ORIGINAL ARTICLE

Imaging of the equine abdomen using point of care ultrasound (POCUS): Effects of sedation on intestinal motility in horses

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Background Point of care ultrasonographic (POCUS) assessment of the equine abdomen is now readily available to the equine practitioner using hand-held ultrasound transducers. Commonly used medications may alter the sonographic appearance or function of the small intestine, caecum or colon.

Aim To demonstrate qualitative and quantitative effects of xylazine sedation on intestinal motility of healthy horses using hand-held, wi-fi ultrasound transducers and validate POCUS methodology by determination of intra- and interobserver agreement.

Methodology Double-blind cross-over study of eight healthy horses using hand-held, wi-fi ultrasound transducers to determine the effects of sedation on intestinal motility in comparison with administration of a placebo (saline). Motility was independently assessed by three observers using deidentified videos obtained using hand-held, wi-fi ultrasound transducers. Agreement was assessed by determination of intraclass correlation coefficient (number of duodenal contractions) and weighted kappa statistic for motility grades.

Findings Sedation was associated with fewer duodenal contractions (median 0.5, range 0 to 2) after sedation, compared with administration of saline (median 4, range 3 to 5, $p < 0.001$). Large colon and composite motility grades were also reduced (median 4.5, range 2 to 6 after sedation; median 10, range 7 to 12, after saline, $p = 0.005$), and qualitative changes were evident in the sonographic appearance of jejunal loops in six of eight horses. Interobserver agreement was moderate to good, and intraobserver agreement was good to excellent.

Conclusion POCUS proved to be an effective tool to recognise qualitative and quantitative changes associated with sedation.

Keywords colic; gastrointestinal motility; intra- and interobserver agreement; sonography; xylazine

Abbreviations CAEC, caecum; COLN, colon; DUOD, duodenum; JEJM, jejunum; LC, large colon; MHz, megahertz; mvt, movement; POCUS:, point of care ultrasound

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Background

The use of point of care ultrasonography (POCUS) for the diagnosis and monitoring of horses with colic is becoming increasingly available to the equine practitioner due to the ready availability of affordable, portable equipment[1,2] and dedicated sonographic protocols for the critical abdomen have been established.[3,4] Sedation is commonly used to facilitate veterinary examination or treatment of horses with colic, and the adverse effects of α_2 adrenergic agents on gastrointestinal motility are well recognised.[5] Transcutaneous abdominal ultrasonography has been used to assess the effects of xylazine,[6] and transrectal ultrasonographic assessment has been used to characterise the effects of romifidine,[7] on intestinal motility of horses, but qualitative effects on the sonographic appearance of intestinal movement and contents in treated horses have not been reported. Iatrogenic effects of medications used in the diagnostic or therapeutic management of the equine acute abdomen might influence the clinical assessment of sonographic findings, and effects on intestinal function should be considered in the context of clinical presentation.

The current study was completed to characterise the effects of xylazine on the motility and sonographic appearance of the small and large intestine in healthy horses and to assess the utility of POCUS methodology for this purpose. We hypothesised that administration of xylazine would be associated with reduced intestinal motility.

Materials and methods

Horses and experimental design

Eight healthy adult light breed (Standardbred/Thoroughbred) geldings aged 8 to 20 years (median 12 years) from the teaching herd at Charles Sturt University were included in the study. Power calculations prior to study commencement suggested that this number of horses would be sufficient to detect a mean difference of two duodenal contractions per minute, assuming a standard deviation of one (based on researchers' prior results), with 80% power and $\alpha = 0.05$. Each horse underwent veterinary

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examination prior to inclusion in the study and was familiar with the study environment. Horses were run into yards on the morning of study after being fed on pasture approximately 3 h prior to study commencement. Horses were randomised in pairs, with one horse receiving sedation (0.5 mg/kg xylazine) by intravenous injection 10 min prior to ultrasonographic examination; the reciprocal horse in the pair was treated with a volume of saline equivalent to its calculated xylazine dose. Treatment was allocated by coin toss. Following completion of the ultrasonographic examination, horses were observed by study personnel until recovered from sedation, before being returned to their paddock. All procedures were repeated after 48 h, with horses receiving the reciprocal treatment to that administered on Day 1, prior to repeat ultrasonographic examination. Sonographic assessments were performed at the same time on both days, and horses were examined in the same order, to exclude possible diurnal effects. Ethical approval for this study was granted by Charles Sturt University Animal Care and Ethics Committee (approval number 21415).

Ultrasonographic examination

Sonographic assessment was completed prior to sedation (T0), and 10 min following administration of xylazine (0.5 mg/kg IV) or an equivalent volume of saline (T1), using a hand-held, battery operated, convex 2–5 MHz wireless transducer able to penetrate to 20–25 cm (Vscan Air CL probe, GE Healthcare, Mascot NSW). Images were obtained from four acoustic windows on the right side of the horse (DUOD, CAEC, COLN, JEJM, Table 1, Figure 1). Once optimised, images were recorded on an iPad as 1 min video loops using a screen recording app (https://apps.apple.com/us/app/record-it-screen-recorder/id1245356545) and stored using a unique, randomly generated four digit number for subsequent blinded evaluation of intestinal motility. Deidentified recordings

Table 1. Acoustic windows used to evaluate intestinal motility and subjective grading criteria used in each location.

Window	Method	Grading
Duodenal window (DUOD)	The transducer is placed caudal to the 18th rib or in the last intercostal space level with a line joining the olecranon to the tuber coxae. The transducer is oriented transversely parallel to the ribs to image the duodenum between the base of the caecum and the cranial pole of the right kidney. If the duodenum could not be visualised in this location, it was advanced cranially by 1–2 intercostal spaces to image the duodenum between liver and right dorsal colon. By convention, the transducer is oriented such that dorsal is to the left of screen.	The number of complete axial contractions of the duodenum in 1 min is counted. Duodenal motility is also subjectively graded: 3 contractions of ↑ duration &/or amplitude 2 contractions of ↔ duration & amplitude 1 contractions of ↓ duration &/or amplitude 0 no real mvt observed
Right caudal abdomen (CAEC)	The transducer is oriented transversely in the most caudal intercostal space and moved ventrally past the convergence of ribs to visualise mesenteric vessels of the or caecum (or ascending colon) recognised as two or more hypoechoic circular structures directly adjacent to the intestinal wall and coursing cranioventrally. By convention, the transducer is oriented such that dorsal is to the left of screen.	Caecal or large colon movement is subjectively graded: 3 movement >50% of recording, with obvious mvt of LC away from body wall or near continuous mvt 2 definite mvt for ~50% of recording 1 +/− mvt of bowel – might be mvt of body wall, patient or probe – not convincing 0 no mvt observed
Ventral abdomen (COLN)	The probe placed on the ventral midline immediately caudal to the xiphoid, oriented in a craniocaudal direction and moved caudally and/or sagittally to visualise the most gravity dependent abdominal contents. By convention, the transducer is oriented such that caudal is to the left of screen.	Large colon movement is subjectively graded: 3 movement >50% of recording, with obvious mvt of LC away from body wall or near continuous mvt 2 definite mvt for ~50% of recording 1 +/− mvt of bowel – might be mvt of body wall, patient or probe – not convincing 0 no mvt observed
Inguinal region (JEJM)	The probe is placed into the most caudal part of the abdomen, adjacent the hindlimb and moved axially and cranially to visualise jejunal loops, which may be evident between LC sacculations. In compliant horses, both sides can be imaged from the right. Transducer orientation is varied to effect greatest image quality, with ventral at the top of screen.	Jejunal movement is subjectively graded: 3 all loops of SI visualised are in (nearly) continuous motion, with obvious mvt of ingesta 2 loops of SI are moving for ~50% of recording, or one loop moving whilst other(s) are still 1 little obvious mvt (no change in lumen size, minimal mvt of ingesta) 0 no mvt observed

Abbreviations: LC, large colon; mvt, movement; SI, small intestine.

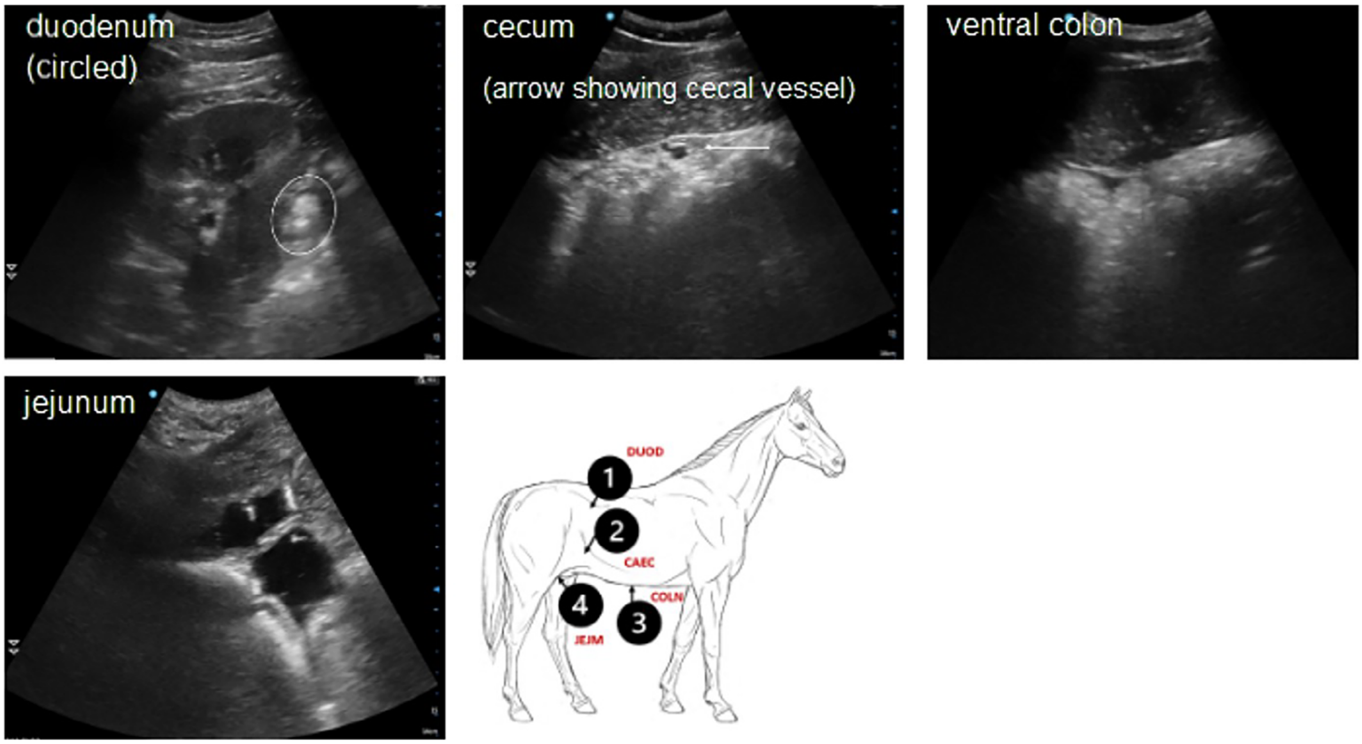

Figure 1. Acoustic windows used for sonographic assessment of intestinal motility before and after sedation in the current study and representative images from each of the four ultrasound windows. CAEC, caecum; COLN, ventral colon; DUOD, duodenum; JEJM, jejunum. A description of each window is provided in Table 1.

were independently assessed by three researchers, two (FF, SLR) specialists in equine internal medicine and one (AC) specialist in veterinary diagnostic imaging. Duodenal, caecal, colon and jejunal motility were subjectively graded using ordinal scales (Table 1) adapted from previous publications,[6,8–10] and the number of concentric duodenal contractions, as defined by Gomaa et al,[9] were counted during the 1 min recording window.

Statistical evaluation

For each sonographic recording, results from the three independent evaluations were combined by taking the mode response. For discordant results (defined as the number of DUOD contractions differing by >2 or grade assigned differing by >1), clips and comments were reviewed to achieve a consensus result prior to decoding. Results were initially explored using appropriate summary statistics. Intestinal motility grades described in Table 1 were treated as ordinal data and analysed using nonparametric tests. Motility grades in each window, and a composite score based on summed grades for each of the four sonographic windows (COMP), were assessed by repeated measures analysis of ranks (Friedman test), with post hoc testing using Dunn's method. The number of axial duodenal contractions (Table 1) was treated as a continuous variable, but data were not normally distributed and were resistant to transformation; these results were also, therefore, evaluated using nonparametric techniques. Effects of sedation were assessed by comparison of motility results at T0 and T1 associated with the administration of xylazine or saline.

Assessment of interobserver agreement (reliability) was based on independent evaluation by three assessors of forty deidentified video clips from each acoustic window used in the sedation study (DUOD, CAEC, COLN, JEJM). Clips were included if they were of acceptable quality and to encompass an even distribution of motility grades. Assessment of intraobserver agreement (repeatability) was based on repeat evaluation of a sub-set of twenty deidentified video clips from each study window saved with a different random identification number and again selected to encompass an even distribution of motility grades. Analyses were completed prior to decoding, review and consensus for discordant results. Agreement for continuous data (number of DUOD contractions in 1 min) was assessed by determining the intraclass correlation coefficient for comparison between each pair of assessors (A-B, B-C, A-C, interobserver agreement), and between initial and repeat scoring for each assessor (intraobserver agreement). Reliability was assessed by calculating Cronbach's alpha. Agreement for ordinal data (motility grades) from each acoustic window was assessed by calculating the weighted Kappa statistic for each pair of assessors, and for repeated evaluations. Statistics were analysed using GraphPad Prism (version 10.0.0; GraphPad Software, Boston, MS) or SPSS (SPSS Statistics for Windows, Version 28.0. Armonk, NY: IBM Corp), with values of $P < 0.05$ considered significant.

Results

Effects of sedation on intestinal motility

Sedation was associated with decreased motility in DUOD, CAEC and COLN windows, with significant differences relative to values obtained at T1 after saline administration and/or relative to T0 values in all windows except JEJM and for composite motility scores (Figure 2). The number of duodenal contractions observed in 60s ranged from 2 to 5 (median 3) at T0. There were significantly fewer contractions at T1 after sedation (median 0.5, range 0 to 2) than were observed for saline treated horses at T0 (median 3, range 3 to 5; $P = 0.016$) or T1 (median 4, range 3 to 5; $P < 0.001$). Motility grade at T1 in sedated horses was significantly reduced in DUOD ($P = 0.012$, compared with T0), CAEC ($P = 0.040$, compared with unsedated horses at T1) and COLN ($P = 0.047$, compared with T0) windows, and the composite motility grade (COMP) was significantly reduced at T1 following sedation (median 4.5, range 2 to 6) compared with results at T0 (median 9.5, range 7 to 11; $P = 0.016$) or results at T1 following saline treatment (median 10, range 7 to 12; $P = 0.005$) (Figure 2). Abnormal (decreased) duodenal contractions were characterised in assessor comments as being sluggish or feeble, and often accompanied by anechoic intestinal content in comparison with normal (or increased) motility grades. Qualitative differences were evident in jejunal loops imaged in horses following sedation, with anechoic fluid content (Figure 3) noted in jejunal loops for six (of eight) horses.

Inter- and intraobserver agreement is shown in Table 2. Between observers, determination of the number of duodenal contractions (DUOD count) demonstrated moderate to good agreement, and, within observers, there was good to excellent agreement (repeatability). The grading of intestinal motility spanned fair to substantial agreement, depending on the observer pair, and a similar result was observed for intraobserver agreement.

Discussion

The current study was undertaken to evaluate the effects of xylazine sedation on quantitative and qualitative measures of intestinal function in healthy horses using hand-held, wi-fi probes suitable for POCUS evaluation of the equine abdomen in field and clinical settings. Intestinal motility was decreased following sedation, as expected, with quantitative effects most apparent for DUOD motility grades and for COMP motility score. Whereas counting of complete axial duodenal contractions did not demonstrate as clear an effect, assessors were possibly more able to recognise duodenal contractions as abnormal even when they fulfilled the definition for complete contraction. By contrast, although large intestinal movements were also carefully defined, assessor comments suggested difficulty discriminating true intestinal movement from patient or probe movement might have reduced the ability to more accurately characterise

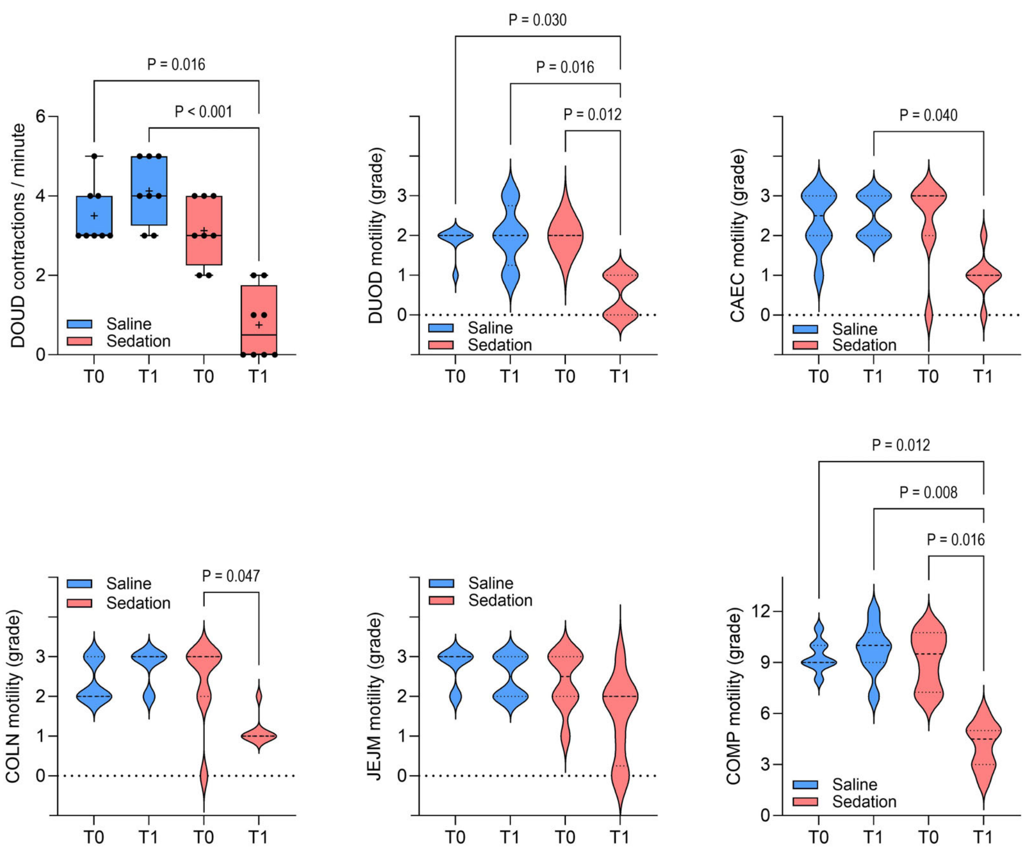

Figure 2. Effects of sedation on intestinal motility. Results for continuous variables (duodenal contractions) are shown as box and whisker graphs with mean (+), median (horizontal line), quartiles (box) and range (whiskers) indicated, with all data shown; Friedman test demonstrated a significant time-treatment interaction (*P* < 0.001); all data and results of post hoc testing using Dunn's method are shown. Results for categorical variables are shown as violin plots with median (solid line) and quartiles (dashed line) shown. Significant pairwise comparisons are shown.

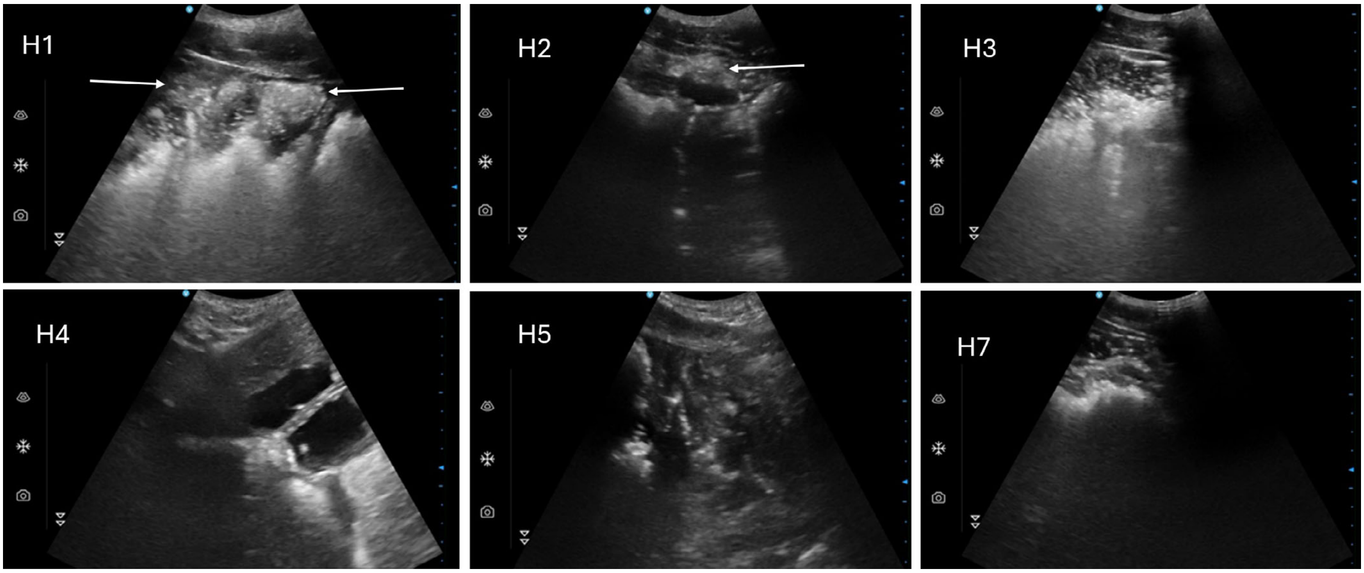

Figure 3. Representative images demonstrating small to moderate amounts of fluid content in jejunal loops in six horses following administration of xylazine. In H1 and H2, sedimentation of content (arrows) can be appreciated (ventral is to top of image). Video recordings pre- and postsedation from this window for two horses are provided in supplementary information.

large intestinal movement. Although a quantitative effect was not demonstrated for JEJM motility, sedation was associated with qualitative changes in the sonographic appearance of the jejunum, including abnormal motility and increased anechoic fluid content. Sonographic appearance should be interpreted in relation to clinical context and presentation, as qualitative changes were recognised by all assessors as abnormal and α_2 agonists, such as xylazine, are commonly used in the management of colic. Similar changes have been documented following administration of spasmolytic agents that might be used in the management of colicky horses,[9,10] and sonographic changes have been characterised in the stomach and proximal intestine following nasogastric administration of fluids[11,12] and following gastroscopy.[13]

Effects of α_2 agonists on gastrointestinal motility are well characterised, with documented effects on various parts of the gastrointestinal tract. Detomidine delays gastric emptying in a dose-dependent manner,[14] and duodenal motility and contraction amplitude were decreased after xylazine[15] and detomidine[16] administration in horses. Romifidine,[7] xylazine and detomidine[17] are known to cause reduced motility and increased relaxation of the large intestine. Recent studies using noninvasive elastointestinography techniques have shown that detomidine adversely affects caecal and colonic motility.[18] Xylazine decreases propulsive motility in the distal jejunum, caecum and pelvic flexure of healthy ponies for up to 140 min.[19] In addition to characterising the effects of α_2 adrenergic agents, ultrasound evaluation of gastrointestinal motility has been used in horses to characterise response to other medications,[8,20,21] neural blockade of the celiac plexus,[22] anaesthesia[23] and postoperative recovery,[24,25] and effects of feeding,[26] nasogastric administration of fluid[11] and gastroscopy.[13]

The intravenous administration of xylazine,[5] romifidine[27] or detomidine[28] has been associated with reduced borborygmi in horses. Although abdominal auscultation was outside the scope of the present study, human studies have demonstrated that there is little correlation between auscultation findings and sonographic measures of intestinal motility and have suggested that ultrasonographic evaluation is superior to auscultation for assessment of intestinal function.[29–31]

Agreement between observers in the current study was consistent with previous studies using transabdominal ultrasonographic assessment of intestinal wall thickness measurements[32] and rectal sonographic evaluation of (small intestinal) motility,[10] and also with agreement studies on grading of gastrointestinal auscultation.[5] Not surprisingly, higher agreement has been reported in studies evaluating only equine populations with reduced motility.[33] In the current study, agreement between observers on the number of duodenal contractions ranged from moderate to good. Despite strict definition of what constituted a contraction, discrepancies arose in the application of the definition to borderline observations, or when multiple contractions occurred in quick succession (differentiation of one contraction from the next was challenging). The more subjective motility grades demonstrated a greater range of agreement (fair to good) and, interestingly, repeated evaluation (intraobserver agreement) was only slightly more reliable. However, as is commonly observed for grading systems routinely used in clinical practice, moderate agreement may be sufficient to allow differentiation of clinically relevant changes in individual patients and in study populations, and agreement was similar to that reported for auscultation findings in equine[34] and human[30,35] patients. Moreover, the qualitative changes evident in sedated horses were flagged by all observers and are relevant to clinical assessment despite not being readily included in assessment scales.

As evidenced by the observer agreement and image quality obtained in the current study, POCUS equipment proved effective for

Table 2. **Inter- and intraobserver agreement between three observers (A, B, C) for intestinal motility. The number of duodenal contractions in 1 min (DUOD count) was compared by determination of intraclass correlation coefficients. Ordinal data (motility grades in each sonographic window) were compared by determining the weighted Kappa statistic for each pair of comparisons.**

Intra-class correlation co-efficient				
Inter-observer agreement	A–B	B–C	A–C	Cronbach's α
DUOD count	0.758	0.633	0.872	0.903 (95% CI 0.836–0.945) $P < 0.001$
Weighted kappa value				
DUOD grade	0.442	0.257	0.609	
CAEC grade	0.582	0.397	0.548	
COLN grade	0.440	0.358	0.734	
JEJM grade	0.487	0.468	0.640	

Intra-class correlation co-efficient				
Intra-observer agreement	A–A′	B–B′	C–C′	
DUOD count (95% CI)	0.959 (0.897–0.984)	0.818 (0.540–0.928)	0.846 (0.610–0.939)	$P < 0.001$
Weighted kappa value				
DUOD grade	0.878	0.350	0.571	
CAEC grade	0.947	0.792	0.462	
COLN grade	0.695	0.422	0.778	
JEJM grade	0.833	0.647	0.643	

Interpretation

Intraclass correlation coefficient (reliability)		Weighted kappa value (agreement)		Cronbach's α (reliability)	
>0.90	Excellent	0.81–1.00	Almost perfect	>0.90	Excellent
0.75–0.90	Good	0.61–0.80	Substantial (good)	0.81–0.90	Good
0.50–0.75	Moderate	0.41–0.60	Moderate	0.71–0.80	Acceptable
<0.50	Poor	0.21–0.40	Fair	0.61–0.70	Questionable
		0.00–0.20	Slight	0.51–0.60	Poor
		<0.00	Poor		

objective characterisation of intestinal response to medication and for subjective observation of qualitative differences in the sonographic appearance of the intestine. Changes were not of sufficient magnitude to compromise critical clinical decision-making, such as decisions for surgical referral: distention was not marked and mural thickening was not evident. However, the characterisation of qualitative findings associated with sedation was considered important for the practicing clinician to facilitate recognition of iatrogenic effects of medications and other interventions in clinical cases presented for evaluation.

The current study used blinded assessment of deidentified videos of ultrasound evaluation, but did not assess differences that might have been apparent if sonographic images were obtained by different operators, and the duration of effect following sedation was not ascertained. Validated scoring systems for intestinal motility are lacking.[36] Additional techniques to more objectively quantify intestinal health, such as the use of Doppler to measure blood flow or the aboral movement of ingesta,[6,37,38] might be explored using existing capacity of the sonographic equipment used in this study.

Conclusion

This study confirmed that administration of xylazine is associated with reduced intestinal motility and qualitative changes to small intestinal content and function in healthy horses. Effects on intestinal motility of medications used in the diagnostic and therapeutic management of colic may affect sonographic findings, and clinical effects on slowing of the passage of ingesta should be considered in drug selection. POCUS examination is rapidly completed, noninvasive and well tolerated by horses. Reliability and agreement were comparable to studies using referral-level equipment. Our findings suggest that POCUS is well suited to the assessment of gastrointestinal structure and function in horses in research and clinical settings.

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Conflicts of interest and sources of funding

The authors declare no conflicts of interest or sources of funding for the work presented here.

Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Supporting information

Additional Supporting Information may be found in the online version of this article at the publisher's web-site: http://onlinelibrary.wiley.com/doi/10.1111/avj.70068/suppinfo.

File S1. Cineloops from the jejunal (inguinal) window for Horse 1 obtained pre- (left) and postsedation (right) showing reduced motility and sedimentation of content following sedation (file: H1_JEJM window sedation effects.ppsx).

File S2. Cineloops from the jejunal (inguinal) window for Horse 4 obtained pre- (left) and postsedation (right) showing reduced motility following sedation (file: H4_JEJM window sedation effects.ppsx).

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