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Veterinary echocardiographers' preferences for image selection, timing, and caliper placement for left atrial two-dimensional size assessment in dogs: the BENEFIT project☆

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Abstract *Introduction/Objectives:* This study aimed to investigate veterinary echocardiographers' preferences for assessing left atrial (LA) size in dogs using linear two-dimensional echocardiography, focusing on image selection, timing, caliper placement, and thresholds used for LA enlargement. A secondary aim was to explore the impact of experience and training on echocardiographers' linear two-dimensional measurements of LA size in dogs.
Animals, Materials and Methods: A global online study was conducted, asking veterinary echocardiographers to measure LA size using static echocardiographic images.
Results: A total of 533 echocardiographers (63% non-specialists and 37% specialists, of which 43% were cardiology board certified) completed the study. Most echocardiographers (86%, n = 459/533) used a right parasternal short-axis (RPSAX) view for LA and aortic (Ao) measurements. Of these, 57% (n = 261/459) favored the same image angulation for performing measurements and 76% (n = 351/459) timed measurements at end-systole/early-diastole. Caliper placement near pulmonary venous inlets impacted their LA dimension measurements the most. Thirty-nine percent (n = 207/533) used right parasternal long-axis (RPLAX) views. The upper limit for LA enlargement varied across all commonly used methods. Training and experience level influenced interobserver variation for LA dimension measurements obtained from a RPLAX four-chamber view, but not from a RPSAX view.
Study Limitations: Static images may not reflect real-time clinical settings or allow precise identification of anatomical structures.
Conclusions: The RPSAX view was most favored for LA size assessment in dogs, but variations existed in image selection, timing, caliper placement, and threshold used for LA enlargement. Training and experience level influenced interobserver variation in LA dimension measurements obtained from a RPLAX four-chamber view.

Abbreviations

2D	two-dimensional
ACVIM	American College of Veterinary Internal Medicine
Ao	aorta, aortic
BENEFIT	gloBal caninE and feliNE leFt atrial sIze assessmenT
ECG	electrocardiogram
ECVIM	European College of Veterinary Internal Medicine
LA	left atrium, left atrial
LVOT	left ventricular outflow tract
MMVD	myxomatous mitral valve disease
RPLAX	right parasternal long-axis
RPSAX	right parasternal short-axis

Introduction/objectives

Assessment of left atrial (LA) size is widely recognized to be important in diagnosis, staging, prognostication, and management of canine heart disease. Echocardiographic LA enlargement is associated with the risk of congestive heart failure and bears implications for medical management [1—5]. As a result, assessment of LA size is an integral part of echocardiographic examination of dogs [1,6].

Over the years, several different methods of linear two-dimensional echocardiographic LA size assessment in dogs have been published, each differing in view for image acquisition, instructions for caliper placement, and/or reference values used [6—10]. Left atrial size assessment in the right parasternal short-axis (RPSAX) view is used in the current recommendation to define disease stage in myxomatous mitral valve disease (MMVD) [1], which is the most common heart disease in dogs. However, there is a lack of widely accepted guidelines for echocardiographic LA size assessment in dogs, which could contribute to interobserver variability [11—13], possibly resulting in differences in how individual dogs are managed in clinical and research practice. To date, no formal assessment of echocardiographic practice has been conducted in veterinary medicine.

The gloBal caninE and feliNE leFt atrial sIze assessmenT (BENEFIT) project is an international research collaboration aimed at achieving a better understanding of the use of different echocardiographic methods in dogs and cats among veterinary echocardiographers. This may serve as background information for future harmonization. One part of this project involved investigating veterinary echocardiographers' current or past practices concerning LA size assessment. Initially, we found that most respondents used linear two-dimensional-based methods for LA size assessment in dogs, opting for a RPSAX view and indexing the LA to aorta (Ao) [14]. These conclusions were drawn from participants' responses about their most used linear two-dimensional methods, without knowing if they used multiple linear two-dimensional methods or requiring them to make prospective measurements on echocardiographic images.

The primary aim of the present prospective study was to investigate the linear two-dimensional preferences of veterinary echocardiographers for acquiring and measuring LA size in dogs, specifically concerning image selection, time-point identification, caliper placement, and threshold for LA enlargement for different methods. A secondary aim was to investigate whether experience and training level were associated with echocardiographers' linear two-dimensional measurements when assessing LA size in dogs.

Animals, materials and methods

An image-based survey instrument in English was constructed and validated using recognized principles and deployed using an online platform (Netigate AB, Stockholm, Sweden). The study design process has previously been described (Supplemental Table A) [14]. Respondents could only participate once, and all answers were anonymous. The study was adapted for use on personal computers, tablets, and smartphones. Respondents received no financial incentives. Responses were collected from June 23rd to September 16th, 2022. Respondents were asked to answer questions based on their working situation prior to COVID-19 restrictions. Respondents who no longer worked in clinical practice were asked to answer questions according to their past practice. Because the study was voluntary and it neither perceived to risk harm to respondents in any way nor involved the use of animals, no institutional review board approval was sought.

A veterinary echocardiographer was defined as a person who performed echocardiography in veterinary practice and, accordingly, was not limited to veterinarians or veterinary cardiologists. A national/international trained respondent was defined as a person who had undergone or was undergoing an international training program (e.g., American/European/Asian College of Veterinary Internal Medicine [ACVIM/ECVIM/AiCVIM] cardiology residency), national training program, or cardiology intern training program. A respondent with board certification or expert title was defined as a person who had finished the national/international training program and had achieved the title.

Study respondents

Eligibility for inclusion—Individuals who performed, or had previously performed, linear two-dimensional echocardiography that included assessment of the LA size in dogs and who indexed the LA to the Ao when assessing LA size.

Not eligible for inclusion—Individuals who did not meet the inclusion criteria or those who provided contradictory responses (e.g., respondents who stated, in an initial question, that they performed echocardiography in dogs and then provided contradictory responses in a subsequent question) were excluded.

Survey instrument

In contrast to the earlier phases of the BENEFIT project, where respondents reported their experience-based preferences retrospectively [14], this study required respondents to evaluate a predetermined set of echocardiographic images/graphic illustrations prospectively. Ninety-eight questions were constructed and divided into three parts (Fig. 1). Respondents were directed to relevant subsequent questions depending on their answers to the preceding questions. Thus, they were required to respond only to those questions related to the methods they used. The study questions and answer alternatives included echocardiographic images and diagrams and were supported by graphic illustrations, if relevant, to improve clarity of interpretation by respondents. Related questions were arranged on the same page. Respondents were not permitted to modify their responses once they proceeded to a subsequent page to prevent any influence from the newly presented images or diagrams on their

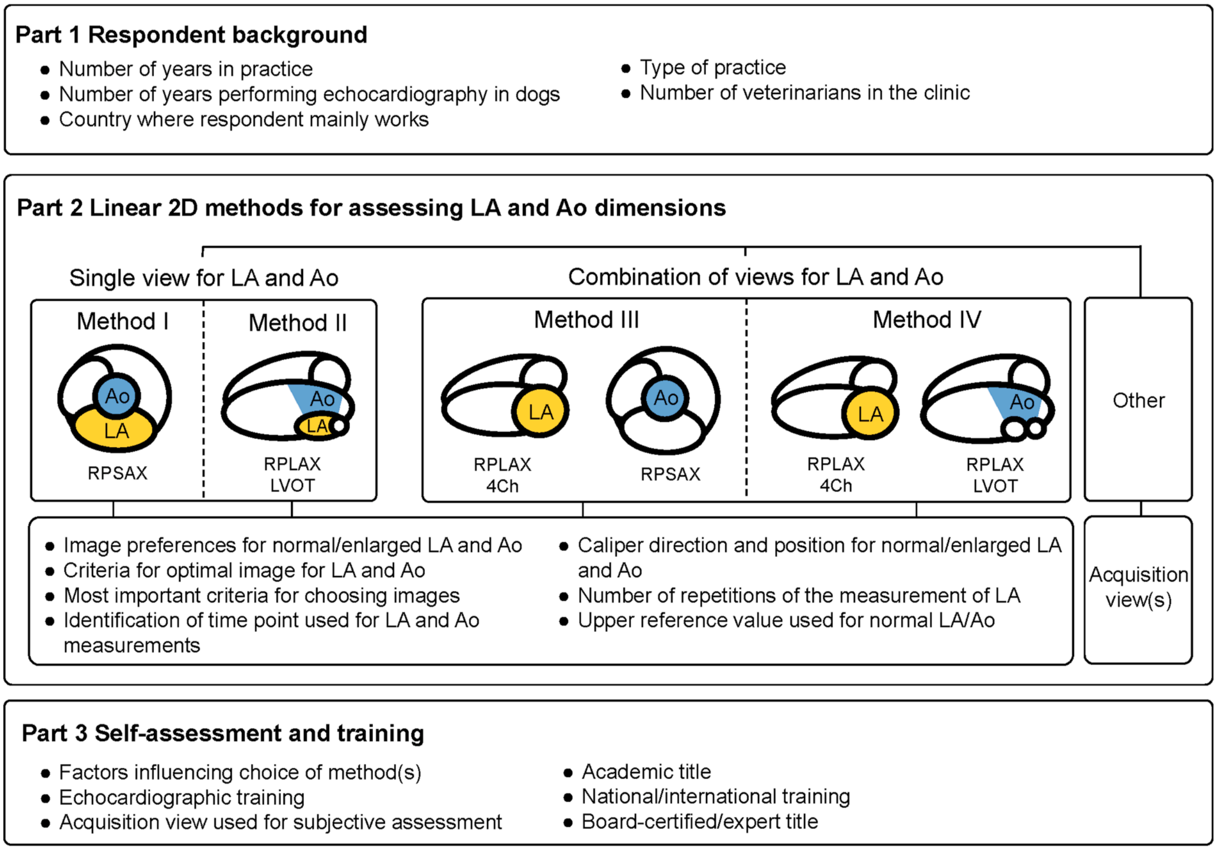

Figure 1 Survey instrument structure and overview of questions. Illustrations correspond to the four different linear two-dimensional methods evaluated in the study. See Supplemental Figures I–VI for further details about the questions and answer alternatives. 2D: two-dimensional; 4Ch: four chamber; Ao: aorta; LA: left atrium; LVOT: left ventricular outflow tract; RPSAX: right parasternal short-axis; RPLAX: right parasternal long-axis.

previous responses. Most questions (93/98) were mandatory and were primarily formatted as multiple-choice questions. Free-text answers were made possible if respondent's alternative of choice was missing from the alternatives listed. Five optional questions were open-ended.

Part 1—Respondent background. Questions related to respondents' demographic and professional characteristics and their eligibility to participate in the study were assessed (Fig. 1).

Part 2—Linear two-dimensional **methods for LA size assessment in dogs.** Questions related to the use of the four linear two-dimensional methods in right parasternal windows for acquiring LA and Ao dimensions for LA size assessment (Fig. 1 and Supplemental Figures I–VI).

- **Method I.** Single view— RPSAX view (Supplemental Figures I–III)
- **Method II.** Single view—RPLAX left ventricular outflow tract (LVOT) view (Supplemental Figures I, II, and IV).
- **Method III.** Separate views—RPSAX view (Ao) and RPLAX four-chamber view (LA) (Supplemental Figures I, II and V).
- **Method IV.** Separate views—RPLAX LVOT view (Ao) and RPLAX four-chamber view (LA) (Supplemental Figures I, II, and VI).

Respondents using other methods were asked to provide information about the view(s) they used. Respondents were directed to answer the specific questions based on their method(s) of use, allowing them to respond to questions related to one or multiple methods. Additional questions were designed to assess intrarespondent consistency when transitioning between different methods.

Image preference

Images of RPLAX and RPSAX views with varying degrees of angulation were provided as answer alternatives. Respondents were asked which image most closely resembled the one they would prefer to use for measuring LA and/or Ao dimension(s) (Supplemental Figure I).

Criteria used for image selection

Respondents were asked which criteria they considered important regarding visibility, position, shape, and outline of various anatomical landmarks for selecting optimal images for measurement and to rank the importance of each criterion for image selection (Supplemental Figure II).

Timing

Respondents were asked to state the phase of the cardiac cycle during which they measured LA and Ao dimensions, whether using electrocardiogram (ECG), valvular motion, LA size, or other.

Caliper placement

Respondents were asked to place calipers to identify start points and end points of measurements on different static echocardiographic images, depending on their method(s) of choice. Two images that had been obtained from a RPSAX view—one from a dog with a normally sized LA and another from a dog with an enlarged LA—and one image that had been acquired from a RPLAX four-chamber view in a dog with a normally sized LA were used in this segment of the study. The measured distances for LA dimensions provided a unitless number that allowed comparisons between different observers when measuring within the same image and were used for evaluating how selection of caliper placements affected the measurement length. The format of questions is depicted in Supplemental Figures III—VI.

Part 3—Self-assessment and others. Questions related to respondents' training in echocardiography and veterinary medicine (Fig. 1).

Pretest verification

A three-phase pretest was performed using the modified Delphi method [15], as previously described (Supplemental Table A) [14].

Data collection

Veterinary echocardiographers received an invitation to participate in the study via **(1)** chairpersons of national veterinary organizations and key opinion leaders of veterinary internal medicine/cardiology associations in 34 countries; **(2)** the ACVIM and ECVIM-Cardiology ListServe hosted by the Veterinary Information Network (VIN.com). The subscribers of the ListServe included veterinarians globally who have voluntarily registered to receive ListServe emails because of their interest in veterinary cardiology and included all ECVIM-Companion Animals and ACVIM cardiology diplomates (board-certified specialists) and candidates (trainees), as well as other interested veterinarians; **(3)** invitations at the end of scientific presentations at the ACVIM Forum and ECVIM annual congresses; and **(4)** respondents who already participated in the study and transmitted a link to other veterinary echocardiographers. The number of echocardiographers who received the study information globally was unknown. Two reminders were sent out after 30 and 45 days to groups (1) and (2), respectively.

Statistical analysis

Descriptive analyses of the study results were performed. Response counts and percentages were calculated. A statistical program[i] was used for statistical analyses. Significance was set at $P<0.050$. To investigate whether years of experience and training level were associated with echocardiographers' linear two-dimensional measurements when assessing LA size in dogs, group median values of LA and Ao measurements were compared using the Wilcoxon rank-sum test. Differences in variance of measurements between groups were tested using the 2-sided F-test. Groupwise comparisons were not performed if any of the groups had fewer than 50 responses due to concern for lack of statistical power.

Results

In total, 725 individuals provided responses; of these, 557 (76.8%) completed the entire study. Entries from 24 respondents were considered invalid and excluded, and the results described below are, accordingly, from responses provided by 533 respondents (Fig. 2). Approximately one-

[i] JMP, v. 17.0, SAS Institute Inc., Cary, NC.

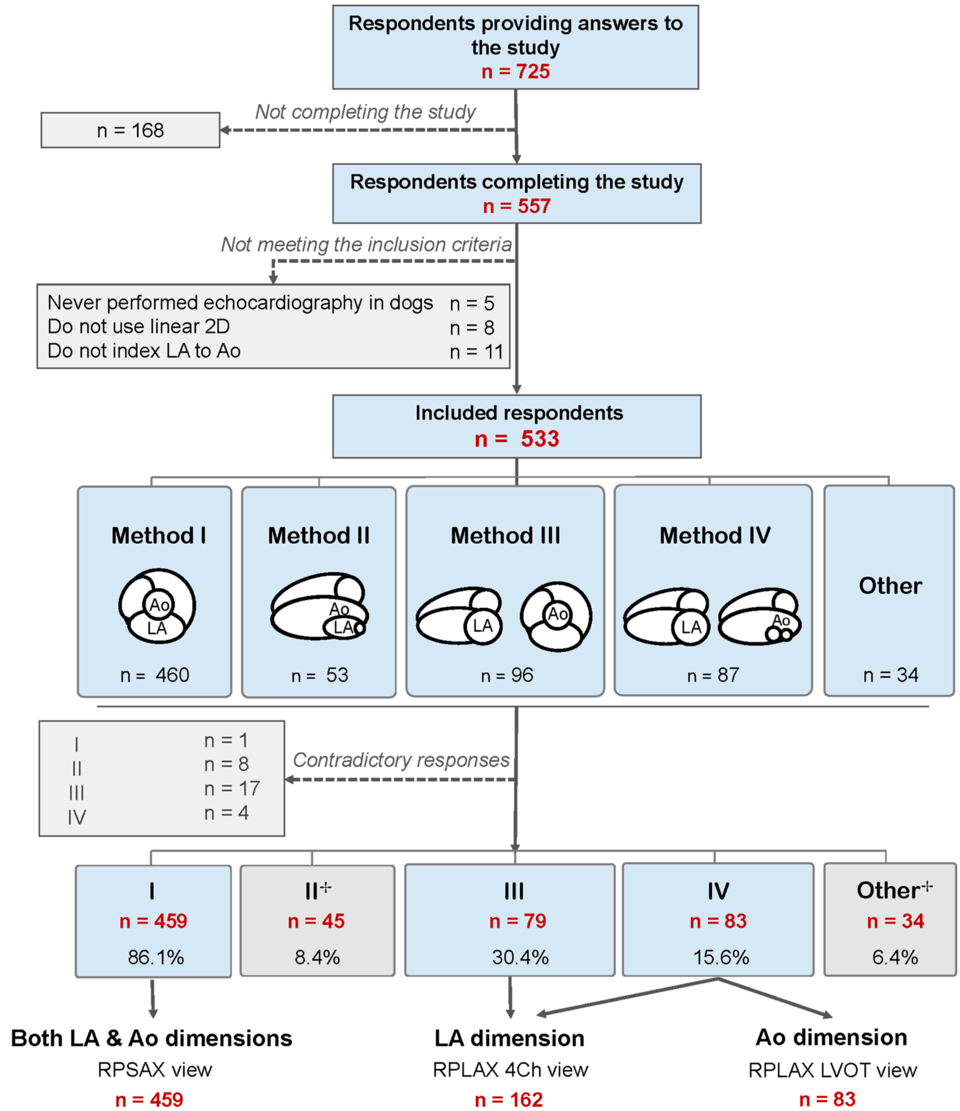

Figure 2 Flow chart demonstrating the process of extracting 533 valid responses. Contradictory responses for an echocardiographic technique led to exclusion of that respondent's responses for that method, whereas the remaining responses from these respondents were retained. 2D: two-dimensional; Ao: aortic; LA: left atrial; LVOT: left ventricular outflow tract; RPSAX: right parasternal short-axis; RPLAX: right parasternal long-axis.
✢ Less than 10% of respondents used the RPLAX LVOT view (Method II) or other views for measuring, leaving the sample size of these groups deemed insufficient for further analyses.

third (36%) of respondents had participated in a recently published survey concerning echocardiographic LA assessment in dogs and cats conducted within the BENEFIT project [14,16].

Geographic, demographic, and professional characters

The respondents included clinically active echocardiographers from 48 countries across six continents (Supplemental Figure VII). Ninety-nine percent (n = 524/533) reported that they had performed echocardiography regularly during the 12 months preceding the study. The demographic and professional characteristics of respondents are shown in Table 1 and Supplemental Table B. Sixty percent (n = 318/533) had learned to perform echocardiography at echocardiography courses, and 44% (n = 235/533) were self-taught.

Table 1 Distribution of background of respondents with formal postgraduate training.

International/national training	
International training program	n = 153
National training program	n = 139
Cardiology intern training program	n = 44
Board-certified/expert title	
International board-certified title	
ACVIM (Cardiology)	n = 56
ECVIM-CA (Cardiology)	n = 24
ACIM/ECVIM Diplomate but field not specified	n = 12
ACVECC	n = 10
ECVDI	n = 4
ACVIM (Cardiology, SAIM)	n = 2
ACVIM and ECVIM-CA (both in Cardiology)	n = 2
AiCVIM (Cardiology)	n = 2
ACVR	n = 2
AiCVIM (SAIM)	n = 1
ACVIM (SAIM)	n = 1
ECVECC	n = 1
ECVIM-CA (Internal Medicine)	n = 1
EVPC	n = 1
ACZM and ACVECC	n = 1
ACVAA and ACVECC	n = 1
National title/specialists	n = 77

ACVAA: American College of Veterinary Anesthesia and Analgesia; ACVECC: American College of Veterinary Emergency & Critical Care; ACVIM: American College of Veterinary Internal Medicine; ACVR: American College of Veterinary Radiology; ACZM: American College of Zoological Medicine; AiCVIM: Asian College of Veterinary Internal Medicine; ECVDI: European College of Veterinary Diagnostic Imaging; ECVECC: European Veterinary Emergency and Critical Care; ECVIM-CA: European College of Veterinary Internal Medicine-Companion Animals; EVPC: European Veterinary Parasitology College; SAIM: Small Animal Internal Medicine.

Preferences for linear two-dimensional methods

Respondents' preferences for linear two-dimensional method(s) for LA size assessment in dogs are depicted in Figure 3. The most commonly used linear two-dimensional method for LA size assessment in dogs was method I, followed by methods IV and III [Fig. 3(A)]. Five respondents normalized LA size using indexing methods other than dimensions related to the Ao. Most commonly, respondents used method I alone, followed by combining methods I and IV [Fig. 3(B)]. The threshold for LA enlargement used by respondents varied markedly for the four methods [Fig. 3(C)].

Image preferences, image selection criteria, timing, and caliper placement

Preferences of all respondents are reported below, ranked by acquisition view regardless of the method(s) they used the most (Fig. 2).

Left atrial and aortic dimensions in the right parasternal short-axis view (n = 459)

Just over half (51%) of the respondents preferred the same angulation of the heart on the RPSAX view for measuring the LA dimension measured from a RPSAX view (LA_{SAX}) and Ao dimension measured from a RPSAX view (Ao_{SAX}) [Fig. 4(A)]. Eighteen percent of respondents were satisfied with either angulation [Fig. 4(A)]. Most respondents (93%) timed LA and Ao dimensions simultaneously; 57% timed measurements for both structures by visualizing the aortic valvular motion. Most respondents (77%) measured the LA and Ao at the onset of diastole/end-systole (aortic valve closure) [Fig. 5(A)]. The most commonly used criteria for image selection were the visibility of the aortic commissure, shape of the Ao, and outline of the LA (Supplemental Figure IIA).

Seventy-two percent of respondents used an inner edge-to-inner edge technique to measure LA_{SAX}. The caliper placement on the LA lateral wall for LA_{SAX} varied near pulmonary venous inlets, and the interobserver variation in LA measurement was similar in normal and enlarged LAs [Fig. 5(D)]. The LA_{SAX} measurements in both normal and enlarged LAs were comparable regarding group median value and variance between respondents with and without national/international training and with and without board certification/expert title and were not influenced by the length of experience in echocardiography.

The Ao_{SAX} was measured as an extension of the commissure of the non-coronary and left coronary aortic cusps by 81% and 78% of respondents in the image representing normally sized and enlarged LAs, respectively. Seventy percent of respondents used an inner-to-inner edge technique to measure Ao_{SAX} in both the normally sized and enlarged LAs. Similar to LA_{SAX}, the Ao_{SAX} measurements in both normally sized and enlarged LAs were comparable regarding group median values and variance between groups of varying experience and training.

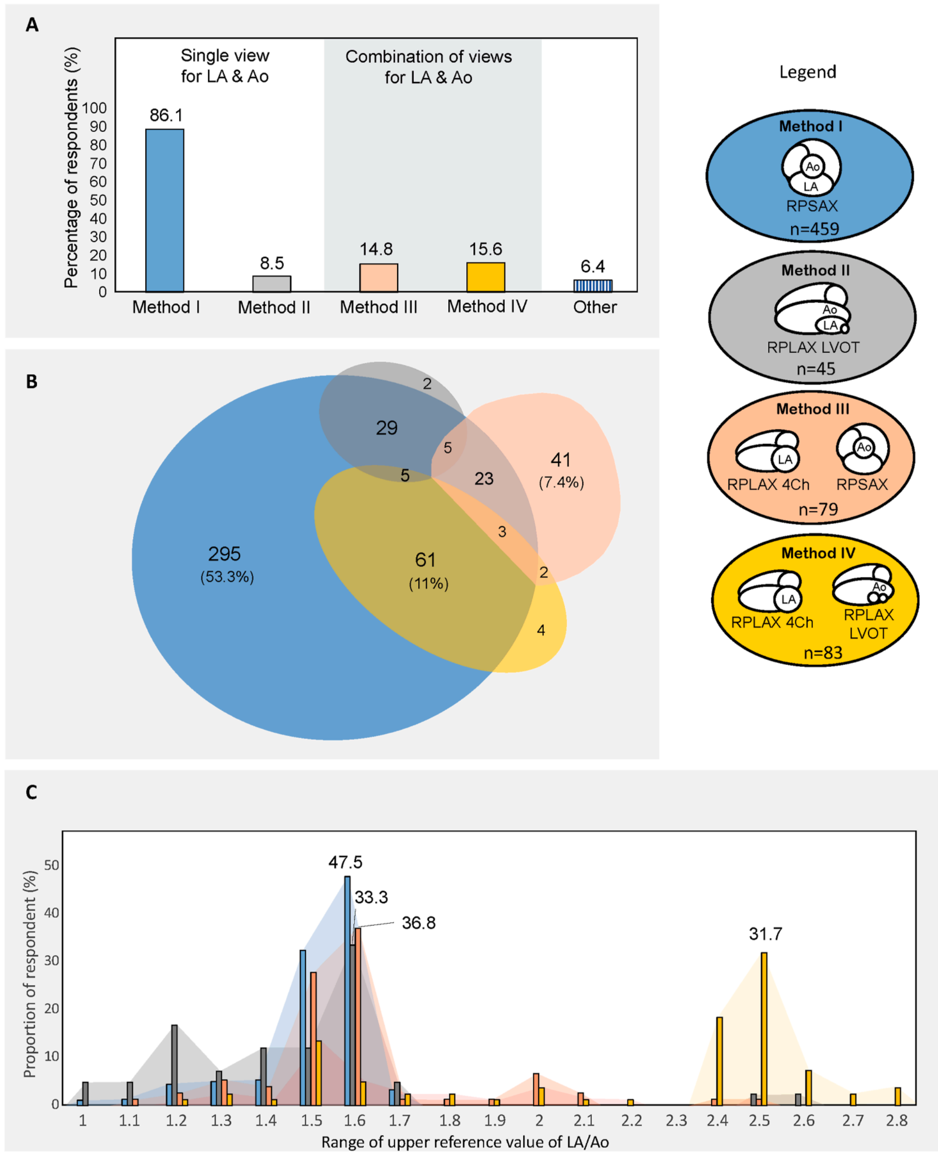

Figure 3 An overview of veterinary echocardiographers' preferences for linear two-dimensional methods for LA size assessment in dogs (n=533). The different methods in each graph (A—C) are indicated by the colors in the legend. (A) shows the most commonly used linear two-dimensional methods for this purpose and (B) demonstrates how echocardiographers combined different methods for LA size assessment and highlights the reported frequency of use of each combination. Respondents who used other methods (n=34) and other combinations (n=29) were not included in (B). The size of the areas in (B) is approximately in proportion to the actual number of responses for each method, and the numbers represent the responses for each method and the combination of methods. (C) Bar graphs superimposed on areas showing the range of upper limit of LA/Ao for each method used by respondents to identify normal LA size. The numbers on top of the bars represent the most commonly used value for each method (e.g., 47.5% of the respondents using method I used LA/Ao = 1.6 as the upper limit for defining a normally sized LA). 4Ch: four chamber; Ao: aorta; LA: left atrium; LVOT: left ventricular outflow tract; RPLAX: right parasternal long-axis; RPSAX: right parasternal short-axis.

Left atrial dimension in the right parasternal long-axis four-chamber view (n = 162)

Most respondents (80%) preferred the same angulation of the heart on the RPLAX four-chamber view for measuring the LA dimension measuring from a RPLAX view (LA_{LAX}) [Fig. 4(B)]. Most respondents (75%) timed the measurement by visualizing mitral valvular motion. Most respondents (82%) measured LA_{LAX} at early-diastole/end-systole [Fig. 5(B)]. The most commonly used criteria for image selection were visibility of the

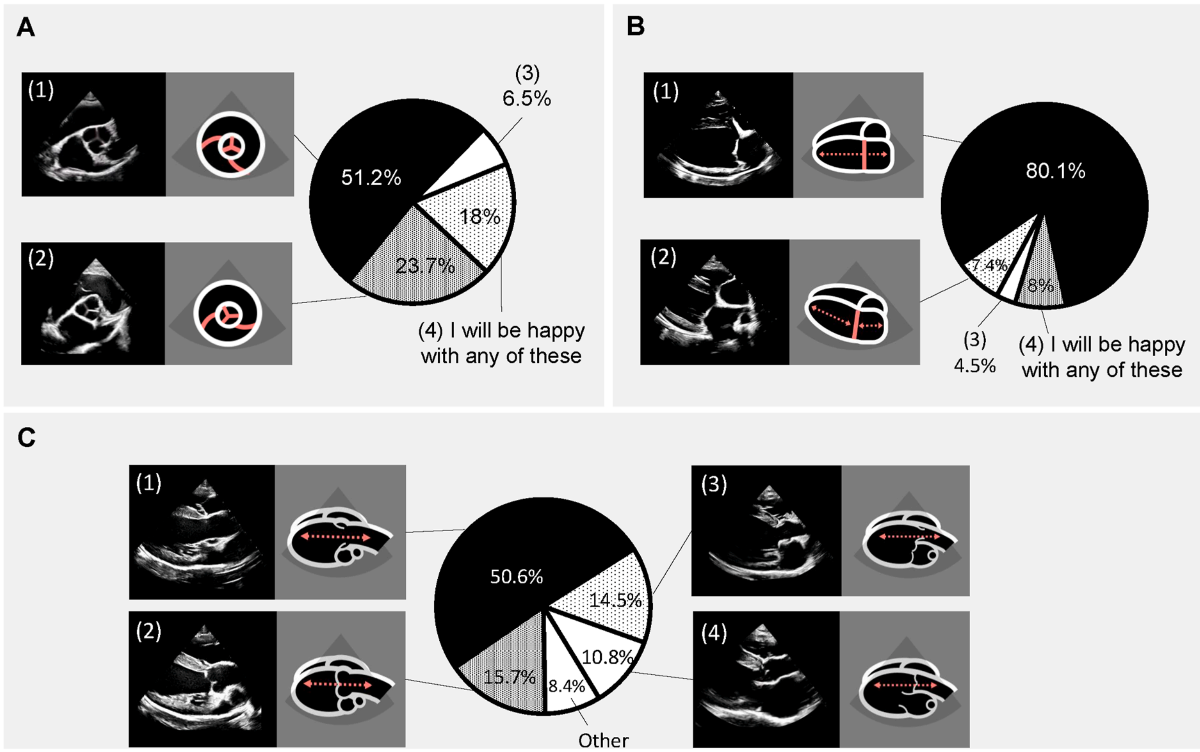

Figure 4 Echocardiographer preferences regarding angulation (A—C) and timing (C) when measuring left atrial and/or aortic dimensions for left atrial size assessment in cardiac-healthy dogs using (A) right parasternal short-axis view (n=459), (B) right parasternal long-axis four-chamber view (n=162), and (C) right parasternal long-axis left ventricular outflow view (n=83). Images of answer alternative (3) in both (A) and (B) can be found in Supplemental Figure I. The pie charts and associated numbers show the proportions of respondents favoring the view that the slice is connected to by a line. e.g. in (A), 51.2% of the respondents using right parasternal view preferred the angulation shown in the upper left. The red dotted lines with arrowheads represent the angulation of the structure of interest in the image. See Supplemental Figure I for further details about the questions and answer alternatives.

mitral valve leaflet, visibility of the interatrial septum, and position of the LA wall (Supplemental Figure IIB).

In the image representing a normally sized LA, 75% of respondents used an inner-to-inner edge technique to measure the LA_{LAX} dimension. Varied caliper placement for LA_{LAX} measurements, for both the septal and lateral wall, in relation to the mitral valve annular plane led to measurement variation [Fig. 5(B)]. The group of respondents with national/international training or board certification/expert title exhibited lower interobserver measurement variation than those who had not undergone national/international training ($P=0.002$) or did not hold a board certification/expert title ($P=0.001$), despite similar median values for the LA_{LAX} dimension. Furthermore, the group of respondents with >5 years of experience in echocardiography had lower interobserver LA_{LAX} measurement variation than respondents with less experience ($P=0.008$).

Aortic dimension in the right parasternal long-axis left ventricular outflow view (n=83)

Just over half (51%) of the respondents preferred the same angulation of the heart on the RPLAX LVOT view for measuring the Ao dimension measured on a RPLAX view (Ao_{LAX}) [Fig. 4(C)]. Most respondents (89%) timed the measurement by visualizing the aortic valvular motion. Most respondents measured the Ao_{LAX} at either mid-systole (47%) or end-systole/early-diastole (37%) [Fig. 5(C)]. The most commonly used criteria for image selection were visibility of the aortic valve cusps, visibility of the sinuses of Valsalva, and outline of the LVOT/Ao (Supplemental Figure IIC).

Most respondents (86%) used an inner-to-inner edge technique for measuring the Ao_{LAX}. Respondents varied considerably in their caliper placement for Ao_{LAX} measurement along the

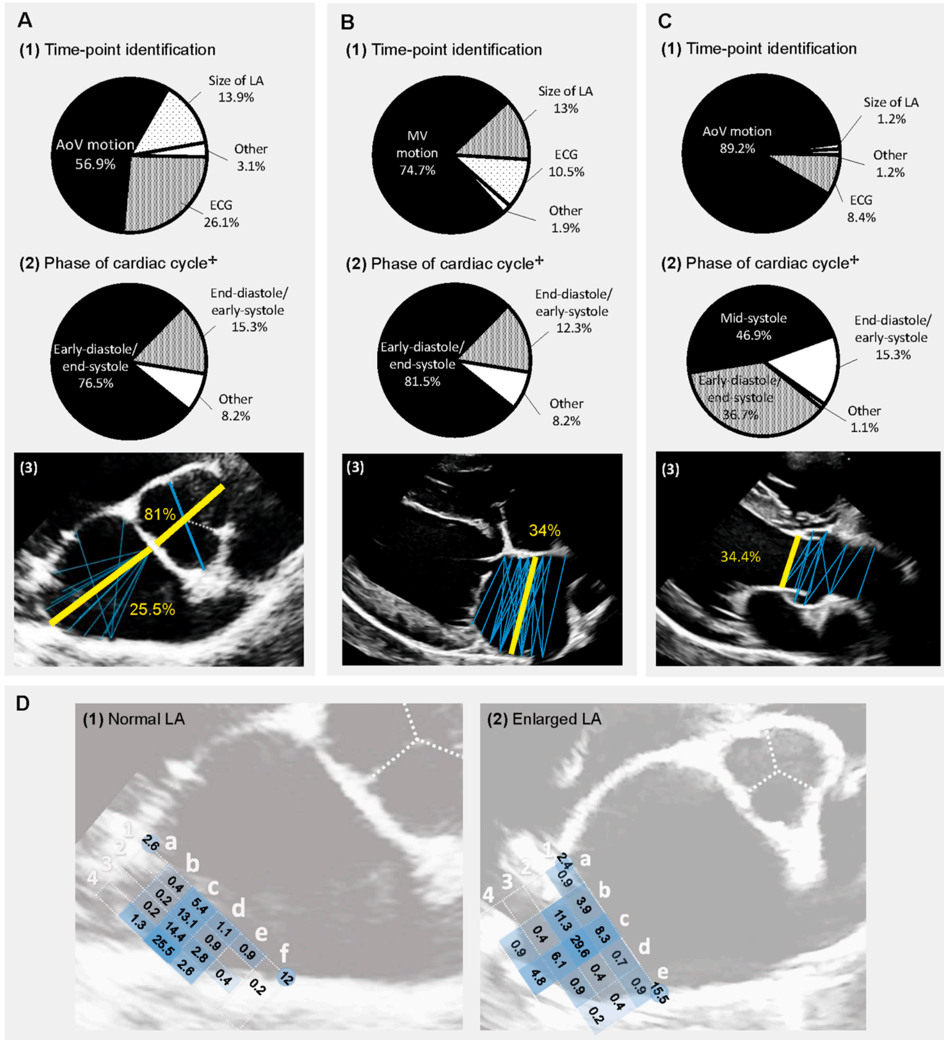

Figure 5 Preferences for time-point identification (A1-C1), phase of the cardiac cycle (A2-C2), and caliper placement (A3-C3) when measuring left atrial and aortic dimensions for left atrial size assessment in cardiac-healthy dogs using (A) right parasternal short-axis view (n=459), (B) right parasternal long-axis four-chamber view (n=162), and (C) right parasternal long-axis left ventricular outflow view (n=83). Caliper placement and directions in Figures A3–C3 are indicated by blue lines, and yellow lines indicate the most common directions and placement, with numerical proportions. For example, the most commonly used direction in A3 for measuring Ao dimension, indicated by a yellow line, was used by 81% of respondents. (D) shows grids superimposed on the area near the pulmonary venous inlets, a common location for caliper placement, and the numbers indicate the proportions of responses for caliper placement. Respondents placing the caliper farther away from the pulmonary venous inlets are not shown, leaving the sum less than 100%. See Supplemental Figure III for further details about the questions and answer alternatives. AoV: aortic valve; LA: left atrium. ⁺Respondents' measurements in different phases of the cardiac cycle were categorized based on their responses regarding time-point identification as described on Supplemental Table C.

length of the Ao, ranging from the valve annulus to the tubular Ao [Fig. 5(C)]. No statistical tests were performed owing to small comparison groups and concerns of lack of statistical power.

Preferences for subjective assessment

Among the respondents who assessed LA size subjectively (n = 498/533), 46% trusted the RPSAX view the most, 38% the RPLAX four-chamber view, and 9% the left parasternal apical four-chamber view.

Discussion

Based on responses from a large cohort of veterinary echocardiographers, we report the most commonly used methods, image selection criteria, caliper placement, and threshold used for measuring LA enlargement in dogs. Respondents working in 48 countries across six continents, and with a variety of professional backgrounds, contributed data. The majority of respondents favored utilizing a single RPSAX view for measurement of both LA and Ao dimensions for LA size assessment. Conversely, a minority of respondents expressed a preference for employing a single RPLAX view or a combination of views. No statistically significant differences were found for interobserver variation of LA dimension assessment using a RPSAX view among respondents with different training levels or lengths of experience in echocardiography. However, the groups of respondents who had undergone national/international training, held a board certification/expert title, or had extensive echocardiography experience exhibited less interobserver variation in LA dimension measurements when using the RPLAX four-chamber view.

Method preferences

Over 86% of respondents measured both LA and Ao dimensions in a single RPSAX view to obtain LA_{SAX}/Ao_{SAX} (method I) for LA size assessment [Fig. 3(A)]. Approximately half (n = 295/533, 53.3%) of respondents used this method exclusively to assess LA size [Fig. 3(B)]. This method has been used for decades to evaluate LA size in dogs [7,9]. Several reasons may exist as to why this method is so popular among veterinary echocardiographers. First, this method has the advantage of including both structures that are measured in the same view, which is convenient for the operator. Second, adult healthy dogs vary considerably in size and body weight, and as a result, bodyweight-independent measures of heart size are therefore easy to use in clinical practice. Indexing LA size to Ao diameter provides a bodyweight-independent measure of LA size. Third, the method has been used to evaluate canine patients in several landmark clinical trials [2,4,17,18] and is used in current guidelines for staging MMVD [1]. Lastly, the LA_{SAX}/Ao_{SAX} measurement has consistently been shown to be a powerful predictor of outcomes (morbidity and mortality) in dogs with MMVD [19–22], with, hitherto, no clinical study showing that other linear two-dimensional methods are superior in this aspect [23].

Thirty-nine percent (n = 207/533) of respondents used images acquired from RPLAX views for obtaining LA dimensions (methods II, III, and IV) [Fig. 3(A)]. There may be several reasons why long-axis views are used less frequently for LA size assessment than short-axis views (n = 459/533). In recent years, studies evaluating LA dimensions in cardiac-healthy dogs of specific breeds, and/or in non-pedigree dogs, have used two separate views to obtain LA_{LAX}/Ao_{LAX} (method IV), which adds to complexity and time consumption [8,11,24–26]. Furthermore, the commonly employed methods for measuring LA_{LAX} have not seen extensive use in large clinical trials and guidelines, in contrast to the widespread utility of LA_{SAX}.

When subjectively assessing LA size, 43% and 36% of respondents trusted the RPSAX view and the RPLAX four-chamber view, respectively. From a practical perspective, estimating the LA size from a short-axis view offers the advantage of simultaneously visualizing a reference structure, the Ao, and experienced operators may approximate the LA/Ao subjectively during the echocardiogram.

Image plane and orientation

Regarding preferences for imaging plane and orientation of the Ao cusps, interatrial septum, and left auricle when using the RPSAX views (method I), only 50% of respondents favored the same image. Eighteen percent of respondents did, however, express satisfaction with all three alternatives presented to them [Fig. 4(A) and Supplemental Figure I]. The most commonly used imaging selection criteria when optimizing the acquisition view were aortic commissures, aortic shape, and LA outline (Supplemental Figure IIA). This demonstrates that even within a group of echocardiographers using the same method, variation exists in preferences regarding the overall appearance of the image. Variation of the imaging plane may result in differences in the relative position of the LA to the Ao and a different outline of borders and landmarks. This could introduce variability in measurements [7,9].

Over 80% of respondents using a RPLAX four-chamber view (methods III and IV) for measuring LA_{LAX} preferred the image in which both the LA and LV were horizontally aligned when instructed to focus on the orientation of the LV, LA, and mitral annulus [Fig. 4(B)]. Interestingly, this image angulation differs from the images presented in many veterinary publications, where a tilted LV chamber or both tilted LA and LV chambers have been described [7,25–31]. Respondents who used an RPLAX LVOT view for measuring the Ao_{LAX} (methods II and IV) had different preferences regarding how certain structures should appear in this view [Fig. 4(C)], such as the size of the LA and the visibility of the left auricle. This variability, likewise, could be expected to lead to variations in Ao_{LAX} measurements. We observed a comparably large variation in the imaging views used in different veterinary publications to illustrate Ao_{LAX} measurements in the RPLAX LVOT view, five-chamber view, or RPLAX view optimized for LVOT [8,28–32]. This might be a contributing factor for the variation found in the present study.

The results from our study demonstrate that even when echocardiographers obtain the same view to assess LA size, considerable variation exists in image acquisition, selection, and caliper placement, which may inevitably result in increased variability in LA and Ao measurements. Several veterinary publications [23,28,30–34] detailing methods for evaluating LA size discuss transducer location and spatial relationships among anatomical features, paralleling the descriptions employed in human echocardiography [35]. However, authors have rarely focused on the orientation of the LA and the criteria for image selection. Furthermore, veterinary publications and textbooks provide differing imaging planes for the views suggested, perhaps even more in long-axis than in short-axis views. Although readers of textbooks and articles may have a general understanding of which structures are supposed to be imaged in a specific view, the way in which a certain structure is angled or included in a specific view is likely to vary between examiners.

To improve the accuracy and consistency of echocardiographic measurements, future recommendations for standardizing tomographic planes should preferably include detailed descriptions of the views (ideally with one or more representative images) highlighting the orientation of structures as well as the positions and directions of anatomical landmarks relative to each other.

Timing

Irrespective of whether respondents used RPSAX or RPLAX views, more than half relied on valvular motion for identifying the timing of LA measurements, and the majority measured at ventricular end-systole/early-diastole [Fig. 5(A, B)]. This preference may simply mirror the recommendation in veterinary guidelines cited in a large number of veterinary publications [1,2,7,9,17,19,20] and align with the timing used for LA linear dimension measurements in human studies [36–39]. Measuring the LA_{LAX} has the advantage of potentially achieving more consistent timing in measurements than measuring LA_{SAX} [10,40,41]. Visualizing the mitral valve opening in the long-axis view is potentially easier than visualizing the aortic cusps in the short-axis view in some dogs. However, the timing of Ao_{SAX} [method I, Fig. 5(B)], mainly at ventricular end-systole/early-diastole, was found to be more consistently preferred by respondents in the present study than Ao_{LAX}, with respondent preferences widely distributed throughout the cardiac cycle [methods II and IV, Fig. 5(C)]. This inconsistency may reflect the fact that the timing of Ao_{LAX} has been identified in different ways in the literature [8,23,25,42]. Another plausible rationale for timing measurements based on valvular motion is the potential elimination of the need to connect a patient's ECG when utilizing valvular motion as the timing reference, and echocardiograms are commonly performed without ECG monitoring on dogs in a point-of-care context. Left atrial size varies during the cardiac cycle [43–45], and timing influences LA measurements [25,41,46]. Additionally, timing can influence aortic size [40,47].

Caliper placement

The direction of measuring Ao_{SAX}, which involves following the commissure between the non-coronary and left coronary aortic cusps, exhibited little variation among respondents [Fig. 5(A)]. This stands in contrast to the measurement of Ao_{LAX} [Fig. 5(C)]. Different landmarks were proposed in two publications that focused on measuring the LA_{SAX}/Ao_{SAX}, offering guidance for measuring the Ao [7,9]. Despite this distinction, these two frequently utilized approaches are regarded as interchangeable [48]. However, one of the methods [9] has generally been preferred and has been used to assess LA size in dogs with MMVD in large clinical trials of medical management of MMVD [2,4,17,18]. Additionally, this method has been recommended for staging MMVD in dogs according to ACVIM consensus guidelines [1].

The preferred direction of the line to measure normally sized and enlarged LA_{SAX} from the aorta to the LA wall varied more among respondents than the direction of the line used for Ao_{SAX} measurements [Fig. 5(A, D)]. Only 26% of respondents selected the same direction and end point position for LA_{SAX} measurements in the normally sized LA. While the majority of respondents selected a similar start point for the line, variation was mostly observed when selecting the end point of the line at the LA wall, in both the image showing a normally sized LA and the image showing an enlarged LA. The position of the end point of caliper placement for LA_{SAX} influenced the LA_{SAX}-to-Ao_{SAX} ratio. The level of training and length of experience in echocardiography were not associated with variations in the LA_{SAX} measurements. The end point of the line is intended to mark the lateral LA wall. The description of where to place the calipers on an echocardiogram varies among the original articles [7,9] and textbooks [28,34] describing this method. Furthermore, pulmonary veins enter the LA in the area where the end point could potentially be placed in many dogs. Indeed, this study showed that many responders placed the caliper in the pulmonary vein, which violates the description of this method in one of the original studies [9].

Owing to the study design, the interobserver variability of the measurements could be estimated for each still image separately and not compared between images. This study found that experience did not affect the interobserver variation for the RPSAX view but that the interobserver variation was lower for experienced responders for measurements in the RPLAX view. Because many more responders measured on the RPSAX view compared to the other views, it can be speculated that responders measuring the RPSAX images represented a more diverse population of echocardiographers trained at many sites, whereas responders choosing to measure in the RPLAX view could have been less diverse and trained more similarly.

Both direction as well as position (including start and end point of the line) for measuring the Ao and LA in RPLAX views showed considerable variation among respondents [Fig. 5(B, C)]. This could again be explained by different caliper placements being used for RPLAX views in veterinary medicine and the absence of clear anatomical landmark for guidance [8,23,24,26,42]. Therefore, in forthcoming recommendations for LA size assessment, precise instructions regarding the direction of caliper placement as well as the start and end points of linear measurements are desirable.

Threshold for left atrial enlargement

Respondents were asked to provide a single upper value for the LA/Ao to differentiate a normal LA from an enlarged one. Unsurprisingly, according to the aforementioned variations found in image preferences, timing, and caliper placement, aggregated responses resulted in a wide range of values for each method. This suggests that different respondents used different thresholds, even when using the same method. The differences in threshold values may reflect a combination of factors, including published literature, the considerations discussed earlier, and clinical expertise. Variations in threshold values used for LA enlargement may have an impact on clinical management of cases, including disease staging and prognostication.

Limitations

The responses could not be verified independently because the results were based on self-reported responses, a situation shared with many other survey studies.

Evaluating the representativeness of our study of real-life clinical practice is challenging. The analyses and reporting were based on all completed responses, without setting a lower limit for the number of respondents in each category of geographic, demographic, or professional characteristics. Nevertheless, respondents included veterinary echocardiographers from 48 countries across six continents, reflecting diverse professional backgrounds, training levels, and work settings. Hence, this sample can be considered representative of a broader group of veterinary echocardiographers. The responses could not be independently verified because the results were based on self-reported responses.

The data collection platform was presented only in English, which might have led to misunderstanding or misinterpretation of questions and answer alternatives, or lack of accessibility, to non-native English-speaking respondents. To address this limitation preemptively, we invited 12 veterinarians (nine non-native English speakers) working in various fields and countries to validate the content and we used their comments to make changes prior to dissemination. Only respondents who had access to internet and the study link could participate in the study. The number of respondents in each country could have been affected by how the local contact person promoted the study and therefore might not be in proportion to the number of echocardiographers in the specific country.

Based on findings from our literature review prior to constructing the survey, we endeavored to offer several answer options for each question. However, considering the need to ensure good survey quality, we were unable to list too many answer options for each question in the various survey pages. Consequently, it is possible that some angles and image criteria used by some respondents were not included.

The echocardiographic images provided to respondents were static and not dynamic echo loops, which could fail to accurately represent real-world practice and might not provide enough information for respondents to accurately define relevant anatomical structures and borders.

Conclusions

When evaluating LA size using linear two-dimensional methods in dogs, most veterinary echocardiographers used a single RPSAX view to measure both LA and Ao dimensions. However, among the echocardiographers using this method, considerable variation was found in image selection, timing of the measurement, caliper placement, and threshold used for LA enlargement. Likewise, substantial within-method variability of image selection, time-point identification, caliper placement, and threshold used for LA enlargement were found for the less-frequently used methods. Differences in training and experience were not associated with the magnitude of variability of LA size measurements in a RPSAX view, whereas national/international training and experience was associated with less variation in LA size measurements in a RPLAX view. The findings of the present study demonstrate the extent of variability that exists among echocardiographers today when assessing LA dimensions. Future studies should be conducted in order to investigate how assessment of the LA size can be better harmonized between echocardiographers and, furthermore, how the assessment of the LA size using such an established standardized linear two-dimensional method agrees with volumetric assessment results of the chamber.

Conflicts of Interest Statement

The authors do not have any conflicts of interest to disclose.

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Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.jvc.2025.07.006.

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