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JOURNAL TITLE: Veterinary Record

PUBLISHER: BMJ Publishing Group

PUBLICATION DATE: 20 September 2019

DOI: 10.1136/vr.105468

This article has been accepted for publication in VetRec following peer review.
The definitive copyedited, typeset version is available online at 10.1136/vetrec-2019-105468

Title

ULTRASONOGRAPHIC VISUALISATION OF THE MESENTERIC VASCULATURE IN HORSES WITH LARGE COLON COLIC

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Abstract

Background:

Ultrasonographic visualization of the mesenteric vasculature of the large colon (LC) from the right side of the abdomen in cases of displacement and volvulus has been described. However, the LC can move freely within the abdomen and its mesentery can potentially contact both sides of the abdominal wall.

Methods:

Thirty-four horses presented with LC -related colic that had visible LC mesenteric vasculature visible on abdominal ultrasound were included. A control group was made including horses with confirmed small intestinal-related colic. Our objective was to evaluate

the visibility of LC mesenteric vasculature with transabdominal ultrasonography in horses with LC-related colic and to determine its diagnostic value.

Results:

The LC mesenteric vasculature was identified on the right side of the abdomen in 16/34 horses with right dorsal displacement of the LC (RDDLC), 180º LC volvulus (LCV), 540º LCV or LC impaction. On the left side of the abdomen LC mesenteric vessels were identified in 17/34 horses with left dorsal displacement of the LC (LDDLC), 180º LCV or RDDLC. Vessels were visualized on both sides in one horse with a 180º LCV. Presence of LC mesenteric vasculature in the dorsal aspect on the left side of the abdomen was significantly associated with LDDLC.

Conclusion:

LC mesenteric vasculature can be visualised on transabdominal ultrasound from either side of the abdomen in horses with different forms of LC-related colic.

Introduction

Large colon (LC) disorders represent more than 44% of the causes of colic in horses,[1] with displacement and volvulus of the ascending colon being most commonly diagnosed.[2] Ultrasonography is a fast and non-invasive imaging modality that is widely used in the diagnostic work-up of abdominal discomfort in horses. In conjunction with other clinical and laboratory findings, ultrasonography helps in the pre-operative identification of the source of acute abdominal pain,[3] as it provides real time information about the presence and characteristics of peritoneal fluid, gastric size and contents, intestinal motility and contents, as well as about intestinal wall thickness and diameter. The latter is considered of paramount importance in smaller or very large equine patients that cannot undergo effective rectal palpation.[4] Most clinicians consider it highly advisable to include ultrasonography routinely

in the examination of the equine acute abdomen because it helps to better identify conditions that may require surgical intervention.[5]

Vascular supply to the LC is provided by two arteries: the colonic branch of the ileocaecal artery and the right colonic artery (figure 1). These two vessels course in the mesocolon along the mesenteric border of the LC to the pelvic flexure where they anastomose.[6] During transabdominal ultrasonographic examination of a normally positioned LC, the luminal contents create an acoustic shadow that prevents visualisation of deeper structures, such as these mesenteric vessels. Ultrasonographic visualisation of the colonic mesenteric vasculature is possible if the LC is displaced and its mesenteric surface is in contact with the right abdominal wall, thereby exposing the normally invisible mesenteric vessels.[7,8] This feature has been reported as a specific ultrasonographic indicator of either a right dorsal displacement of the large colon (RDDLC) and/or a 180º large colon volvulus (LCV).[8] The lack of a mesenteric attachment in the abdomen allows the LC to move freely within this cavity[6] and makes it susceptible to several types of displacement and/or a volvulus.[1] The mesenteric border of the LC could therefore potentially also come in contact with the left abdominal wall, which would allow for ultrasonographic identification of the mesenteric vessels from the left side or from both sides of the abdomen in selected conditions.

The objective of the present retrospective study was to evaluate the transabdominal ultrasonographic visibility of the LC mesenteric vessels in horses with large colon colic and to determine its diagnostic value. We hypothesized that the LC colonic vessels can be visualised from the left or right side or both sides of the abdomen in horses with large colon colic, depending on the type of condition.

Materials and Methods

Study population

78 The clinical records at the (masked for peer review) between January 2013 and December
79 2017 were reviewed. Horses with large colon-related colic and complete medical records,
80 including transabdominal ultrasonography findings, were included in the study. Details
81 obtained for each case included sex, age, breed, ultrasonographic findings, treatment
82 (exploratory laparotomy or medical management), intraoperative and/or post-mortem
83 findings, as well as final diagnosis.
84 A control group was made including horses referred in the same period of time for surgical or
85 necropsy confirmed small intestinal-related colic.
86
87 *Ultrasonographic examination*
88 All horses were examined using an ultrasound machine equipped with a 2.5-5 MHz
89 curvilinear and a 7-12 MHz linear transducers (Logiq 5 Expert, GE Healthcare, Solingen,
90 Germany) on admission to the hospital. The skin was wetted with alcohol without previous
91 clipping to facilitate contact and image acquisition. All complete transabdominal
92 ultrasonographic examinations were performed by a single examiner (GMD) in similar
93 fashion, working from caudal to cranial over both the left and right sides of the thorax and
94 abdomen.
95
96 *Image analysis*
97 Ultrasonographic images were reviewed by two examiners (GMD and JLSR) simultaneously
98 using a DICOM image viewing software (Osirix 10.0, Osirix Image processing Software,
99 Geneva, Switzerland). Examiners were blinded to clinical presentation, other imaging
100 findings and surgical or post-mortem findings prior to assessment, the results of which were
101 recorded as a consensus statement. Large colon mesenteric vasculature was identified as the
102 presence of 2 or more hypoechoic circular structures situated directly adjacent to the colon

wall (figure 2).[8] Care was taken to differentiate the colon mesenteric vessels from the lateral caecal vessels, which were identified close to the body wall, starting in the middle portion of the right flank, caudal to the costal arch. They coursed cranioventrally, lateral to the caecum and caudal to the costal arch. In the ventral abdomen, they continued further craniomedially up to the level of the caecal apex (figure 3).

Additionally, the following parameters were recorded: Localisation referred to the side (left/right/both) and the level (dorsal, middle or ventral aspect) of the abdomen where the large colon mesenteric vessels were identified with ultrasonographic examination. The three levels of the abdomen were allotted using two horizontal and parallel lines: line 1 – from the shoulder joint to the coxofemoral joint and line 2 - from the elbow joint to the stifle joint. Therefore, the dorsal portion corresponded to the area dorsal to line 1, the middle aspect corresponded to the area between line 1 and 2, and the ventral portion corresponded to the area ventral to line 2. The intercostal spaces where the vessels could be visualised were recorded, as well as the length, stated as the number of intercostal spaces from where the vessels were identified. Finally, the direction the vessels were followed ultrasonographically from the flanks was noted (vertical or horizontal).

Data analysis

Continuous data were tested for normality and summarized as mean ± SD or median (Range). Categorical data were summarized. Case and control groups were compared by Chi-square test. Fisher's exact test was used to test for association between visibility and localisation of large colon mesenteric vessels (side and level) and final diagnosis. An additional variable was created by combining the side and the level where the vessels where identified and compared to the diagnosis. A P-level of ≤ 0.05 was considered statistically significant. All

127 statistical analyses were performed using a commercially available statistical software (SAS
128 9.4 software, SAS, version 9.4 for Windows, USA).
129
130 **Results**
131 Fifty-four horses met the inclusion criteria. Evaluated were 34 case horses (mean age of 8.81
132 years, ± 4.64 years; range 5 months to 25 years; 13 geldings, 11 stallions and 10 mares; 11
133 Spanish Pure Breed Horse, 8 Spanish Sport Horse, 8 Cross Breed Horse, 2 Lusitano, 1
134 Warmblood, 1 Thoroughbred, 1 Selle Francais, 1 Arabian and 1 Draft Horse) and 20 control
135 horses (mean age of 11.70 years, ± 6.29 years; range 2 to 23 years; 8 stallions, 7 geldings and
136 5 mares; 10 Spanish Pure Breed Horse, 5 Spanish Sport Horse, 2 Thoroughbred, 1
137 Warmblood, 1 Selle Francais and 1 Arabian).
138
139 Of the 34 cases, 26 horses underwent exploratory laparotomy, 6 horses were treated
140 successfully with medical treatment and 2 horses were euthanized and necropsy subsequently
141 was performed. A tentative diagnosis was achieved in the horses treated medically based on
142 the clinical presentation and clinical findings.
143 The complete results are summarized in Table 1. Diagnoses at surgery included RDDLC (n =
144 14), 180° LCV (n = 8), 540° LCV (n = 1) and left dorsal displacement of the large colon
145 (LDDLC) (n = 3). Horses with medical treatment included LC impaction (n = 2), RDDLC (n
146 = 1) and LDDLC (n = 3). A 180º LCV and a RDDLC were diagnosed in the horses that
147 underwent necropsy.
148 Of the 20 horses included in control group, 18 horses underwent exploratory laparotomy and
149 2 horses were euthanized and necropsy subsequently was performed. Diagnoses included
150 inguinal hernia (n = 6), epiploic foramen entrapment (n = 6), volvulus (n = 4), strangulation
151 by pedunculated lipoma (n = 2), mesenteric rent (n = 1) and ileal impaction (n = 1). Vessels

were identified on the ventral portion of the right side of the abdomen in a single horse (1/20, 5%) with a jejunum volvulus.

Of 34 horses included in case group, the LC mesenteric vasculature was identified on the right side of the abdomen in 16/34 horses and on the left side of the abdomen in 17/34 horses. In one horse with 180º LCV, the vessels were visualised on both sides of the abdomen. The LC mesenteric vasculature was distinctly different from the caecal vessels when it was identified on the right side of the abdomen. The vessels were identified through at least 2 intercostal spaces, between 9^{th} and 17^{th} rib. In all cases but one horse with RDLLC, the LC mesenteric vasculature had a horizontal direction. On both sides, vessels were localized at the dorsal (n = 6), middle (n = 25) and ventral (n = 3) aspects of the abdomen.

When vessels were identified on the right side of the abdomen, diagnoses included RDDLC (11/16 horses), 180º LCV (2/16 horses), 540º LCV (1/16 horses) and LC impaction (2/16 horses). When vessels were identified on the left side, diagnoses included LDDLC (6/17 horses), 180º LCV (6/17 horses) and RDDLC (5/17 horses). Vessels were seen in both sides of the abdomen in a single horse with 180º LCV. No statistical significance was identified between the diagnosis and the side where the vessels were identified.

The identification of the colonic mesenteric vasculature was significantly associated with horses presented with large colon-related colic (case group) ($p < 0.0001$). Furthermore, the identification of this mesenteric vasculature in the dorsal aspect on the left side of the abdomen was significantly associated with LDDLC ($p < 0.0001$).

Discussion

The results of this study confirm our hypothesis that the LC mesenteric vasculature can be also visible with transabdominal ultrasonography from the left side of the abdomen in cases

of horses with LC colic. In 50% (17/34 horses) of the cases, vessels were identified from the left side, and in one additional horse, they were visible from both sides.

Previous studies have described visualisation of the LC mesenteric vasculature on the right side of the abdomen in horses with RDDLC and 180º LCV.[7,8] In the present study, LC mesenteric vessels were also identified from the right side in a horse with a 540º LCV and in two horses with LC impaction. With an intestinal rotation of 540º in case of an LCV, the mesenteric surface of the colon is in contact with the right abdominal wall. This could explain why the colon mesenteric vasculature was visualised at this location in one horse.

LC impaction occurs when ingesta cause an intraluminal obstruction. This condition does usually not involve displacement or torsion of the intestine.[9] The fact that the LC mesenteric vasculature was supposedly identified in two patients with LC impaction in our study should be interpreted carefully. In both cases, vessels were observed in the ventral aspect of the right side of the abdomen. This was unusual, as the majority of colonic mesenteric vessels in the other cases in the study were identified in the middle aspect of the flanks. Based on this unusual location, these vessels could potentially also have represented the lateral caecal vessels. However, the lateral caecal vessels were always visible in the right flank in addition to this extra vessel, and had a more ventromedial position in comparison to these vessels in question. It is conceivable that these vessels represent a branch of the lateral caecal vessels, also known as the artery and vein of the arch (figure 3). This specific branch passes along the lesser curvature at the base of the caecum and continues on the lateral aspect of the origin of the large colon.[6] The physiological position of the LC within the abdominal cavity in the horses with LC impaction might have allowed the visualization of these vessels, in contrast to the rest of the horses that had some kind of LC malposition. However, the exact relationship between LC impaction and the visualization of this additional vessel is unknown and it might be coincidental, as one of the control horses also showed a vessel in a similar position. A

previous study has reported the ultrasonographic identification of an additional vessel in the ventral aspect of the right side of the abdomen in horses with a variety of LC disorders. The authors also concluded that these vessels may not always be part of the LC mesenteric vasculature.[10] Ultrasonographic visualisation of vessels at the very ventral aspect of the right abdomen should therefore be carefully interpreted, as the vessels of the arch could represent a normal finding and should not be confounded with the LC mesenteric vasculature. Their more ventral location and the concurrent identification of the lateral caecal vessels might help the examiner with correct differentiation and interpretation of this finding.

In this study, the LC mesenteric vasculature was identified on the left side of the abdomen in horses with various LC conditions, including 180º LCV, RDDLC and LDDLC. This ultrasonographic finding has not previously been reported. If a LCV involves an intestinal rotation of 180º or 540º, the mesenteric surface of the colon contacts the abdominal wall. However, depending on where the volvulus occurs (at the base of the LC, at the level of the caecocolic ligament or at the sternal and diaphragmatic flexures) and the degree of gas distention, the actual LC segment that contacts the abdominal wall, as well as the side on which this contact occurs, can vary. In this study three different presentations of horses with LCV were seen, with the vessels being visible from either the right or the left side of the abdomen, or from both sides at the same time in a single horse. Similarly, location of LC segments can vary with RDDLC, where different configurations have been previously described.[11] This could explain why the colonic vessels were identified from either side of the abdomen in the present study. We therefore think that visualisation of the LC mesenteric vasculature on either side of the abdomen cannot be used as the only feature to differentiate between LCV and RDLLC, as previously described.[8]

Interestingly, identification of the colonic vasculature in the dorsal aspect of the left side of the abdomen was significantly associated with LDDLC. In all (6/34) horses with LDDLC

included in this study, LC mesenteric vessels were visualised at a left dorsal location, either medially to the dorsal border of the spleen or dorsal to it. With entrapment of the LC within the nephrosplenic space, it can mainly rotate along its long axis, thereby exposing the mesenteric side that contacts the medial surface of the spleen or the left dorsal body wall (figure 4). This could explain the consistent ultrasonographic features identified in the cases of LDDLC in our study.

Although in the majority of our cases the LC mesenteric vasculature was identified in the middle aspect of the flank, the cranial to caudal position and the number of intercostal spaces from which visualisation was possible differed considerably. A thorough and complete transabdominal ultrasonographic examination is therefore recommended. We think that use of limited examination protocols, such as the FLASH technique,[12] may not be thorough enough for this purpose and, in some cases, the LC mesenteric vessels may be missed.

It is important to note that occasionally LC mesenteric vasculature can also be identified in the absence of intestinal displacement or a torsion. The normal colonic contents usually create a strong acoustic shadow that precludes examination of the mesenteric intestinal wall.[13] However, if there are ingesta with a high fluid content in the LC lumen, it can be possible to visualise the mesenteric side of a normally positioned colon and, thus its mesenteric vasculature. However, in this situation, the LC mesenteric vasculature is identified at a deeper position and not in proximity to the body wall (figure 5).

A potential limitation of this study was the inclusion of horses that had a positive outcome with medical treatment and therefore lacked the diagnostic gold standard of surgical exploration or necropsy. This group contained 2 LC impactions, 1 RDDLC and 3 LDDLC. The authors decided to include these cases to demonstrate that identification of LC mesenteric vasculature does not necessarily imply the need for surgery. It has previously

been shown that some horses with LDDLC or RDDLC can be successfully treated with medical treatment.[1]

In summary, determination of the position of the LC in horses with acute abdominal pain is very useful when formulating a preoperative diagnosis and prognosis. Ultrasonographic identification of the LC mesenteric vessels through the body wall when the mesenteric aspect is situated against it is a particularly helpful feature. Visualisation of these vessels in the right side of the abdomen can be a predictor of RDDLC or 180º LCV.[7,8] However, to the best of our knowledge, this is the first description of transabdominal ultrasonographic visualisation of the LC mesenteric vasculature through the left side of the abdomen and that this should be considered an indicator of either LDDLC, RDDLC or 180º LCV in horses with LC colic. Additionally, identification of LC mesenteric vasculature in the dorsal aspect of the left abdomen appears highly suggestive of LDDLC.

Acknowledgements

The authors thank Ricardo García Mata for performing the statistical analyses of the data.

Funding

The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests

None declared.

Welfare and ethics

This is a retrospective case series. Explicit owner informed consent for inclusion of animals in this study was not stated.

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Figure legends

Figure 1

Anatomical diagram of the blood supply of the ascending colon and the caecum (medial view). 1- cranial mesenteric artery; 2 - lateral caecal artery; 3 - medial caecal artery; 4 - colic branch of ileocaeolic artery; 5- right colic artery. RDC – right dorsal colon; RVC – right ventral colon; LDC – left dorsal colon; LVC – left ventral colon; C – caecum.

Figure 2

317 Transverse ultrasonographic image obtained on the right 11th intercostal space of a horse
318 with RDDLC, dorsal is to the left. The large colon mesenteric vasculature is identified as two
319 hypoechoic circular structures (arrowheads), situated directly adjacent to the colon wall
320 (arrows). Part of the liver is visible (asterisk).
321
322 Figure 3
323 Anatomical diagram of the caecum and the large colon from the right side, cranial is to the
324 right. 1 – lateral caecal artery; 2 – artery of the arch. RDC – right dorsal colon; RVC – right
325 ventral colon; C – caecum; D – duodenum; RK – right kidney.
326
327 Figure 4
328 A - Diagram of the position of the large colon in relation to the spleen (asterisks) with
329 LDDLC with entrapment of the LC within the nephrosplenic space (caudal view). B and C –
330 transverse ultrasonographic images obtained from the dorsal portion of the left side of the
331 abdomen in two different horses with LDDLC, dorsal is to the left. The large colon
332 mesenteric vasculature can be identified (arrowheads) dorsally (B) and medially (C) to the
333 spleen (asterisk).
334
335 Figure 5
336 Transverse ultrasonographic image obtained on the right 16th intercostal space of a horse
337 with diarrhoea, dorsal is to the left. The right ventral colon is filled with fluid content
338 (asterisk) which allows for the large colon mesenteric vasculature to be identified in a deep
339 position (arrowheads).
340

Tables

Table 1. Complete signalment, ultrasonographic parameters, treatment and final diagnosis of the horses included in case group. EL, exploratory laparotomy; MM, medical management; RDDLC, right dorsal displacement of the large colon; LDDLC, left dorsal displacement of the large colon; LCV, large colon volvulus.

Horse	Age	Breed	Gender	Side	Level	Length	Direction	Treatment	Diagnosis
1	10 y	Spanish Pure Breed	Mare	Right	Middle	4	Horizontal	EL	RDDLC
2	5 y	Cross Breed	Gelding	Right	Middle	4	Horizontal	Euthanasia	RDDLC
3	7 y	Spanish Pure Breed	Stallion	Right	Middle	3	Horizontal	EL	RDDLC
4	9 y	Cross Breed	Gelding	Right	Middle	4	Horizontal	EL	RDDLC
5	6 y	Spanish Sport Horse	Mare	Right	Middle	7	Horizontal	EL	RDDLC
6	25 y	Spanish Pure Breed	Stallion	Right	Middle	4	Horizontal	MM	RDDLC
7	4 y	Spanish Sport Horse	Mare	Right	Middle	3	Horizontal	EL	RDDLC
8	11 y	Spanish Pure Breed	Gelding	Right	Middle	3	Vertical	EL	RDDLC
9	5 m	Spanish Sport Horse	Gelding	Right	Middle	3	Horizontal	EL	RDDLC
10	6 y	Lusitano	Mare	Left	Middle	7	Horizontal	EL	RDDLC
11	11 y	Spanish Pure Breed	Stallion	Left	Middle	4	Horizontal	EL	RDDLC
12	8 y	Cross Breed	Gelding	Left	Middle	8	Horizontal	EL	RDDLC
13	10 y	Draft horse	Gelding	Left	Middle	6	Horizontal	EL	RDDLC
14	11 y	Spanish Pure Breed	Stallion	Left	Dorsal	2	Horizontal	EL	LDDLC
15	7 y	Spanish Pure Breed	Stallion	Left	Dorsal	4	Horizontal	MM	LDDLC
16	8 y	Spanish Pure Breed	Stallion	Left	Dorsal	5	Horizontal	MM	LDDLC
17	10 y	Thoroughbred	Mare	Left	Dorsal	8	Horizontal	MM	LDDLC
18	11 y	Cross Breed	Gelding	Left	Dorsal	5	Horizontal	EL	LDDLC
19	9 y	Warmblood	Mare	Right	Ventral	3	Horizontal	MM	Colon impaction
20	17 y	Arab	Stallion	Right	Ventral	4	Horizontal	MM	Colon impaction

21	18 y	Cross Breed	Gelding	Right	Middle	7	Horizontal	EL	LCV
22	4 y	Spanish Pure Breed	Stallion	Right	Middle	8	Horizontal	EL	LCV
23	6 y	Spanish Pure Breed	Stallion	Right	Middle	6	Horizontal	EL	LCV
24	11 y	Spanish Pure Breed	Stallion	Left	Middle	4	Horizontal	Euthanasia	LCV
25	5 y	Lusitano	Stallion	Left	Middle	5	Horizontal	EL	LCV
26	13 y	Spanish Sport Horse	Gelding	Left	Middle	8	Horizontal	EL	LCV
27	11 y	Cross Breed	Gelding	Left	Middle	6	Horizontal	EL	LCV
28	7 y	Spanish Sport Horse	Mare	Left	Middle	2	Horizontal	EL	LCV
29	6 y	Spanish Sport Horse	Gelding	Left/Right	Middle	6	Horizontal	EL	LCV
30	10 y	Spanish Sport Horse	Mare	Left	Middle	2	Horizontal	EL	LCV
31	7 y	Spanish Sport Horse	Gelding	Right	Middle	10	Horizontal	EL	RDDLC
32	2 y	Cross Breed	Mare	Right	Middle	9	Horizontal	EL	RDDLC
33	7 y	Selle Francais	Gelding	Left	Dorsal	11	Horizontal	EL	LDDLC
34	7 y	Cross Breed	Mare	Left	Middle	6	Horizontal	EL	RDDLC

346