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[Original Article]

Reference Values and Repeatability of Ultrasonographical Assessment of Caudal Vena Cava and Aorta in Clinically Healthy Small Ruminants

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Abstract

THE present study provides reference values of the caudal vena cava and aorta parameters in clinically healthy sheep with normal hydration status, to provide a guide to assess such large blood vessels, which will be helpful in diagnosing conditions that affect blood volume and, subsequently, theses large blood vessels. For this study, 30 clinically healthy sheep, with no observable clinical evidence of dehydration or cardiovascular disease, were identified for inclusion in the study. Using transabdominal ultrasonography, the measurements of both the diameter and area of caudal vena cava and aorta were evaluated using the paralumbar window view. The mean ± SD of the ultrasonographic measurements as well as the calculated indices for the caudal vena cava to aorta diameter and area ratios in the selected sheep were as follows 1.22 ± 0.11 mm for the diameter of caudal vena cava, 1.20 ± 0.11 mm for the diameter of aorta, 1.75 ± 0.15 mm2 for the area of caudal vena cava, 1.21 ± 0.11 mm2 for the area of aorta, 1.01 ± 0.02 mm for the index of the diameter of caudal vena cava to aorta, and 1.44 ± 0.05 mm2 for the index of the area of caudal vena cava to aorta. This is the initial study to provide reference values for the caudal vena cava and aorta parameters in clinically healthy sheep, informed by probability theory and statistical methodologies, the coefficient of variation, thereby demonstrating the precision of the assay. The ultrasound assessment of the caudal vena to aorta ratio is a promising method for early recognition of changes in vascular volume status in veterinary medicine. Thus, Knowing the reference values for the normal parameters of the large blood vessel parameters in clinically healthy small ruminants supports the future use of the caudal vena cava: aorta ratio as a novel index for assessing the hydration status in diseased sheep.

Keywords: Sheep, Abdominal ultrasonography, Dimension, Area, Caudal vena cava, Aorta.

Introduction

Sheep are examples of small ruminants, which are essential to rural communities' ability to support themselves and build environmentally responsible sustainable agricultural systems [1]. Moreover, small ruminants form a major category of farm animals, playing a crucial role in generating income and providing employment for those living in rural communities [2]. However, a number of studies showed how crucial it is to prioritize small ruminant livestock production in order to provide food security in rural areas as well as to contribute to the reduction of poverty and improve household well-being [3,4]. The relevance of small ruminants in smallholder agriculture is highlighted by their distinctive attributes, such as shorter production cycles and accelerated growth rates. Furthermore, they are easier to oversee, require less financial investment, carry a lower risk of loss, and have minimal feed requirements. They also show greater adaptability to harsh environmental conditions compared to large ruminants [5].

Surgical intervention is frequently necessary for abdominal diseases in small ruminants, which may result in life-threatening hypotension due to hypovolemia and/or septicemia. Likewise, in diseased small ruminants, diarrhea can result in hypovolemia and severe dehydration [6].

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Consequently, the effective management of hypovolemic and distributive shock in small ruminants has the potential

to enhance survival rates [7,8]. Nevertheless, accurately evaluating the intravascular volume status in these animals remains a challenge. Clinical, hemodynamic, and biochemical signs can all be used to diagnose acute circulatory failure; however, recent research has shown that measuring the human inferior vena cava and the caudal vena cava (CVC) may be a quick, accurate, and safe way to determine the intravascular volume status of individuals who are critically ill [9-12].

The appropriate administration of intravenous fluids is fundamental to animal care, particularly during pre-operative phases and in the management of diverse medical conditions. In small animal medicine, fluid therapy protocols are predominantly determined by the patient's body weight and physical assessment [13], as well as clinical examination and vital signs. However, this protocol has low ability to forecast humans' fluid response [14] and have weak correlations with both cardiac output and intravascular volume status in dogs [15].

Approximately 70% of the circulating blood volume is contained within the venous system, which serves a reservoir that aids in the return of blood from the extremities back to the heart, playing a crucial role in the preservation of cardiac hyperemia. Therefore, during episodes of hypovolemia caused by bleeding or other reasons, sympathetic tone triggers the contraction of peripheral veins, effectively directing blood into the vena cava, which is vital for supplying blood to the heart and for enhancing central venous pressure [16].

When central venous pressure rises, it causes an increase in right ventricular end-diastolic pressure, which in turn elevates both ventricular volume and cardiac output per cycle [17]. This relationship positions the venous system as a vital indicator of hemodynamic function. Nonetheless, the high compliance of venous vessels renders their volume susceptible to external factors, including cardiac ailments, airway pressure, and intra-abdominal pressure [18]. Therefore, the development of appropriate diagnostic tools for vascular volume disturbances, the evaluation of vascular volume status, and the anticipation of fluid responsiveness is vital for the effective emergency management and critical care of small ruminant animals.

In human medicine, patients with reduced inferior vena cava diameter have decreased circulating blood volume. Numerous studies have highlighted the effectiveness of ultrasonography in evaluating the dimensions of the inferior vena cava as a means of identifying reduced circulating blood volume [19]. Studies within the field of veterinary medicine have highlighted the necessity of measuring the dimensions of the CVC utilizing both radiographic and ultrasonographic approaches. An enlarged CVC diameter seen in thoracic radiographs of dogs can be indicative of right heart failure, while a smaller CVC diameter reflects a decrease in circulating blood volume. Recently, there have been attempts to apply ultrasonography in order to analyze the circulatory dynamics in dogs by measuring the size of CVC, with particular emphasis on the ratio of CVC diameter to the diameter of the aorta (Ao). This index has been suggested to have a correlation with the volume of circulating blood [20]. As a result, this study was carried out to establish reference values for large blood vessels, specifically the CVC and Ao parameters, in clinically healthy sheep with normal hydration status, to provide a guide to assess these vessels, which will be helpful in diagnosing conditions that affect blood volume and, subsequently, theses large blood vessels.

Material and Methods

Animals and clinical examination

The current study was performed on a sample of 30 clinically healthy sheep, which included 10 males and 20 non-pregnant females. These sheep were randomly selected from a broad age spectrum to achieve a relatively balanced distribution across the age groups of 2 years to more than 5 years, with weights between 70 and 100 kg. The body condition scores for the studied sheep were recorded as follows: 10 sheep received a score of 3, 15 sheep were assigned a score of 3.5, and 5 sheep obtained a score of 4. All sheep were selected for the study based on their clinical health status, ensuring they were healthy; free from any signs of dehydration or any cardiovascular diseases. This was ensured through a comprehensive clinical examination, which included assessing the hydration status and a thorough cardiac evaluation that assessed heart rate, rhythm regularity, intensity of heart sounds, presence of any unusual heart sounds, along with the analysis of electrocardiographic data, is crucial [21]. As a result, it is imperative to consider any sign of systemic disease, any sign of dehydration, tachycardia, arrhythmias, heart murmurs, and any detectable cardiac defects, and sheep that were noncompliant with handling protocols were established as exclusion criteria. The selected sheep were housed indoors at the Faculty of Veterinary Medicine, Kafr Elsheikh University, Kafr Elsheikh, Egypt. The nutritional regimen for all sheep, involved in the study, consisted of a maintenance balanced mixed ration, which included ad libitum access to chopped wheat straw, along with 1.0 to 2.5 kg of bran and 1.0 to 2.5 kg of crushed corn, enriched with a mixture of trace elements and minerals that are appropriately adjusted for their age, in alignment with the standards established by the National Research Council (NRC). Throughout the duration of the experiment, Uniform management and feeding practices were implemented for all sheep, with careful veterinary supervision in place. The protocols for animal care and use were rigorously followed in accordance with all relevant institutional and national standards, as outlined by the Medical Research Ethics

Committee at the Faculty of Veterinary Medicine, Kafr Elsheikh University, Kafr Elsheikh, Egypt, under code No. KFS-IACUC/171/2023.

Ultrasonographic examination

The ultrasonographic evaluations were carried out on sheep in a standing position, without the use of sedation. The sheep were gently secured using a seated holder that provided lateral support to the animal's neck. A small square section of the skin, located on the right para lumbar region beneath the 3rd to 6th lumbar vertebrae, was shaved, and surgical spirit was utilized to disinfect the area. Subsequently, ultrasound coupling gel was applied and permitted to penetrate the skin for at least five minutes to facilitate better contact with the probe. In order to conduct the ultrasonographic assessments, a 6.5 to 8 MHz phased micro convex array transducer (Vinno 5 Ultrasound Machine) (Portable Ultrasound Diagnostic System, Vinno Technology (SUZHOU) CO., LTD, China) was used. The transducer was placed and adjusted over right para lumbar region under 3rd to 6th lumbar vertebrae to get the required standard image. Furthermore, adjustments were made to the depth and gain controls to improve the image's appearance as required. Both transverse and longitudinal images of the CVC and AO were obtained according to standard method. Each sheep underwent three assessments of both the diameter and area of CVC and AO within a single batch on the same examination day, which is essential for calculating the intra-assay coefficient of variation. All ultrasonographic evaluations were performed after 9:00 AM by a single trained examiner and subsequently reviewed by two experts to minimize individual variations.

Ultrasonographic views

A routine transabdominal ultrasonography was conducted to assess both the diameter and area of CVC and AO at the paralumbar window [20, 22-24]. At the outset, the transducer was initially positioned transversely on the right flank, posterior to the last rib, which facilitated the observation of the left kidney. The probe was then progressively tilted from a cranial to a caudal alignment until both the CVC and AO were visible. Following this adjustment, the transducer was rotated by 90o, which is necessary to obtain a longitudinal view that enabled the CVC and AO to be visualized parallel to one another within the same imaging frame. Utilizing both the paralumbar transverse and longitudinal views, the investigator assessed the diameter of both CVC and AO by measuring from the inner wall to the inner wall. Additionally, the areas of both the CVC and AO were determined. The indices of the diameter and area for both were computed as the ratio of the CVC to the AO.

Statistical analysis

Statistical analyses were carried out using GraphPad Prism for Windows version 9.0, provided by GraphPad Software Inc., California, USA. In order to evaluate the normality of the distribution of the diameters and areas of the CVC and AO obtained data, the Kolmogorov–Smirnov normality test was utilized, confirming that the data followed a normal distribution. Moreover, the report presents the frequency distribution and summary statistics, detailing the mean ± SD, 95% CI, median (range), and the 10th, 25th, 75th, and 90th percentiles for the ultrasonographic measurements, including the diameters and areas of the Ao and CVC, as well indices for the CVC to Ao diameter and area ratios in the selected sheep were calculated. The reliability of these measurements was examined through the determination of the intra-assay coefficient of variation (CV). A CV of less than 15% was categorized as low variability. Whereas, a CV ranging from 15% to 25% was deemed to exhibit moderate variability. However, a CV exceeding 25% was classified as high variability. P-value falling below 0.05 was acknowledged as indicative of statistical significance.

Results

The clinical examination confirmed that all selected sheep were in good health, were not dehydrated, and had not received fluid therapy. The body temperature, heart rate, respiratory rate, appetite, rumination pattern, and hydration status were within the normal range all over the entire experiment. The body temperature was 38.5 – 40.0 o C (Mean ± SD 39.12 ± 0.44). The heart rate was 70 – 80 beat/minute (Mean ± SD 73.83 ± 5.42). The respiratory rate was within normal range 20 – 34 respiratory cycle / minute (Mean ± SD 23.43 ± 4.67). The analysis revealed no statistically significant differences between both sexes in age (P = 0.212), body weight (P = 0.513), heart rate (P = 0.408), and respiratory rate (P = 0.575).

The ultrasonographic images acquired from the right paralumbar window revealed the CVC and AO. Views from the paralumbar site were successfully documented in all selected sheep. The ultrasound measurements, including the diameters of the CVC and AO (Figure 1), as well as the areas of the CVC and AO (Figure 2), along with the calculated indices for the CVC to Ao diameter and area ratios, were presented based on the paralumbar views.

Regarding the frequency distribution of the ultrasonographic measurements, including the diameters and areas of the CVC and Ao, as well as the calculated indices for the CVC to Ao diameter and area ratios, which were derived using the paralumbar view in the examined sheep, the highest frequency of ultrasonographic measurements was 1.25 – 1.30 mm for the diameter of both CVC and Ao, 1.75 – 1.90 mm2 for the area of CVC, 1.10 – 1.35 mm2 for the area of Ao, 0.99 – 1.06 mm for the index of the diameter of CVC to AO, and 1.38 – 1.50 mm2 for the index of the area of CVC to AO. Meanwhile, the lowest frequency of ultrasonographic measurements was 0.85 – 0.90 mm for the diameter of CVC, 0.85 – 1.00 mm for the diameter of Ao, 1.35 – 1.45 mm2 for the area of CVC, 0.85 – 0.90 mm2 for the area of Ao, 0.97 – 0.99 mm for the index of the diameter of CVC to AO, and 1.34 – 1.36 mm2 for the index of the area of CVC to AO (Table 1).

Concerning the results of the ultrasonographic measurements, including the diameters and areas of the Ao and CVC, as well as the calculated indices for the CVC to Ao diameter and area ratios, which were derived from the paralumbar views in the selected sheep, the mean ± SD of the obtained measurements was as follows: 1.22 ± 0.11 mm for the diameter of CVC, 1.20 ± 0.11 mm for the diameter of AO, 1.75 ± 0.15 mm2 for the area of CVC, 1.21 ± 0.11 mm2 for the area of Ao, 1.01 ± 0.02 mm for the index of the diameter of CVC : AO, and 1.44 ± 0.05 mm2 for the index of the area of CVC : AO (Table 2).

Regarding the intra-assay CV of the ultrasonographic measurements, including the diameters and areas of the Ao and CVC, as well as the calculated indices for the CVC to Ao diameter and area ratios, which were derived from the paralumbar views in the selected sheep, showed low (CV < 15%) variability (Table 3).

Discussion

Based on the findings indicated that the diameter of the CVC diminished with an increase in the level of dehydration, while it subsequently increased following fluid therapy; conversely, the AO diameter showed no significant change. The evaluation of index of the CVC to Ao diameter ratio using ultrasound assessment presents a promising approach for the early detection of alterations in vascular volume status within the field of veterinary medicine. Therefore, this article provides the reference values for the normal parameters of the large blood vessels parameters, specifically the CVC and Ao parameters, in clinically healthy small ruminants with normal hydration status. These values will serve a guide to assessing these vessels, which will be helpful in diagnosing conditions that affect blood volume and, subsequently, theses large blood vessels. This will also support the use of the CVC to Ao ratio as a novel approach for determining the hydration status in sheep that are critically ill. Assessing preload on a routine basis is a considerable challenge for clinicians treating critically ill patients or those undergoing surgery. Although physical examination is vital in these cases, the hemodynamic parameters that are routinely measured do not provide a reliable correlation with preload status [20,25]. As a result, they may not effectively distinguish between hypovolemic and hypervolemic patients. In the past 20 years, our insights into fluid responsiveness have undergone significant transformation. Hence, new indicators have been introduced and have been shown to be superior to previous [26,27]. The availability of the normal parameters of the large blood vessels parameters in clinically healthy small ruminants facilitates the prediction of fluid response in such a population. Thus, the CVC to Ao ratio serves as an effective monitoring instrument for assessing the need for fluid therapy and customizing it to meet the specific needs of individual patients in critical regions of sheep. It is possible to carry out this procedure rapidly and without invasive methods, facilitating the easy monitoring of hemodynamic trends.

In this investigation, we established that the CVC and Ao can be conveniently visualized at the appropriate paralumbar site by positioning the probe beneath the 3rd to 6th lumbar vertebrae in sheep of varying ages. Moreover, a study on calves confirmed that the CVC and Ao can be effectively evaluated through the right paralumbar site, with measurements of both the diameter and area of the CVC and Ao showing high reproducibility and repeatability [23]. The imaging of the CVC and AO in neonatal foals can be accomplished by placing the ultrasound probe in the ipsilateral paralumbar fossa or the 17th intercostal space [22,28]. For dogs the transducer is strategically placed in the right paralumbar fossa, which is situated between the last rib and the tuber coxae [20,24,29,30]. This non-invasive procedure has been shown to be well tolerated in healthy sheep, indicating its potential as a promising technique for quantitatively assessing the diameters and areas of the CVC and AO, as well as for calculating indices related to these measurements in both healthy and diseased sheep.

In studied sheep, the ultrasonographic measurements, including the diameters and areas of the Ao and CVC, as well as the calculated indices for the CVC to Ao diameter and area ratios, which were derived from the paralumbar views, the mean ± SD of the obtained measurements was as follows: 1.22 ± 0.11 mm for the diameter of CVC, 1.20 ± 0.11 mm for the diameter of AO, 1.75 ± 0.15 mm2 for the area of CVC, 1.21 ± 0.11 mm2 for the area of Ao, 1.01 ± 0.02 mm for the index of the diameter of CVC to AO, and 1.44 ± 0.05 mm2 for the index of the area of CVC to AO. In a study conducted on dairy cattle using radiographic examination [31], the mean ± SD of the assessed measurements in growing cattle was as follows: 25.10 ± 4.70 mm for the diameter of CVC, 36.15 ± 4.13 mm for the diameter of AO, and

0.60 ± 0.10 mm for the index of the diameter of CVC to AO. However, the mean ± SD of the assessed measurements in adult cattle was as follows: 30.34 ± 5.38 mm for the diameter of CVC, 40.92 ± 4.96 mm for the diameter of AO, and 0.62 ± 0.09 mm for the index of the diameter of CVC to AO. In a study conducted in calves [23], the mean ± SD of the assessed measurements was as follows: 1.06 ± 0.03 mm for the diameter of CVC, 1.17 ± 0.03 mm for the diameter of AO, 1.08 ± 0.03 mm2 for the area of CVC, 0.91 ± 0.03 mm2 for the area of Ao, 0.91 ± 0.03 mm for the index of the diameter of CVC to AO, and 0.99 ± 0.04 mm2 for the index of the diameter of CVC to AO. In a study conducted on foals [22], the mean ± SD of the assessed measurements was as follows: 16.5 ± 2.5 mm for the diameter of CVC, 16.1 ± 2.1 mm for the diameter of AO, 16.4 ± 3.4 mm2 for the area of CVC, 20.7 ± 5.4 mm2 for the area of Ao, 10.5 ± 1.9 mm for the index of the diameter of CVC to AO, and 9.1 ± 2.8 mm2 for the index of the diameter of CVC to AO. In a study conducted on dogs [20,24] and cats [32], the mean ± SD of the assessed measurements was as follows: 0.90 ± 0.21 mm for the diameter of CVC, 1.10 ± 0.25 mm for the diameter of AO, and 0.81 ± 0.36 mm for the index of the diameter of CVC to AO. In a study conducted on human [33], the mean ± SD of the assessed measurements was as follows: 19.02 ± 2.95 mm for the diameter of the inferior vena cava, 15.70 ± 1.60 mm for the diameter of AO, and 1.21 ± 0.23 mm for the index of the diameter of CVC to AO.

In the current study, the intra-assay CV of the ultrasonographic measurements, including the diameters and areas of the Ao and CVC, as well as the calculated indices for the CVC and AO diameter and area, which were derived from the paralumbar views in the selected sheep showed low (CV < 15%) variability, indicating that the data points are tightly grouped around the mean, providing valuable insights into the data distribution and and the reliability of the statistical inferences drawn from the dataset [34].

The overall impressions of the ultrasonographic measurements, including the diameters and areas of the Ao and CVC, as well as the calculated indices for the CVC to Ao diameter and area ratios, which were derived from the paralumbar views in the studied sheep, were nearly similar to those obtained in healthy calves [23]. Nevertheless, it exhibited several significant differences when compared to the data produced in another studies involving dairy cattle [31], foals [22], dogs [20,24], cats [32], and human [33], which suggests significant differences among species, as the size and mass of the heart are intricately linked to the weight, height, and physical abilities of individuals. Additionally, it underscores a substantial variation between species, given that both the diameter and area of the CVC and AO are affected by changes in abdominal pressure and the compliance of the CVC, which differs among various species.

Our research encountered several limitations that warrant consideration. We focused on healthy sheep, leaving the potential changes or clinical significance of evaluating the CVC and AO in diseased sheep uncertain. Additionally, the actual volume status of the sheep involved in this study was determined through historical data and findings of clinical examination, which poses challenges in accurately assessing healthy sheep. The sheep were evaluated while standing, and it is recognized that the patient's position can affect these measurements in human. Currently, there are no studies that address the changes in the diameters of the CVC and Ao when the patient is in a prone position. Sick sheep are typically examined in a recumbent state, whereas our study involved standing sheep. Therefore, further research is necessary to explore the impact of body position on the CVC and Ao in sheep. Lastly, the limited sample size presents another concern, as a larger cohort may reveal differences among observers.

Conclusion

In conclusion, abdominal ultrasonography has proven to be a feasible, repeatable, and accurate method, establishing itself as an effective tool for evaluating the caudal vena cava and aorta in sheep. This investigation has produced new data that establish a foundational set of initial values for the diameters and areas of the caudal vena cava and aorta in sheep, which enables the calculation of indices for both the diameter and area of these vessels. The ultrasound assessment of the caudal vena cava to aorta ratio shows potential as a method for the early detection of changes in vascular volume status in veterinary medicine. Therefore, understanding the reference values for normal parameters of large blood vessels in clinically healthy small ruminants will aid in the future application of the caudal vena cava to aorta ratio as a novel index for evaluating hydration status in affected sheep.

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Declaration of Conflict of Interest

The authors declare that there is no conflict of interest.

Ethical of approval

This study follows the ethics guidelines of the Faculty of Veterinary Medicine, Kafr Elsheikh University, Kafr Elsheikh, Egypt, (ethics approval number; KFS-IACUC/171/2023).

TABLE 1. Frequency distribution of the ultrasonographic measurements, including the diameters and areas of the caudal vena cava and aorta, as well as the calculated indices for the caudal vena cava to aorta diameter and area ratios in 30 clinically healthy sheep

variables	Highest frequency		Lowest frequency	
	Value	No (%)	Value	No (%)
Diameter of CVC (mm)	≥ 1.25 – 1.30	61 (67.78 %)	≥ 0.85 – 0.90	3 (3.33 %)
Diameter of Aorta (mm)	≥ 1.25 – 1.30	58 (64.44 %)	≥ 0.85 – 1.00	5 (5.56 %)
Area of CVC (mm^2)	≥ 1.75 – 1.90	63 (70.00 %)	≥ 1.35 – 1.45	4 (4.44 %)
Area of Aorta (mm^2)	≥ 1.10 – 1.35	73 (81.11 %)	≥ 0.85 – 0.90	3 (3.33 %)
Index of diameter CVC to Aorta (mm)	≥ 0.99 – 1.06	81 (90.00 %)	≥ 0.97 – 0.99	4 (4.44 %)
Index of area CVC to Aorta (mm^2)	≥ 1.38 – 1.50	76 (84.44 %)	≥ 1.34 – 1.36	4 (4.44 %)

Abbreviations: CVC, caudal vena cava; Ao, aorta.

TABLE 2. Summary statistics of the ultrasonographic measurements, including the diameters and areas of the caudal vena cava and aorta, as well as the calculated indices for the caudal vena cava to aorta diameter and area ratios in 30 clinically healthy sheep

	Mean ± SD	95% CI	Median (range)	Percentile			
				10%	25%	75%	90%
Diameter of CVC (mm)							
	1.22 ± 0.11	1.20 – 1.24	1.27 (0.85 – 1.33)	1.02	1.20	1.29	1.31
Diameter of Aorta (mm)							
	1.20 ± 0.11	1.17 – 1.22	1.24 (0.84 – 1.30)	1.00	1.18	1.28	1.29
Area of CVC (mm^2)							
	1.75 ± 0.15	1.72 – 1.78	1.81 (1.34 – 1.90)	1.50	1.69	1.86	1.88
Area of Aorta (mm^2)							
	1.21 ± 0.11	1.19 – 1.23	1.25 (0.87 – 1.34)	1.02	1.20	1.29	1.31
Index of diameter CVC to Aorta (mm)							
	1.01 ± 0.02	1.01 – 1.02	1.01 (0.97 – 1.08)	1.00	1.00	1.02	1.04
Index of area CVC to Aorta (mm^2)							
	1.44 ± 0.05	1.43 – 1.45	1.43 (1.35 – 1.57)	1.38	1.40	1.47	1.52

Abbreviations: CVC, caudal vena cava; Ao, aorta.

TABLE 3. Intraassay coefficient of variation of the ultrasonographic measurements, including the diameters and areas of the caudal vena cava and aorta, as well as the calculated indices for the caudal vena cava to aorta diameter and area ratios in 30 clinically healthy sheep

	Mean ± SD	95% CI	Median (range)	Percentile			
				10%	25%	75%	90%
Diameter of CVC (mm)							
	9.34 ± 0.22	9.18 – 9.50	9.35 (9.00 – 9.70)	9.01	9.18	9.53	9.69
Diameter of Aorta (mm)							
	9.60 ± 0.24	9.42 – 9.78	9.69 (9.12 – 9.95)	9.14	9.41	9.76	9.94
Area of CVC (mm^2)							
	8.38 ± 0.16	8.26 – 8.49	8.42 (8.12 – 8.63)	8.12	8.21	8.45	8.62
Area of Aorta (mm^2)							
	9.37 ± 0.20	9.23 – 9.52	9.28 (9.12 – 9.73)	9.13	9.24	9.56	9.72
Index of diameter CVC to Aorta (mm)							
	1.78 ± 0.16	1.66 – 1.90	1.80 (1.50 – 2.00)	1.51	1.60	1.90	1.99
Index of area CVC to Aorta (mm^2)							
	3.46 ± 0.19	3.33 – 3.60	3.48 (3.21 – 3.78)	3.21	3.30	3.58	3.77

Abbreviations: CVC, caudal vena cava; Ao, aorta

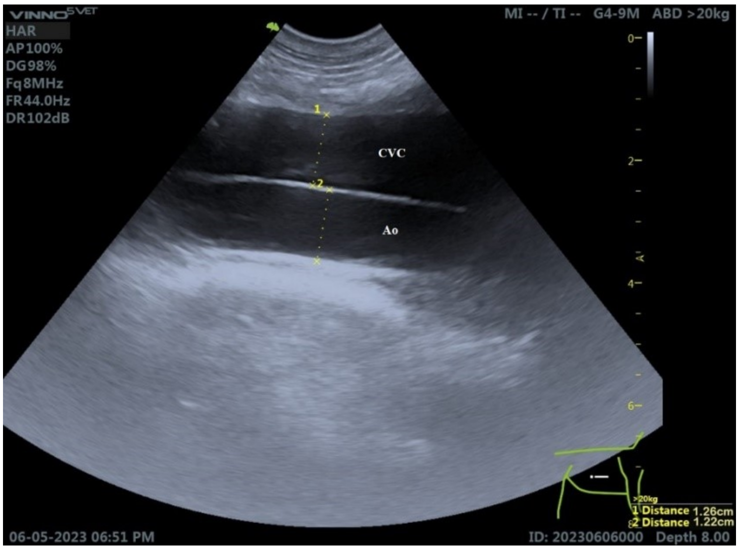

Fig. 1. Standard paralumbar ultrasonographic view for measurement of the diameter of the caudal vena cava (CVC) and aorta (Ao).

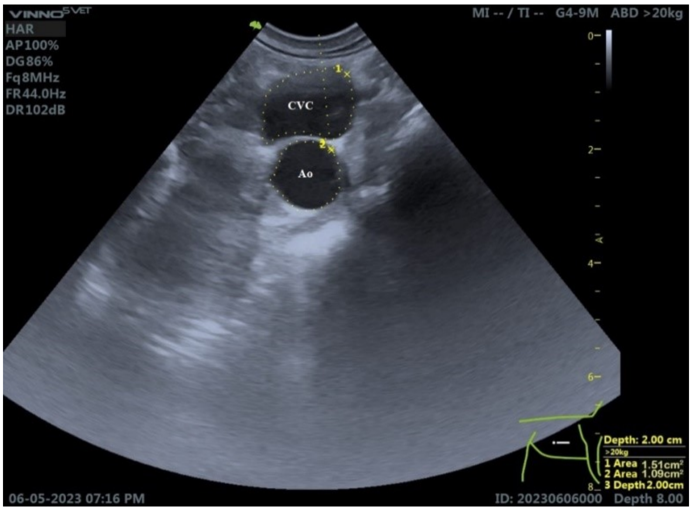

Fig. 2. Standard paralumbar ultrasonographic view for measurement of the area of the caudal vena cava (CVC) and aorta (Ao).

References

1. Berihulay, H., Abied, A., He, X., Jiang, L. and Ma, Y. Adaptation mechanisms of small ruminants to environmental heat stress. *Animals*, **9**, 75 (2019).

2. Offor, E.I., Ekweanya, N.M. and Oleka, A.C. Effects of socioeconomic factors on small ruminant production in Ohafia agricultural zone of Abia State, Nigeria. *Agro-Science Journal of Tropical Agriculture, Food, Environment and Extension*, **17**, 711 (2018).

3. Peacock, C. Goats A pathway out of poverty. *Journal of Small Ruminant Research*, **60,** 179186 (2005).

4. Dossa, H. L., Gauly, M., & Wollny, C. Smallholder's perceptions of goat farming in Southern Benin and opportunities for improvement. *Tropical Animal Health and Production*, **39**, 4957 (2007).

5. Ahuya, C.O., Ojango, J.M.K., Mosi, R.O., Peacock, C.P. and Okeyo, A.M. Performance of Toggenburg dairy goats in smallholder production systems of the eastern highlands of Kenya. *Journal of Small Ruminant Research*, **83**, 7-13 (2009).

6. Fecteau, G., Desrochers, A., Francoz, D. and Nichols, S. Diagnostic Approach to the Acute Abdomen. *Veterinary Clinics of North America: Food Animal Practice*, **34**, 19-33 (2018).

7. Lausch, C.K., Lorch, A., Giertzuch, S., Rieger, A., Knubben-Schweizer, G. and Trefz, F.M. Prognostic Relevance of Pre- and Postoperative Plasma L-Lactate Measurements in Calves with Acute Abdominal Emergencies. *Journal of Dairy Science,* **103**, 1856-1865 (2020).

8. Constable, P.D., Trefz, F.M., Sen, I., Berchtold, J., Nouri, M., Smith, G. and Grünberg, W. Intravenous and Oral Fluid Therapy in Neonatal Calves With Diarrhea or Sepsis and in Adult Cattle. *Frontiers in Veterinary Science*, **7**, 603358 (2021).

9. Meneghini, C., Rabozzi, R., and Franci, P. Correlation of the Ratio of Caudal Vena Cava Diameter and Aorta Diameter with Systolic Pressure Variation in Anesthetized Dogs. *American Journal of Veterinary Research*, **77**, 137-143 (2016).

10. Behnke, S., and Robel-Tillig, E. Index from Diameter of Inferior Vena Cava and Abdominal Aorta of Newborns—A Relevant Method for Evaluation of Hypovolemia. *Zeitschrift für Geburtshilfe und Neonatologie*, **224**, 199-207 (2020).

11. Mercolini, F., Di Leo, V., Bordin, G., Melotti, R., Sperotto, F., Pettenazzo, A., Amigoni, A., and Tosoni, A. Central Venous Pressure Estimation by Ultrasound Measurement of Inferior Vena Cava and Aorta Diameters in Pediatric Critical Patients: An Observational Study. *Pediatric Critical Care Medicine*, **22**, e1-e9 (2021).

12. Sänger, F., Dorsch, R., Hartmann, K., and Dörfelt, R. Ultrasonographic Assessment of the Caudal Vena Cava Diameter in Cats during Blood Donation. *Journal of Feline Medicine and Surgery*, **24**, 1098612X211028838 (2021).

13. Davis, H., Jensen, T., Johnson, A., Knowles, P., Meyer, R., Rucinsky, R., and Shafford H. American Association of Feline Practitioners; American Animal Hospital Association. 2013 AAHA/AAFP fluid therapy guidelines for dogs and cats. *Journal of the American Animal Hospital Association*, **49** (3), 149-159 (2013).

14. Mackenzie, D. C., and Noble, V. E. Assessing volume status and fluid responsiveness in the emergency department. *Clinical and Experimental Emergency Medicine*, **1**, 67-77 (2014).

15. Rabozzi, R., and Franci, P. Use of systolic pressure variation to predict the cardiovascular response to mini-fluid challenge in anaesthetized dogs. *The Veterinary Journal*, **202**, 367-371 (2014).

16. Sedgwick, S., Lorenzutti, A.M., Araos, J.B., Gleed, R.D., and Martin-Flores, M. Evaluation of an oscillometric blood pressure monitor in anesthetized dogs: Agreement with direct measurements and ability to detect hypotension. *Research in Veterinary Science*, **135**, 162-166 (2021).

17. Levick, J. R. Haemodynamics: flow, pressure and resistance. In: An Introduction to Cardiovascular Physiology, 5th ed. (Levick JR ed.), Hodder Arnold, London,116-146 (2010).

18. Cavaliere, F., Cina, A., Biasucci, D., Costa, R., Soave, M., Gargaruti, R., Bonomo, L., and Proietti, R. Sonographic assessment of abdominal vein dimensional and hemodynamic changes induced in human volunteers by a model of abdominal hypertension. *Critical Care Medicine*, **39**, 344-348 (2011).

19. Johnson, J.J., Garwe, T., Albrecht, R.M., Adeseye, A., Bishop, D., Fails, R.B., Shepherd, D.W., and Lees, J.S. Initial inferior vena cava diameter on computed tomographic scan independently predicts mortality in severely injured trauma patients. *Journal of Trauma and Acute Care Surgery*, **74**, 741-745 (2013).

20. Hanazono, K., Nakamoto, M., Hori, A., Miyoshi, K., Nakade, T., Itami, T., Sano, T., Kato, K., Ito, A., Tanaka, K., Yamashita, K., and Endoh, D. Evaluation of caudal vena cava size using computed tomography in dogs under general anesthesia. *The Journal of Veterinary Medical Science*, **84** (12), 1556-1562 (2022).

21. Constable, P.D., Hinchcliff, K.W., Done, S.H., and Grünberg, W. Clinical Examination and Making a Diagnosis. In: Veterinary Medicine: a textbook of the diseases of cattle, horses, sheep, pigs and goats. 11th ed. St. Louis, MO: Elsevier Ltd,1-28 (2017).

22. Tuplin, M. C., Romero, A. E., and Boysen, S. R. Influence of the respi ratory cycle on caudal vena cava diameter measured by sonography in healthy foals: A pilot study. *Journal of Veterinary Internal Medicine*, **31** (5), 1556-1562 (2017).

23. Casalta, H., Busoni, V., Eppe, J., Grulke, S., Merveille, A.C., Moula, N., and Gommeren, K. Ultrasonographical Assessment of Caudal Vena Cava Size through Different Views in Healthy Calves: A Pilot Study. *Veterinary Sciences*, **9** (7), 308 (2022).

24. Holland, M., Hudson, J., Bao, Y., and Gaillard P. Aortic to caudal vena cava ratio measurements using abdominal ultrasound are increased in dogs with confirmed systemic hypertension. *Veterinary Radiology and Ultrasound*, **61** (2), 206-214 (2020).

25. Sasaki, K., Mutoh, T., Yamamoto, S., Taki, Y., and Kawashima R. Comparison of noninvasive dynamic indices of fluid responsiveness among different ventilation modes in dogs recovering from experimental cardiac surgery. *Medical Science Monitor*, **24**, 7736-7741 (2018).

26. Marik, P. E., Cavallazzi, R., Vasu, T., and Hirani, A. Dynamic changes in arterial waveform derived variables and fluid responsiveness in mechanically ventilated patients: a systematic review of the literature. *Critical Care Medicine*, **37**, 2642-2647 (2009).

27. Carsetti, A., Cecconi, M., and Rhodes A. Fluid bolus therapy: monitoring and predicting fluid responsiveness. *Current Opinion in Critical Care*, **21**, 388-394 (2015).

28. Hoffmann, K. L., Wood, A. K. W., and McCarthy, P. H. Ultrasonographyof the equine neonatal kidney. *Equine Veterinary Journal*, **32** (2), 109-113 (2000).

29. Cambournac, M., Goy-Thollot, I., Violé, A., Boisvineau, C., Pouzot-Nevoret, C., and Barthélemy, A. Sonographic assessment of volaemia: Development and validation of a new method indogs. *Journal of Small Animal Practice*, **59** (3), 174-182 (2018).

30. Darnis, E., Boysen, S., Merveille, A. C., Desquilbet, L., Chalhoub, S., and Gommeren, K. Establishment of reference values of thecaudal vena cava by fast-ultrasonography through different viewsin healthy dogs. *Journal of Veterinary Internal Medicine*, **32** (4), 1308-1318 (2018).

31. Jilintai, Hashiyama S, Gonda Y, Ishikawa H, Sato M, and Miyahara K. Radiographic evaluation of caudal vena cava size as a useful parameter for the diagnosis of heart disease in dairy cattle. The *Journal of Veterinary Medical Science*, **68** (9), 995-998 (2006).

32. Vosugh, D., and Nazem, M. N. Radiological evaluation of caudal vena cava in domestic shorthair cats with regard to right heart failure diagnosis. *Bulgarian Journal of Veterinary Medicine*, **22** (2), 220-226 (2019).

33. Durajska, K., Januszkiewicz, E., Szmygel, Ł., and Kosiak, W. Inferior vena cava/aorta diameter index in the assessment of the body fluid status - a comparative study of measurements performed by experienced and inexperienced examiners in a group of young adults. *Journal of Ultrasonography*, **14** (58), 273-279 (2014).

34. Amovin-Assagba, M., Gannaz, I., and Jacques, J. Outlier detection in multivariate functional data through a contaminated mixture model. *Computational Statistics and Data Analysis*, **174**, 107496 (2022).

القيم المرجعية وإمكانية تكرار التقييم بالموجات فوق الصوتية للوريد الأجوف السفلي والشريان الأورطي في المجترات الصغيرة السليمة سريريًا

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الملخص

تقدم الدراسة الحالية قيمًا مرجعية لمعلمات الوريد الأجوف السفلي والشريان الأورطي في الأغنام السليمة سريريًا مع حالة ترطيب طبيعية، لتوفير دليل لتقييم مثل هذه الأوعية الدموية الكبيرة، مما سيساعد في تشخيص الحالات التي تؤثر على حجم الدم، وبالتالي، هذه الأوعية الدموية الكبيرة. لهذه الدراسة، تم تحديد 30 من الأغنام السليمة سريريًا، مع عدم وجود دليل سريري يمكن ملاحظته على الجفاف أو أمراض القلب والأوعية الدموية، لإدراجها في الدراسة. باستخدام الموجات فوق الصوتية عبر البطن، تم تقييم قياسات كل من قطر ومساحة الوريد الأجوف السفلي والشريان الأورطي باستخدام عرض النافذة القطنية. كان متوسط ± الانحراف المعياري للقياسات بالموجات فوق الصوتية وكذلك المؤشرات المحسوبة لقطر الوريد الأجوف السفلي إلى نسبة الشريان الأورطي ومساحة الأغنام المختارة على النحو التالي 1.22 ± 0.11 ملم لقطر الوريد الأجوف السفلي، 1.20 ± 0.11 ملم لقطر الشريان الأورطي، 1.75 ± 0.15 ملم2 لمساحة الوريد الأجوف السفلي، 1.21 ± 0.11 ملم2 لمساحة الشريان الأورطي، 1.01 ± 0.02 ملم لمؤشر قطر الوريد الأجوف السفلي إلى الشريان الأورطي، و1.44 ± 0.05 ملم2 لمؤشر مساحة الوريد الأجوف السفلي إلى الشريان الأورطي. هذه هي الدراسة الأولية لتوفير قيم مرجعية لمعلمات الوريد الأجوف السفلي والشريان الأورطي في الأغنام السليمة سريريًا، استنادًا إلى نظرية الاحتمالات والمنهجيات الإحصائية، ومعامل التباين، وبالتالي إظهار دقة الاختبار. يعد تقييم الموجات فوق الصوتية لنسبة الوريد الأجوف السفلي إلى الشريان الأورطي طريقة واعدة للتعرف المبكر على التغيرات في حالة حجم الأوعية الدموية في الطب البيطري. وبالتالي، فإن معرفة القيم المرجعية للمعلمات الطبيعية لمعلمات الأوعية الدموية الكبيرة في المجترات الصغيرة السليمة سريريًا تدعم الاستخدام المستقبلي لنسبة الوريد الأجوف السفلي إلى الشريان الأورطي كمؤشر جديد لتقييم حالة الترطيب في الأغنام المريضة.

الكلمات الدالة: الأغنام، الموجات فوق الصوتية على البطن، الأبعاد، المساحة، الوريد الأجوف السفلي، الشريان الأورطي.