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Ultrasonographically visible hepatic location in clinically normal horses

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The results of this study were presented at the Annual Forum of the American College of Veterinary Internal Medicine, 2014, Nashville TN

Abstract:

Objective: Hepatic ultrasound is widely used for evaluating horses with suspected liver dysfunction. Although a change in size is considered suggestive of pathology, no clear guidelines exist to define the hepatic ultrasonographically visible locations (HUVL) in horses. The aim of the study was to describe the HUVL in normal horses, and determine whether this is altered by signalment, height, weight and body condition score (BCS).

Design: Prospective observational study. **Procedure:** Bilateral ultrasonographic evaluation was performed in 58 clinically normal horses with no history of hepatic disease. The most cranial/caudal intercostal spaces (ICS), total number of ICS in which liver was visualized and the ventral extent of the liver was recorded. **Results:** Liver was visualized on the right in 56/58 horses (97%), the left in 41/58 (71%) and on both sides in 39/58 (67%). The most cranial ICS was 5 (right) or 4 (left) and the most caudal 16 (right) and 11 (left). Liver was visualized in 0-11 ICS (right) and 0-5 ICS (left). Liver was not visualized ventral to the costochondral junction. There was no significant effect of sex, breed, height, weight or BCS on HUVL. Liver was visible in significantly fewer ICS on the right in horses aged 24 years and older compared to younger horses (median 3.5 vs 7 ICS; p=0.016). **Conclusion:** These findings suggest that the liver should be consistently visualized on the right side, but absence of ultrasonographically visible liver on the left is unlikely to be clinically relevant. Liver dimensions may be decreased in older horses.

Key words: liver; imaging; size; atrophy

Abbreviations:

HUVL: hepatic ultrasonographically visible locations

ICS: intercostal space

Introduction

Ultrasonographic examination of the liver is widely utilised in the investigation of horses with suspected hepatic disorders. Other imaging modalities such as computed tomography and magnetic resonance imaging, which are routinely employed in people and small animals such as cats and dogs cannot be performed on adult horses because of their size. In addition, the liver cannot be palpated either per rectum or via transabdominal palpation. As such, hepatic ultrasound has become a key tool in the investigation of hepatic disorders in horses.[1-4] Ultrasound is used to evaluate hepatic echogenicity, for the presence of masses and to assess hepatic size.[1-5] Although the sensitivity of ultrasound for detecting hepatic disease is low (26%), the specificity and positive predictive value are relatively high (86% and 85% respectively) suggesting that when hepatic abnormalities are present ultrasonographically, they correlate to organ dysfunction.[5] An increase in hepatic size as determined by ultrasonographic examination has been reported in conjunction with a number of different disorders including neoplasia, cholangiohepatitis and cholelithiasis, hepatic lipidosis, non-neoplastic masses, liver lobe torsion and Tyzzer's disease.[3,4, 6,7] A smaller than normal liver has been reported secondary to hepatic fibrosis, cholelithiasis and Theiller's disease.[3,4] Right liver lobe atrophy has been described as a post mortem finding in a group of horses aged 5-30 years, and was hypothesized to be secondary to chronic colonic compression of the hepatic parenchyma.[8] Although hepatic ultrasound findings were not reported in this study, a decrease in the size of the right hepatic lobe identified via ultrasound examination has been described as a normal finding in older horses.[3,4] Data to support this observation has not, to the authors' knowledge, been presented, nor the age at which this finding might occur.

Despite hepatic size being a key factor in the ultrasonographic evaluation of the liver, reference ranges for ultrasonographically visible hepatic dimensions have not been determined in horses, and the majority of assessments are made based on a subjective evaluation of hepatic size.[3,4]

The lack of defined hepatic ultrasonographic dimensions means that assessment of hepatic size remains subjective. Documenting the location of the left and right liver lobes could potentially provide more objective information for clinicians attempting to assess liver size in the horse. The aims of this study were thus to (1) Determine the ultrasonographically visible hepatic location (based on visibility within each ICS) in clinically normal horses; and (2) Determine whether these locations are altered by age, breed, sex, weight, body condition score and height.

Materials and Methods

The study was approved by the Ethics and Welfare Committee of the Royal Veterinary College and informed owner consent was obtained prior to examination. Percutaneous ultrasonographic examination was performed on 58 clinically normal horses with no history of hepatic disease. Horses were recruited from three separate locations including an equine charity, a facility for retired working horses and an equine referral hospital population. Horses with no clinical evidence or history of hepatic disease were included. Horses with a history of hepatic disease, or those being evaluated in the referral hospital for gastrointestinal disease were excluded. The age, breed and sex of each horse were recorded. Prior to examination each horse’s weight was recorded, height at the withers measured in centimeters and body condition score (BCS) assigned utilising the Henneke system.[9] The feeding and management routines varied according to location and individual horse, and horses were not withheld from food or water prior to examination.

Ultrasound examination was performed using either a MyLab^{TM} 30 VET Gold (Esaote Group, Genova, Italy) or a Vivid 7 Dimension (GE Healthcare, Hatfield, Herts UK) using a 2.5MHz phased-array transducer at a frequency of 3.5 MHz.

The examinations were performed during the summer months, and horses were not clipped or sedated for the procedure. Contact was enhanced by ensuring coats were free of dirt and dust followed by liberal application of surgical spirit. The examination was performed on both sides of the abdomen starting in the paralumbar fossa and progressing cranially in each intercostal space. In each space, the presence or absence of the liver was noted following evaluation in longitudinal section from the dorsal aspect of the abdominal cavity as determined by the characteristic appearance of gastrointestinal viscera and/or the presence of the pleural reflection to a point ventral to the costo-chondral junction. The probe was maintained perpendicular to the horse's skin and was not angled in a cranial or caudal manner within each ICS. The presence or absence of the liver in each ICS was determined in real time by an experienced ultrasonographer based on the characteristic ultrasonographic appearance as previously described.[3,4,10] The total number of ICS in which the liver could be identified, the most cranial and the most caudal intercostal space in which the liver could be visualised, and whether the ventral margin of the liver extended ventral to the costochondral junction was noted.

For the purposes of the analysis, horses were further categorised based on height (horses 150cm and above; ponies below 150cm); weight (less than 250kg; 251-500kg; greater than 501kg) breed: (pony breeds; Cobs and cob crosses; Thoroughbred/Warmbloods or crosses), and BCS: underweight (1-4) ideal (5-6) overweight (7-9). As there is no definition for the age at which horses are considered 'older' and thus have an increased likelihood of right liver lobe atrophy, three age categories were utilised. These were based on 2 different definitions for geriatric horses (older than 20 years; older than 15 years) as well as a category that defined 'older' horses as the oldest 10% of the study population (in this case 24 years and older).[11-14]

Statistical analysis

Statistical tests were selected and performed by one of the authors (IJ) using a commercially available software package (SPSS 20 for Windows; SPSS Inc, Chicago, IL) and significance was assumed at $P<0.05$. As all data apart from body weight were not normally distributed, the median (± interquartile range [IQR]) is displayed for each measurement. The body weight is expressed as mean (± standard deviation [SD]). The total number of ICS, and the most cranial and caudal ICS in which the liver could be visualized on both sides of the abdomen were compared between age, sex, height, breed, and BCS categories using the Mann Whitney U or the Kruskal-Wallis test as appropriate. A Spearman's/Pearson's rank order correlation was performed to determine whether there was a correlation between horse age, weight, BCS and height, and the total ICS, most cranial and most caudal ICS in which the liver was visualized on both sides of the abdomen. Finally, the proportion of horses in each category (age, weight, breed, sex, BCS and height) in which the liver could be visualized at each ICS was compared using the Chi-squared test for independence.

Results

Ultrasonographic evaluation of the liver was performed in 58 horses representing a wide range of ages, heights, weights, breeds and body condition scores (Table 1). There were 34 male horses (33 geldings and one colt) and 24 mares. The total number of horses within each category is shown in Table 2.

The liver could be visualized in at least one ICS on the right in 56/58 (97%) of horses, on the left in 41/58 (71%) and on both sides in 39/58 (67%). The most cranial ICS in which the liver could be visualised was ICS 5 (right) and ICS 4 (left) and the most caudal was ICS 16 (right) and ICS 11 (left). The number of ICS in which the liver could be visualized ranged from 0 to 11 ICS (median 6.5; IQR 3) on the right side and from 0 to 5 ICS (median 2; IQR 3) on the left. On the right, liver was most consistently visualized in the 12th (53/58 horses), 13th (55/58) and 14th ICS (54/58; Figure 1). The intercostal spaces on the left where liver could most consistently be identified were ICS 6 (27/58) and ICS 7 (30/58; Figure 2). The liver did not extend ventral to the costochondral junctions in any horse. There was no significant effect of sex, breed, height, body weight or BCS on the HUVL. The liver was visible in significantly fewer ICS on the right (median 3.5) in horses aged 24 years and older compared to younger horses (median 7 ICS; p=0.016). (Tables 3a and b)

When the proportion of horses in each age, sex, breed, height, weight and BCS categories in which liver could be visualised ultrasonographically at each ICS was compared, there was no statistically significant difference identified. There was also no significant correlation between horse age, weight, BCS and height, and the total ICS, most cranial and most caudal ICS in which the liver was visualized on both sides of the abdomen.

Discussion

To the authors' knowledge, this is the first study that has detailed the anatomical ultrasonographic position of the liver on both sides of the abdomen in clinically normal horses. A previous report, published over 20 years ago when equine ultrasonography was in its infancy, described the liver as being visible between the 9th and 16th ICS on the right, but did not describe whether it was visible on the left.[15] In the current study, the liver could be seen as far cranially as ICS 5 on the right hand side, albeit in only a small proportion of horses, and could be seen in 71% of horses from the left hand side. These findings are more consistent with more recent suggestions that the liver is usually visible on the right between 8-15 ICS and on the left between 7-10 ICS.[10] In no horses was the liver visible ventral to the costochondral junctions, supporting the suggestion that this finding would be consistent with hepatomegaly.[3,4,] A recent study investigated the frequency with which the liver could be visualized ultrasonographically at sites where a blind percutaneous liver biopsy would be performed.[2] As a result, only the right side of the abdomen was evaluated and evaluation of the entire ICS in a dorso-ventral manner was not performed as the authors were specifically interested in biopsy site location. As such, the findings of this study cannot be directly compared to the current study, although in both studies, the liver was most frequently visualized in the 13th and 14th ICS on the right hand side.

In people, hepatic size can be affected by factors such as body mass index (BMI), age and gender, with reference ranges for normal liver size differing between patients depending on these characteristics.[16,17,18] An increased liver size is seen with higher BMI and in men. A similar finding was not however identified in the current study, although the method for the assessment of liver size differed from human studies. In people, ultrasonographic measurement of liver size as measured by depth of parenchyma at the midclavicular line has been shown to be a good estimate of hepatic size, although computed tomographic (CT) scanning and the calculation of liver volume is considered a more precise measure.[16,19] In the authors' experience, ultrasonographic identification of the liver in obese horses can be difficult, although the findings of the study do not support this clinical impression as there was no difference in the number of ICS in which liver could be identified on either side of the abdomen, regardless of body condition score. However, the number of horses with BCS of 8 or 9 was low (1/58 with BCS 9; 0/58 with BCS of 8) and examination of a larger number of obese horses may provide additional information to support or refute this clinical impression.

The effect of age on the ultrasonographically visible hepatic dimensions was of particular interest. Right liver lobe atrophy is frequently described as a common and normal finding in 'older' horses, with some authors stating that 'little or none' of the right liver lobe is imaged on the right in normal older horses.[3] The age at which horses are considered 'older' and thus when this would be considered a normal finding has not to the authors' knowledge been determined, nor has evidence to support this clinical impression been provided. In the only post mortem study reporting right liver lobe atrophy, the ages of the horses ranged from 5 to 30 years the mean age was 12.6 years.[8] The majority of these horses (15/17) had a history of abdominal pain, and the author hypothesized that a diet high in concentrates may have contributed to atony of the right dorsal colon with resulting distention that then compressed the right liver lobe. An expected decrease in liver weight determined at autopsy has been described with increasing age in people, although there is some disagreement as to whether this change in size can be detected ultrasonographically.[16,20,21]

In the current study, the two horses in which liver could not be identified on the right hand side were aged 42 and 28 years, which may support the age related decrease in size of the right liver lobe described by various authors.[3,4] As described, the age categories chosen for comparative purposes were based on studies in geriatric horses and using these categories no statistical differences in the liver dimensions based on age could be identified.[11-14] It was only when the oldest 10% of horses in the study (older than 24 years) were compared to younger horses that a difference in the number of ICS where liver could be visualized on the right was identified. As there were only 6 horses in this 'older' group, it is unknown whether this difference would remain in a larger group of horses. It is unlikely that determination of the number of ICS in which the liver can be visualized is a sensitive enough measure to identify more subtle hepatic atrophy.

In people, ultrasonographic measurement of liver size based on measurement at the midclavicular line has been shown to be a good estimate of hepatic size.[16] The measurement is obtained with patients in the supine position with right hand placed behind the head to optimise hepatic visualisation. Whether an adaptation of this method could be used to assess hepatic size in horses is unknown, although hepatic depth measurements have been reported in cows and goats with the portal vein and caudal vena cava used as landmarks.[22,23] An increase in pulmonary volume has been reported in horses with chronic lung diseases such as Recurrent Airway Obstruction.[24] Whether this could explain an inability or impaired ability to visualise the liver ultrasonographically is unknown. Neither of the horses in this report had any known respiratory disease, although whether the ability to visualise the liver could be improved by implementation of a rebreathing examination is unknown, as it was not performed in either case.

Whilst the horses in this study did not display any clinical signs consistent with hepatic disease, because biochemical analysis of venous blood was not performed the presence of subclinical hepatic disease cannot be ruled out. Although the horses were relatively evenly distributed within most categories, lighter horses, those with a low (1-4) or a high (8-9) BCS and older horses (>24 years) were relatively underrepresented within their respective categories. Whether a more even distribution of horses would have affected the results is unknown. Finally, although the purpose of the study was to determine the hepatic ultrasonographically visible location , this is a relatively crude measure of hepatic size and does not take into consideration the potential for cranial or caudal displacement secondary to the presence of pathology in adjacent visceral structures (eg. colonic dilation). Ultrasonographic examination including various measurements of the depth of hepatic parenchyma, followed by post mortem examination to determine actual hepatic dimensions would be required to provide further information regarding the normal hepatic ultrasonographic size in horses, and thus whether ultrasound can be used to more accurately determine a change in hepatic size in horses with hepatic disease.

Conclusion

The findings of this study provide information to guide clinicians as to the hepatic location visible on ultrasonographic examination in clinically normal horses. The liver can be expected to be seen on the right hand side most commonly in ICS 12, 13 and 14, and on the left in ICS 6 and 7. The number of ICS in which the liver can be visualised may be lower in older horses, although other characteristics do not appear to affect the HUVL.

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Tables

Table 1: Descriptive Data of 58 Clinically Normal Horses Enrolled in Study

Characteristic	**Median (IQR)**	**Minimum to Maximum**
Age (years)	14.5 (13)	1-42
Height (centimetres)	152.4 (34.3)	83.8-180.3
Weight (kg) *mean (Std Dev)	461.7kg (187.8)	115-918
Body condition score (1-9)	5 (2)	2-9

Table 2: Total Number of Horses in each Category. Cobs/X: Cobs or Cob crosses; TB/WB/X: Thoroughbreds, Warmbloods or crosses; BCS: out of 9

Age (years) **Category; N**	**Breed** **Category; N**	**Sex** **Category; N**	**Height (cm)** **Category; N**	**Weight (kg)** **Category; N**	**BCS** **Category; N**
≤20; 40	Ponies; 20	Male; 34	≥150cm; 30	<250; 11	1-4; 11
20; 18	Cobs/X; 16	Female; 24	<150cm; 28	251-500; 21	5-6; 35
	TB/WB/X; 22			>501; 26	7-9; 12
≤15; 30					
>15; 28					
<24; 52					
≥24; 6					

Table 3a: Comparison of median number of ICS, the most cranial and the most caudal ICS on the right in which liver could be visualised ultrasonographically based on age, sex, breed, height, weight and BCS categories. P<0.05. TB: Thoroughbred. WB: Warmblood. X: cross breed. ICS: Intercostal space. BCS: Body condition score (1-9)

Total ICS right				**P value**
Age category	≤20y	>20y		0.622
Median No. ICS	6	7		
Age	≤15y	>15y		0.399
Median No. ICS	7	6		
Age	<24y	≥24y		0.016*
Median No. ICS	7	3.5		
Sex	Male	Female		0.442
Median No. ICS	7	6		
Breed category	Pony	Cob/X	TB/WB/X	0.556
Median No. ICS	6	7	7	
Height	Horse	Pony		0.620
Median No. ICS	7	6		
Weight category	≤250kg	251-500kg	>500kg	0.780
Median No. ICS	6	6	7	
BCS category	1-4	5-6	7-9	0.556
Median No. ICS	6	6	7	

Most cranial ICS				**P value**
Age category	≤20y	>20y		0.193
Median No. ICS	9	8		
Age	≤15y	>15y		0.914
Median No. ICS	8.5	9		
Age	<24y	≥24y		0.911
Median No. ICS	9	9		
Sex	Male	Female		0.266
Median No. ICS	8	9		
Breed category	Pony	Cob/X	TB/WB/X	0.815
Median No. ICS	9	9	8	
Height	Horse	Pony		0.670
Median No. ICS	8.5	9		
Weight category	≤250kg	251-500kg	>500kg	0.517
Median No. ICS	10	8	8.5	
BCS category	1-4	5-6	7-9	0.590
Median No. ICS	8	9	8	

Most caudal ICS				**P value**
Age category	≤20y	>20y		0175
Median No. ICS	14	15		
Age	≤15y	>15y		0.757
Median No. ICS	14	14		
Age	<24y	≥24y		0.175
Median No. ICS	14	14		
Sex	Male	Female		0.447
Median No. ICS	2	1.5		
Breed category	Pony	Cob/X	TB/WB/X	0.877
Median No. ICS	14	14.5	14	
Height	Horse	Pony		0.904
Median No. ICS	14	14		
Weight category	≤250kg	251-500kg	>500kg	0.657
Median No. ICS	15	14	14	
BCS category	1-4	5-6	7-9	0.692
Median No. ICS	14	14	14	

Table 3b: Comparison of median number of ICS, the most cranial and the most caudal ICS on the left in which liver could be visualised ultrasonographically based on age, sex, breed, height, weight and BCS categories. P<0.05 Thoroughbred. WB: Warmblood. X: cross breed. ICS: Intercostal space. BCS: Body condition score (1-9)

Total ICS left				**P value**
Age category	≤20y	>20y		0.380
Median No. ICS	1.5	2		
Age	≤15y	>15y		0.591
Median No. ICS	1.5	2		
Age	<24y	≥24y		0.249
Median No. ICS	1.5	2.5		
Sex	Male	Female		0.447
Median No. ICS	2	1.5		
Breed category	Pony	Cob/X	TB/WB/X	0.109
Median No. ICS	2	1	2	
Height	Horse	Pony		0.892
Median No. ICS	2	1.5		
Weight category	≤250kg	251-500kg	>500kg	0.678
Median No. ICS	1	2	2	
BCS category	1-4	5-6	7-9	0.167
Median No. ICS	3	1	1	

Most cranial ICS				**P value**
Age category	≤20y	>20y		0.455
Median No. ICS	6	6		
Age	≤15y	>15y		0.100
Median No. ICS	6	6		
Age	<24y	≥24y		0.676
Median No. ICS	6	6		
Sex	Male	Female		0.429
Median No. ICS	6	6		
Breed category	Pony	Cob/X	TB/WB/X	0.430
Median No. ICS	5.5	6	6	
Height	Horse	Pony		0.262
Median No. ICS	6	6		
Weight category	≤250kg	251-500kg	>500kg	0.755
Median No. ICS	6	6	6	
BCS category	1-4	5-6	7-9	0.190
Median No. ICS	5	6	6	

Most caudal ICS				**P value**
Age category	≤20y	>20y		0.460
Median No. ICS	7	8		
Age	≤15y	>15y		0.790
Median No. ICS	7	7		
Age	<24y	≥24y		0.458
Median No. ICS	7	7		
Sex	Male	Female		0.529
Median No. ICS	7.5	7		
Breed category	Pony	Cob/X	TB/WB/X	0.094
Median No. ICS	7	7	8	
Height	Horse	Pony		0.070
Median No. ICS	8	7		
Weight category	≤250kg	251-500kg	>500kg	0.313
Median No. ICS	7	7	8	
BCS category	1-4	5-6	7-9	0.858
Median No. ICS	7	7.5	8	

Figure 1: Percentage of 58 horses in which liver could be visualized via ultrasonography at each intercostal space on the right.

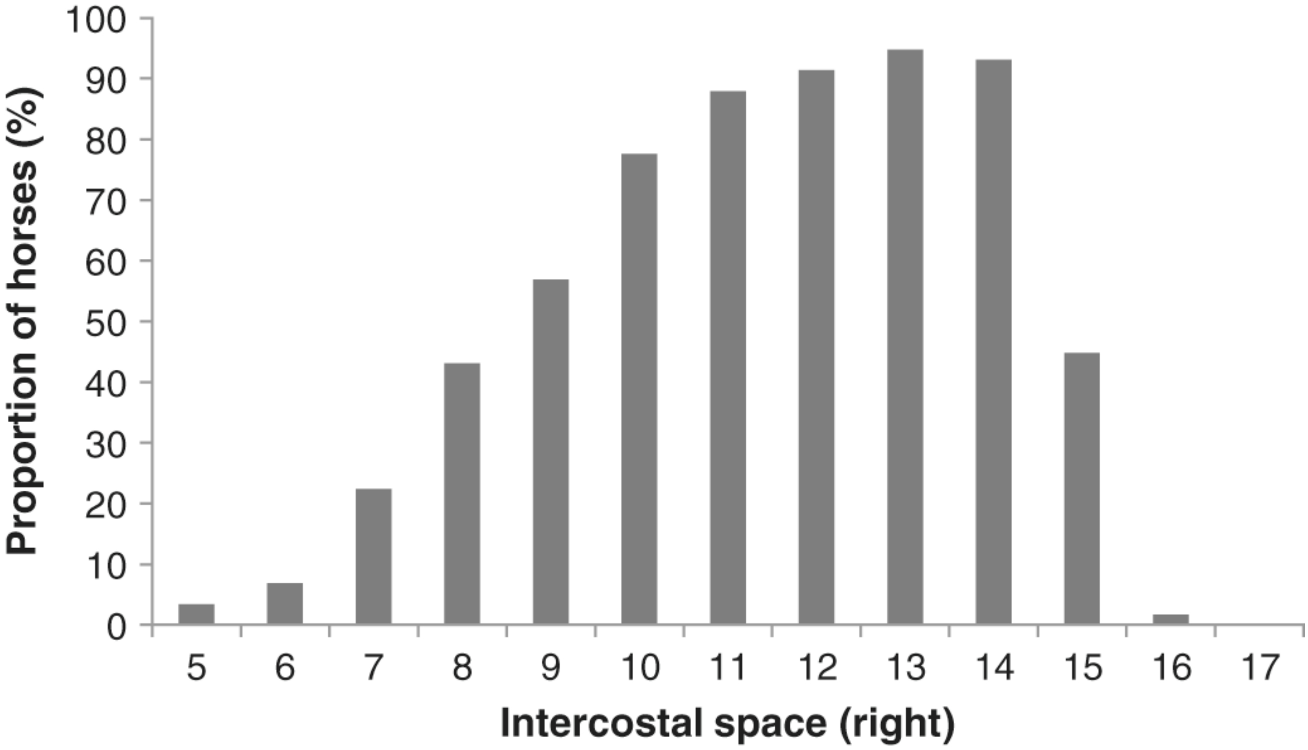

Figure 2: Percentage of 58 horses in which liver could be visualized via ultrasonography at each intercostal space on the left.