a lip twitch and Hausmann's gag were applied. A 3 m, flexible gastroscope† was inserted through the right nostril, the ventral nasal meatus, pharynx and esophagus into the stomach. To allow easy viewing of the various internal parts of the stomach, air was introduced by continuous insufflation via the gastroscope to sufficiently distend it. The examination of the cardia, glandular, and nonglandular aspects of the stomach, as well as the pylorus was then performed.

Sonography was performed from the left seventh to 16th intercostal spaces. The hair on this side was clipped, after which ethanol was applied on the skin to facilitate imaging. Acoustic coupling gel was applied over the transducer, which was then covered by a thin latex sheath to protect its surface from the ethanol. The ultrasonographic examination was performed with a 3.5 MHz curvilinear transducer, which provided optimal resolution, using a laptop Tera Vet T3000‡ ultrasound machine. Scanning was performed from dorsal to ventral along each intercostal space. The transducer was oriented transversely so that dorsal was to the left of the image.

The ultrasound examination was initiated dorsally on the left side (dorsoventral direction) and the image captured when the greater curvature of the stomach wall was visualized, at the most dorsal point of the intercostal space. All the images were captured during expiration, to avoid lung interference.

Using a black marker, a horizontal line was drawn on the skin over the thorax at the level of the *Tuber olecrani*. A single static image was then captured at each intercostal space at the most dorsal point at which the stomach wall was visible. The distance to the horizontal line was measured with a tape measure and recorded as the most dorsal stomach wall height in centimeters. A second static image was captured at each intercostal space at the most ventral point at which the stomach wall was visible and the height above the olecranon process again measured. The difference between these two measurements was the ultrasonographically visible height of the stomach.

Using the static images and the calipers of the ultrasound machine, the depth of the lateral aspect of the stomach wall from the skin surface was also measured. This measurement was done at the most dorsal point in each intercostal space that the stomach was visible. It reflected the distance from the skin surface during stomach distension as well as deflation postendoscopy.

The cranial to caudal dimension of the stomach was recorded as the number of intercostal spaces where the stomach was visible. The presence and number of gastric wall folds and the time at which they occurred was also recorded. In addition, the layers of the stomach wall were noted and measurements of the wall thickness at three different sites done. These sites were the most dorsal, mid, and ventral point along each intercostal space that the stomach was visible. The average of the three measurements was the wall thickness. Statistical analysis of the data was not done, but the means and standard deviations were obtained.

The duodenum was assessed at two locations as previously described.[8] The first was ventral to the caudal pole of the right kidney at the 16th–17th intercostal spaces on the right flank. It was also examined at a second location from the 12th–15th intercostal spaces, between the liver and the right dorsal colon. The locations corresponded to a line drawn from the olecranon on the right forelimb to the tuber coxa. The contents of the duodenum were recorded, namely the presence of chyme, gas, or fluid.

To determine the volume of air introduced during insufflation, air was introduced into a meteorological balloon from the gastroscope over a period of 10 min.[9] The mouth of the balloon was clamped using a Doyen's atraumatic clamp as well as a knot tied to prevent release of the air. The contents of the balloon were then expressed into a Spirometer and the readings on two measurement scales recorded. The volume was calculated using a conversion factor of 1 mm = 0.5158 l. This was the volume at actual temperature and pressure saturated. The reading on a thermometer (in °C) with its bulb within the Spirometer was recorded, as well as the pressure in mmHg of a barometer within the room. The values were then used to determine the conversion factor from a table on the density of air at different pressures.[10] This was used to calculate the volume of air in the balloon at standard temperature and pressure dry. This value was divided by 10 to determine the rate in litres per minute of air introduced via the endoscope. The process was repeated three times and the average rate determined.

Results

Gastroscopy lasted 6–8 min, during which time the stomach was distended by continuous insufflation of air via the gastroscope. The rate of insufflation was approximately 0.5 l air per minute, so a total of about 3–4 l air was introduced.

*Chanazine®, Bayer, Johannesburg, South Africa.
†Olympus GIF XQ240, Tokyo, Japan.
‡Classic Medical Ultrasound, Burlington, MA.

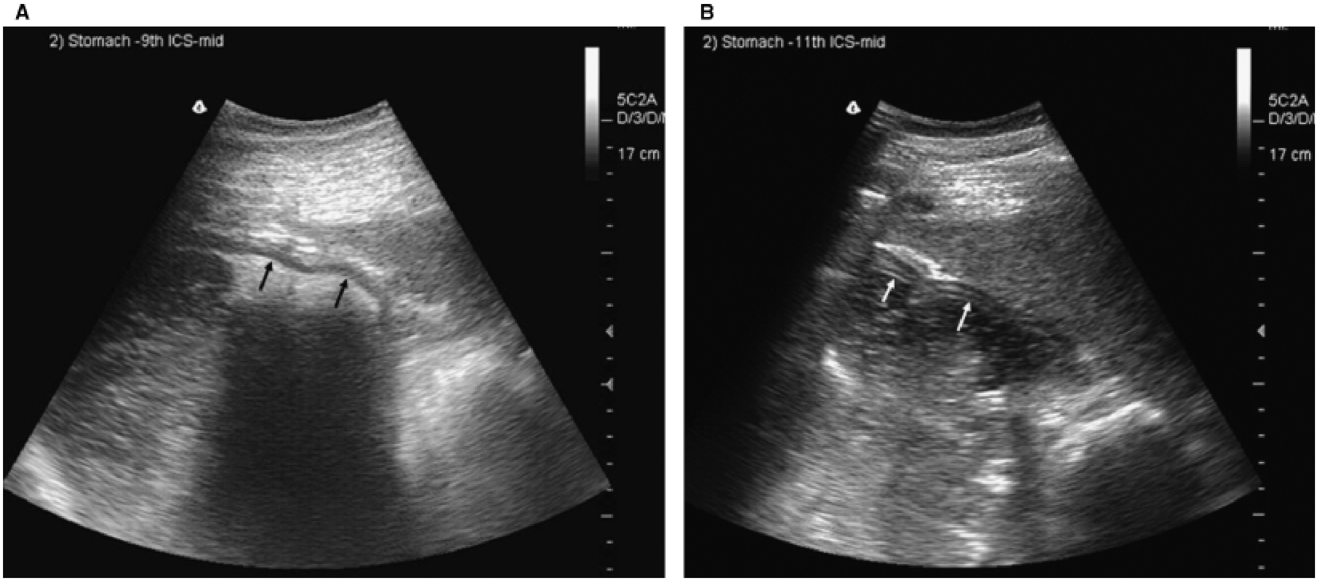

FIG. 1. Ultrasound image of the stomach of pony number 4 immediately postgastroscopy at the 9th and 11th intercostal spaces. The arrows point to the irregular wall outline with the layers visible. Dorsal is to the left.

During gastroscopy, variable amounts of feed and water were still present in the stomach. In three ponies, the stomach was almost completely empty, while in five the feed amounts increased to about 25% of the stomach volume. Two ponies had slightly more feed and water occupying about 1/3 the stomach volume. In addition, the most common gastroscopic finding was a mild hyperkeratosis of the *margo plicatus* in six ponies. Apart from this, there were no significant abnormalities observed on the glandular and nonglandular surfaces of the stomach wall in all the ponies.

Undulations of the wall of the stomach were observed ultrasonographically in nine ponies, but most distinctly in pony number 4. In this pony, they began immediately postgastroscopy, where they were seen at the 9th, 10th, and 11th intercostal spaces. At this time, the folding appeared as a wavy outline of the stomach wall (Fig. 1).

The appearance persisted as a similar wavy fold 1 h postendoscopy at the 11th intercostal space. The folding then became more conspicuous as an invagination of the stomach wall at 2 h postendoscopy at the 10th and 11th intercostal spaces. It was, however, most distinct 4 h postendoscopy at the ninth and 10th intercostal spaces (Fig. 2). The invagination appeared to involve the mucosa and submucosa extending into the stomach lumen.

Eight other ponies had varying degrees of gastric wall folding, but to a lesser extent than in number 4. It appeared most frequently (in five ponies) 1 h postgastroscopy. It was also noted in four ponies immediately after gastroscopy. Unusually, two ponies had some degree of gastric wall undulation 24 h after feeding. In both of these latter ponies, the stomach was distended with feed as determined by an increase in the craniocaudal and dorsoventral dimensions. No undulations or gastric wall folding was observed in the pregastroscopy images. In all ponies, including the nine where undulation or gastric wall folding was seen, there were no obvious contractions of the stomach noted.

The most dorsal height of the stomach was greatest immediately postgastroscopy, after air insufflation. The mean value was 29.3 ± 4.5 cm at this time. The stomach height then decreased progressively in the period after gastroscopy to the lowest value 4 h postgastroscopy; mean of 25.6 ± 4.2 cm. After the ponies had been fed, the dorsal height increased again but not to the same extent as after air insufflation (Fig. 3A). Gastric height increased immediately after gastroscopy, then decreased to reach its lowest value of 7.1 ± 2.6 cm at 2 h postendoscopy. After the horses had been fed, the greatest dorsoventral height of 9.9 ± 2.9 cm was recorded (Fig. 3B). When the depth of the stomach from the skin surface was examined at the different time periods, it was noted that it was greatest after fasting or pregastroscopy (Fig. 3C). The mean depth of the stomach at this time was 8.0 ± 1.1 cm. After air was introduced during gastroscopy, the depth reduced to a mean of 6.6 ± 1.7 cm. It then increased 1 h postgastroscopy and subsequently reduced gradually at the different times postgastroscopy. With feeding, it reduced further to a depth of 6.3 ± 1.7 cm, which was the time the stomach was closest to the skin surface. The craniocaudal dimension of the stomach, as measured by the number of intercostal spaces in which the stomach was visible, varied from 2 to 4 (mean $= 3.5 \pm 0.7$) in fasted ponies (Fig. 3D). Immediately postgastroscopy, it increased slightly to a span of three to five intercostal spaces (mean $= 3.8 \pm 0.6$). It then reduced 1–4 h postgastroscopy to pregastroscopy values. Thereaf-

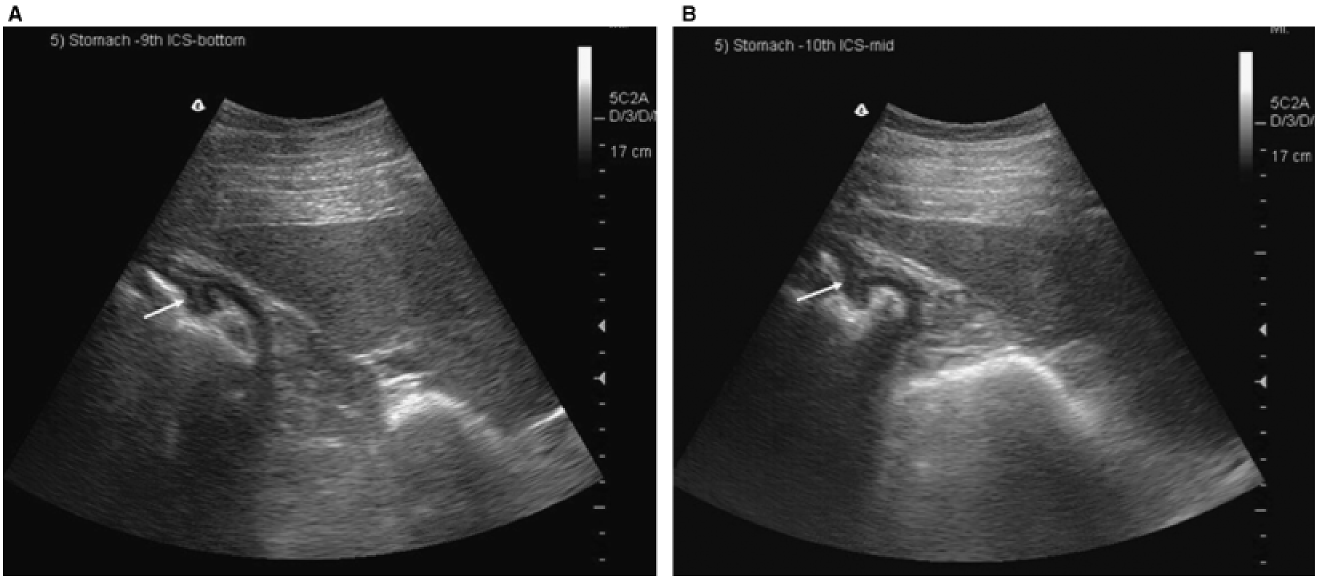

FIG. 2. Ultrasound image of the stomach of pony number 4, done four hours postgastroscopy at the 9th and 10th intercostal spaces. The arrows point to the folding of the gastric wall. Dorsal is to the left.

ter, 24 h after the onset of feeding, the span either remained the same or increased dramatically. The stomach spanned three to five intercostal spaces in seven ponies, while in the other three it extended over eight intercostal spaces from the seventh to 14th or eighth to 15th intercostal spaces. The mean at this time was 5.4 ± 1.9.

When the stomach wall thickness was compared at the different time periods, it was lowest after fasting (Fig. 3E) at a mean of 4.6 ± 1.0 mm. The wall thickness then increased gradually to attain the highest value 2 h postgastroscopy at 5.2 ± 1.1 mm. This was nevertheless fairly close to the mean wall thickness at 4 h postgastroscopy of 5.0 ± 0.6 mm. After the ponies had been fed the wall thickness reduced to a value of 4.7 ± 0.4 mm.

Five ponies had hyperechoic gas specks in the duodenum in pregastroscopy ultrasound images. An additional four ponies (total of nine) had gas in the duodenum immediately after the endoscopic examination. The gas was seen on the dorsal aspect of a transverse section of the duodenum above the chyme and/or fluid contents. It was particularly noted at the 16th or 17th intercostal spaces, where the duodenum was located ventral to the caudal pole of the kidney. In the five ponies that had gas in the duodenum during the pregastroscopy ultrasound, two had more gas postgastroscopy, while the other three had similar amounts as the pregastroscopy scans. One pony did not have any detectable gas in the duodenum in any ultrasound examinations.

When the nine ponies with gas in the duodenum in the postgastroscopy ultrasound were examined 1 h later, the gas was not evident in five ponies. In three other ponies, the gas was not evident in the duodenum 2 h postgastroscopy. Thereafter, the contents consisted of fluid with small amounts of chyme until the scan 24 h after the onset of feeding, where chyme was evident. One pony, however, had gas and fluid/chyme in the duodenum from the ultrasound scan immediately postgastroscopy up to the one 24 h after feeding.

Discussion and Conclusions

Gastric wall folding was observed distinctly in one pony, while an undulating wall was noted in eight other ponies. This occurred after gastroscopy, becoming more distinct with time in pony number 4. The rugal folds, also referred to as gastric folds or plicae, occur as a result of the distensible nature of the stomach as it empties.[11] The fact that they became more distinct with time postgastroscopy in pony number 4 suggest that, in this pony, they were related to the deflation of the stomach as the insufflated air was released gradually. An undulating stomach wall may also have been a response to the deflation, but to a lesser extent. This contrasted with previous observations, where rugal folds of the stomach of horses were stated to arise commonly after the animals had been fasted.[4] The folds were not noted in any of the ponies during the pregastroscopy examination, at which time they had been without food for 10 h.

The volume of air introduced during insufflation of the stomach varied from 3–4 l, over a period of 6–8 min. Pony number 4 had about 3 l of air introduced, which was similar to three other ponies. None of the latter, however, had the same distinct gastric wall folding as pony number 4, so the volume of air per se may not have been the reason for the folding.

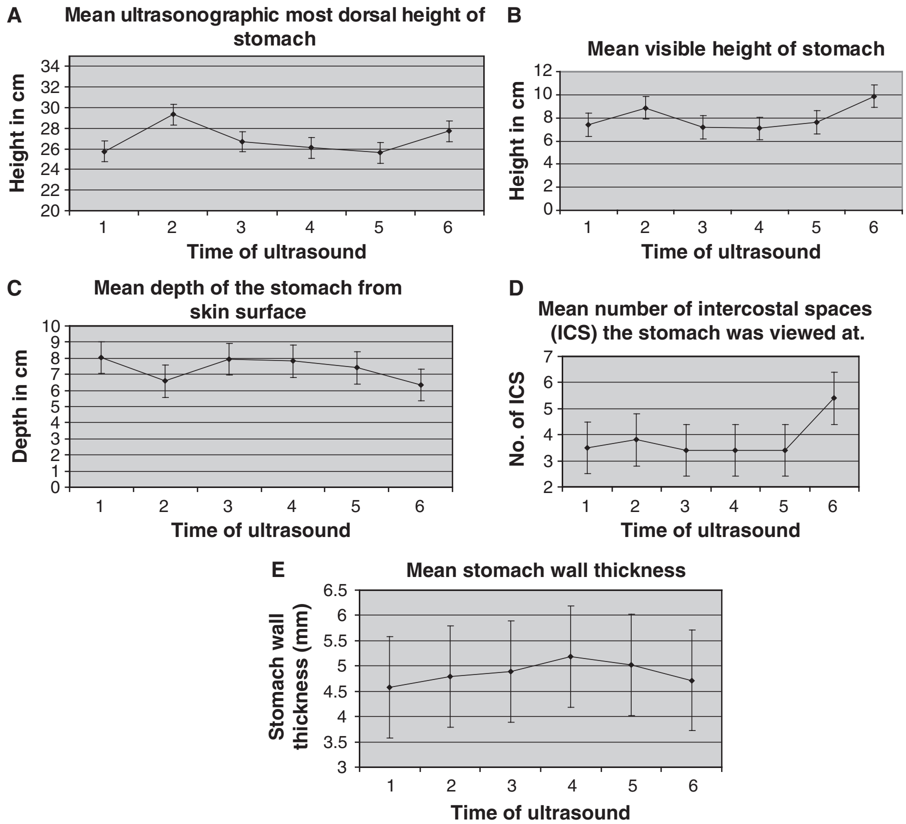

FIG. 3. (A–E) Dimensions of the stomach at different times before and after gastroscopy in the 10 ponies. Key for "Time of Ultrasound": 1, pregastroscopy; 2, immediately postgastroscopy; 3, 1 hour postgastroscopy; 4, 2 hours postgastroscopy; 5, 4 hours postgastroscopy; 6, 24 hours after feeding.

The folds noted 4 h postgastroscopy in pony number 4 appeared to extend into the lumen as a fold of the mucosa and submucosa rather than a fold of the entire stomach wall. Gastric folds, on histologic examination, are also described as folds of the mucosa and submucosa.[12] They form part of the normal gross appearance of the nonglandular part of the equine stomach (Fig. 4). It is not clear, therefore, why more ponies did not have the distinct wall folding. The nonglandular part of the stomach is also the most dorsal hence would be the one viewed during ultrasound examination.

Rugal folds of the stomach have also been described in cats.[13] There they were related to the distension of the stomach with feed. When the stomach was completely distended with ingesta there were no rugal folds evident. When it was half full, with abundant ingesta visible, rugal folds were easily identified. The folds became compact when the stomach was emptied.[13] The ponies in this study did not have any rugal folds after they had been fasted, or even when there was some feed in the stomach. In fact, pony number 4 still had a small amount of feed and fluid occupying about 25% of the volume of the stomach during the endoscopic examination, yet did not have any gastric folds in the preendoscopic ultrasound scan.

The effects on the various stomach measurements of the fasting, air insufflation during gastroscopy, stomach deflation and feeding of the ponies, were evaluated. It was noted that the air insufflation caused the greatest dorsal distension and thus height of the stomach, immediately postgastroscopy. This was most likely due to the air rising

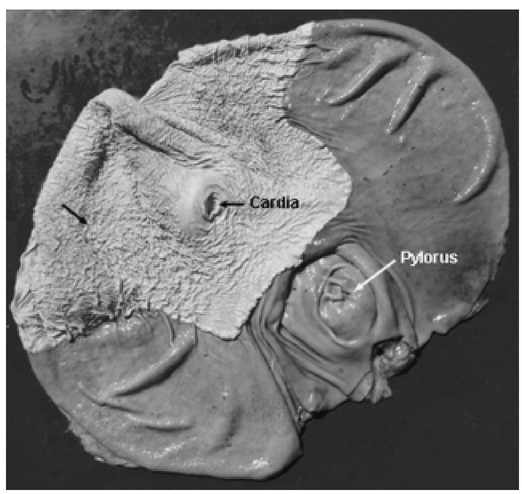

FIG. 4. Non glandular internal aspect of the equine stomach with visible gastric folds (arrow).

to the top of the stomach. Nevertheless, the dorsoventral height of the stomach was greatest in the ponies after feeding. That is, more of the stomach could be viewed after feeding, because the point at which it could still be viewed ventrally was lower in these ponies. Apparently, as the feed settled in the stomach, it was distended ventrally due to the greater weight of the feed. In addition, the feed caused the greatest increase in the craniocaudal span of the stomach as determined by the increased number of intercostal spaces the stomach covered. Overall, therefore, more of the stomach could be viewed ultrasonographically after feeding than after air insufflation or fasting.

In three ponies, the stomach could be seen over eight intercostal spaces, from the seventh to 14th or from the eighth to 15th intercostal spaces, after they were fed. Normally, the stomach is viewed over three to five intercostal spaces, but located between the eighth and 15th intercostal spaces.[4,14] In these ponies, therefore, the stomach appeared more distended than normal, though the ponies did not have any discomfort or signs of colic. It is possible that the ponies ate more because they were fasted. Nevertheless, the other seven ponies in the study had a craniocaudal span of the stomach after feeding of three to five intercostal spaces. It has also been reported that ponies may have a conformational difference with horses where the stomach can be imaged over a greater number of intercostal spaces, and particularly the more caudal ones.[14] Similar observations were made in this study.

The depth of the stomach from the skin surface was greatest after fasting, with a mean of 8.0 ± 1.1 cm. Apparently, the stomach was displaced medially from the skin surface, rather than being pushed more against the body wall by the intestines and other abdominal organs due to its smaller size. When air was introduced during gastroscopy, the stomach wall was pushed closer to the skin surface, hence the depth was reduced immediately postgastroscopy to a mean of 6.6 ± 1.7 cm. With the subsequent deflation of the stomach, the depth increased gradually at the different times postgastroscopy. When the ponies were fed, the distended stomach was pushed closer to the skin surface to a depth slightly lower (i.e., 6.3 ± 1.7 cm) than that after air insufflation. Therefore, the stomach depth proved a useful parameter to evaluate the distension of the stomach with air or feed.

When the stomach wall thickness was compared at the different time periods, it was least in the pregastroscopy scans (mean 4.6 ± 1.0 mm). This was unusual as the partially or completely empty stomach in a contracted state would be expected to have a thicker wall. Nevertheless, the standard deviation was relatively high so a number of ponies actually had thicker stomach walls above the mean. The wall thickness increased to attain the highest values at 2 h (mean 5.2 ± 1.1 mm) and 4 h (mean 5.0 ± 0.6 mm) postgastroscopy, as expected due to the stomach contraction during deflation. The wall thickness was then reduced 24 h after feeding (mean 4.7 ± 0.4 mm), where the distended stomach had a relatively thinner wall, as expected. Despite these variations, however, the stomach wall thickness was within the normal values of 4–7 mm described previously.[4,14] Even when the stomach spanned the greatest number of intercostal spaces (i.e., 8) in three ponies after feeding, this distension did not reduce the wall thickness further significantly. Similar observations have been made in the cat where there was no significant difference observed in the stomach wall thickness at different degrees of distension.[13]

One of the objectives was to determine whether the air introduced during gastroscopy was released cranially through the oesophagus after the examination, or caudally through the duodenum. Nine ponies had evidence of hyperechoic gas specks in the duodenum during the ultrasound scan done immediately after gastroscopy. Four of these ponies did not have gas in the duodenum in the pregastroscopy scans. In the other five ponies, two had more gas in the duodenum in the postgastroscopy scans compared with the pregastroscopy ones. This suggests that the air from the stomach was released at least partly via the duodenum.

The release of air appeared to occur within the first 1–2 h postgastroscopy in most ponies, since it was not evident in the ultrasound scans of the duodenum at these times. In one pony, the gas even persisted up to 4 h postgastroscopy. Horses have a thick cardiac sphincter which accounts for their near inability to vomit.[15] Therefore, when the gastroscope was withdrawn, the closed cardiac sphincter would most probably have prevented the release of most air retained in the stomach into the oesophagus. There were also no obvious contractions of the stomach observed during the study. The air was then most probably released gradually by the peristaltic contractions of the duodenum.

In conclusion, the process of gastroscopy and particularly air insufflation can alter the ultrasonographic appearance of the stomach. Gastric wall folding or undulation can result, becoming most distinct 2–4 h postgastroscopy. Various stomach measurements, including the dorsoventral and craniocaudal dimensions, as well as the stomach depth, are useful parameters to evaluate the extent of stomach distension due to gas or feed. This may have an application in evaluating colic with gastric dilatation. The stomach wall thickness also varies in ponies that have been fasted, air insufflated, or fed and this should be borne in mind when examining ponies or horses with gastric disease where the wall thickness is important in making the diagnosis, e.g. gastritis.

ACKNOWLEDGEMENT

The authors wish to acknowledge the valuable input of Prof. Robert Kirberger of the Department of Companion Animal Clinical Studies, in the formulation of the protocol for this study and the review of the manuscript.

REFERENCES

1. Reef VB. Adult abdominal ultrasonography equine diagnostic ultrasound. Philadelphia: WB Saunders Company, 1998;283, 330–334.

2. Schmitz DG. Abdominal ultrasonography. In: Rantanen NW, McKinnon AO (eds): Equine diagnostic ultrasonography. Baltimore: Williams and Wilkins Co., 1998;60–63.

3. Rantanen NW. Diseases of the abdomen. Vet Clin North Am: Eq Pract 1986;2:67–68.

4. Reef VB, Whittier M, Allam LG. Sonographic evaluation of the adult abdomen. Clin Tech Eq Pract 2004;3:294–307.

5. Lores M, Stryhn H, McDuffee L. Transcutaneous ultrasonographic evaluation of gastric distension with fluid in horses. Am J Vet Res 2007;68: 153–157.

6. McAuliffe SB. Abdominal ultrasonography of the foal. Clin Tech Eq Pract 2004;3:308–316.

7. Byars TD, Halley J. Uses of ultrasound in equine internal medicine. Vet Clin North Am: Eq Pract 1986;2:253–258.

8. Kirberger RM, Van den Berg JS, Gottschalk RD, Guthrie AJ. Duodenal ultrasonography in the horse. Vet Radiol & Ultrasound 1995;36:50–56.

9. Guthrie AJ. Evaluation of the cardiopulmonary flow index as an indication of cardiac function in Thoroughbred horses. M Med Vet Thesis, University of Pretoria, 1987;36–37.

10. Weast RC. Density of moist air, Table III. CRC Handbook of chemistry and physics. Boca Raton, Florida: CRC Press Inc., 1987;F9.

11. Wheater PR, Burkitt HG, Daniels VG. Wheater's functional histology; a text and colour atlas. New York: Longman Group Ltd., 1993;252–253.

12. Banks WJ. Applied veterinary histology. St. Louis, USA: Mosby Year Book Incorporated, 1993;338–345.

13. Newell SM, Graham JP, Roberts GD, Ginn PE, Harrison JM. Sonography of the normal feline gastrointestinal tract. Vet Radiol & Ultrasound 1999;40:40–43.

14. Epstein K, Short D, Parente E, Reef V, Southwood L. Gastrointestinal ultrasonography in normal adult ponies. Vet Radiol & Ultrasound 2008;49:282–286.

15. Budras KD, Sack WO, Rock S. Anatomy of the horse, 4th ed. Hannover, Germany: Schlutersche GmbH & Company KG, 2003;62–63.