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Veterinary echocardiographers' preferences for left atrial size assessment in cats: the BENEFIT project☆

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Abstract *Introduction/objectives:* Veterinary echocardiographers' preferences for left atrial (LA) size assessment in cats have not been systematically investigated. The primary aim of this prospective exploratory study was to investigate

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Preliminary data of the study were presented in abstract form at the 39th ACVIM Forum, June 24th 2022.

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Heart failure;
Cardiomyopathy;
Feline

echocardiographers' preferences concerning LA size assessment in cats. A secondary aim was to investigate echocardiographers' preferences for assessing LA size in subgroups based on geographic, demographic, and professional profiles.
Animals, materials, and methods: An online survey instrument was designed, verified, and distributed globally to veterinary echocardiographers.
Results: A total of 655 veterinary echocardiographers from six continents and 54 countries, working in specialty practice (56%) and in general practice (38%), provided data. Linear two-dimensional (2D) technique was favored by most echocardiographers (n = 612) for LA size assessment. Most commonly, respondents combined linear 2D with subjective assessment (n = 227), while 209 used linear 2D-based methods alone. Most echocardiographers using linear 2D-based methods preferred the right parasternal short-axis view and to index the LA to the aorta (Ao). Approximately 10% of the respondents obtained LA dimensions from a right parasternal long-axis four-chamber view. Approximately one-third of echocardiographers that made linear measurements from 2D echocardiograms shared the same preferences regarding cat position, acquisition view, indexing method and time point identification for the LA measurement. The responses were comparably homogeneous across geographic location, level of training, years performing echocardiography, and type of practice.
Discussion/conclusion: Most veterinary echocardiographers assessed LA size in cats using linear 2D echocardiography from a right parasternal short-axis view, and indexed LA to Ao. Respondents' preferences were similar over geographic, demographic, and professional backgrounds.
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Abbreviations

2D	2-dimensional
Ao	aorta
LA	left atrium, left atrial
LAE	left atrial enlargement
MM	M-mode
RLR	right lateral recumbency

Introduction/objectives

Quantification of LA size is regarded as one of the most clinically important measurements in feline echocardiography. Identification of substantial LA enlargement (LAE) on an echocardiogram suggests underlying cardiac disease in cats presenting with signs of respiratory distress [1,2]. Decisions about treatment strategies and establishment of prognoses for cats affected by cardiomyopathies are, furthermore, also partly based on the degree of LAE demonstrated on an echocardiogram [3—9].

The current state of knowledge regarding LA size assessment in cats is characterized by a lack of updated and universally acknowledged guidelines. This can potentially be attributed to the absence of consensus on the optimal approach for conducting such assessments. Various echocardiographic techniques and methods, as well as various specific recommendations for each of these, have been suggested for LA size assessment in cats. The absence of uniformity in LA size assessments may have negative effects on the accurate evaluation of disease severity and prognosis. Furthermore, this can impede the proper interpretation and implementation of published clinical study findings and expert treatment guidelines. In human medicine, large scale surveys have identified similarities and differences between echocardiog raphic methods used in everyday clinical practice and methods recommended in guidelines [10—12] — to comprehend challenges in complex areas like current LA size assessment in cats [11,13—15]. The gloBal caninE and feliNE leFt atrIal size assessmenT (BENEFIT) project is an international research collaboration aiming to explore veterinary echocardiographers' methods regarding LA size assessment in dogs and cats, aimed at harmonizing or standardizing LA size assessment in veterinary medicine. We recently submitted the

results of the canine portion of this research collaboration for publication[i].

Echocardiographers' preferences of the techniques and methods for assessing LA size in cats has, to our knowledge, not been systematically investigated previously in a large-scale study. Accordingly, the primary aim of this study was to investigate echocardiographers' preferences concerning LA size assessment in cats, including echocardiographic techniques (M-mode (MM), linear 2D, area-based, volume-based, and subjective assessment) and methods (positioning of the cat, acquisition views, indexing methods, and identification of the time point used for the measurement). A secondary aim was to investigate echocardiographers' preferences for assessing LA size in subgroups based on geographic, demographic, and professional profiles.

Animals, materials and methods

An English-language survey instrument was constructed and validated using recognized principles [16—20], and it was deployed using an online platform[j]. Respondents' echocardiographic preferences for dogs and cats were investigated in the same survey[i], and this manuscript includes the part concerning cats. Respondents were instructed to only participate once, and the survey could only be accessed once using the same device. The respondents participated anonymously. Respondents received no incentives to participate. The period of collection of responses was September 18th to November 1st, 2020. Respondents were asked to answer the questions based on their situations prior to COVID-19 restrictions. Respondents who were no longer in clinical practice were asked to answer the questions according to their practice in the past.

Study enrollment

Inclusion criteria: individuals who performed, or had previously performed, echocardiograms in cats.

Exclusion criteria: individuals who did not meet the inclusion criteria, and those who provided contradictory responses (e.g. respondents who stated, in an initial question, that they performed echocardiograms in cats, or that they used a specific echocardiographic technique, but then stated the opposite in a subsequent question).

Survey instrument

A total of 134 questions were created and divided into three parts (Fig. 1). Respondents were directed to relevant subsequent questions according to their answers to preceding questions; thus, they were not required to respond to all questions. Most questions (129/134) were mandatory and primarily formatted as multiple-choice questions comprising both single- and multiple-answer possibilities; free-text answers were made possible if the respondent's choice was missing from the alternatives listed. Five optional questions were open-ended. Questions in parts 1 (12 questions) and 3 (16 questions) were for all respondents. Respondents performing echocardiograms in both dogs and cats were directed to all questions in part 2 (106 questions); respondents only performing echocardiograms in dogs or cats were directed to the relevant questions in part 2 (53 questions). The filter questions and illustrations were designed to reduce the misconceptions regarding animal species for each question. Survey question stems, associated answer alternatives, and illustrations are reported in the Supplemental Document I.

PART 1: general background of respondents. Questions related to the respondents' geographic, demographic, and professional roles related to echocardiography.

PART 2: techniques/methods of echocardiographic assessment of left atrial size in cats. Questions included in part 2.1 were related to the following echocardiographic techniques: (1) subjective assessment, (2) MM (3) linear 2D, (4) area, and (5) volume. Respondents were asked to specify their most commonly used technique(s) for assessing LA size (multiple answers were possible), and respondents were then directed to relevant questions related to their selected technique(s) of choice to provide details. Questions in part 2.2 were related to respondents' opinion of their technique(s)/method(s) of choice.

PART 3: self-assessment regarding echocardiographic preferences and training. Questions related to the respondents' preferences regarding echocardiography, echocardiographic experience, and their level of training.

Pretest verification

A 3-phase pretest was performed using the modified Delphi method [21]:

[i] Dog manuscript: Veterinary echocardiographers' preferences for left atrial size assessment in dogs: The BENEFIT Project (which is Conditional Accept in JVC).

[j] Netigate AB, Stockholm, Sweden.

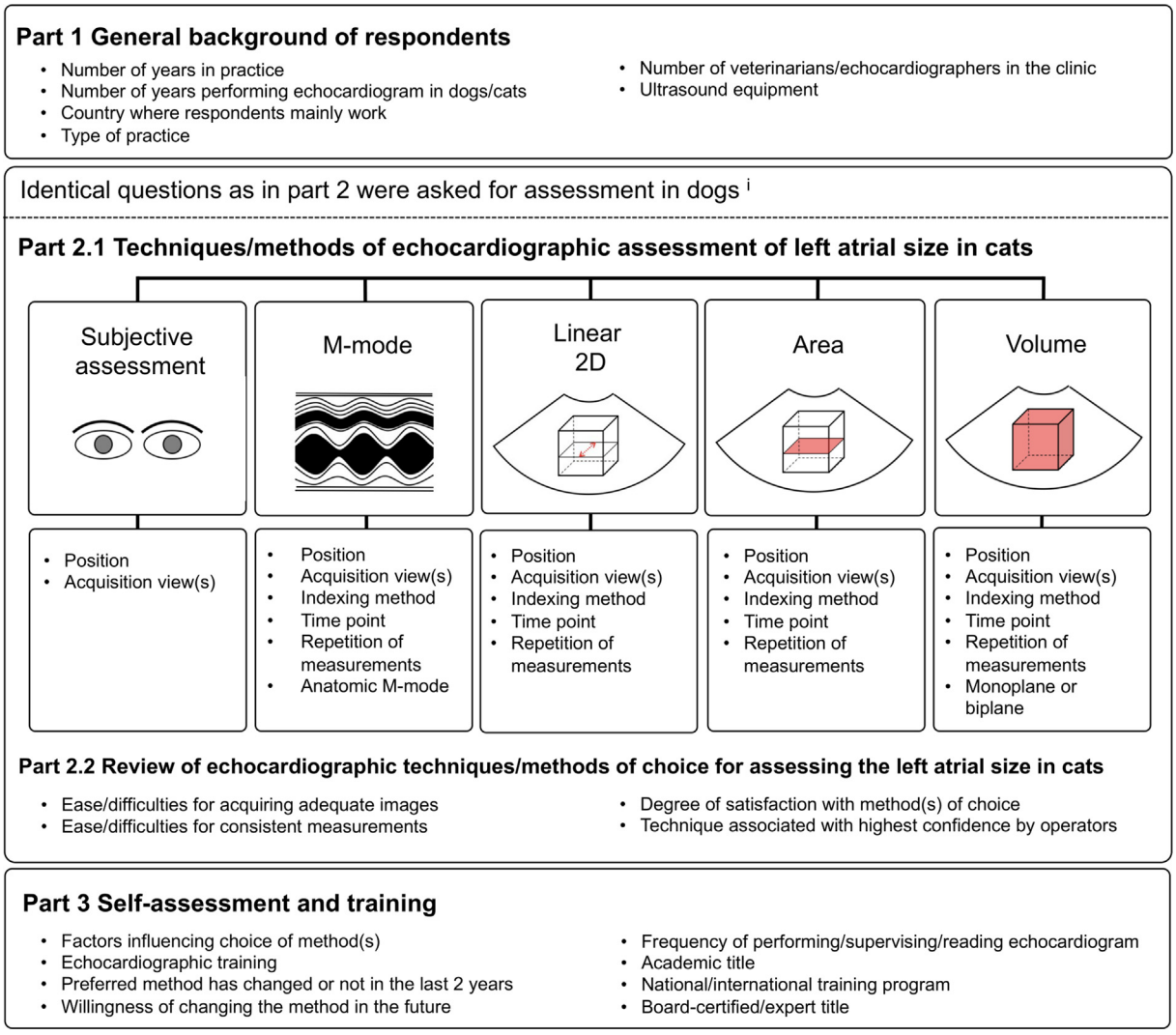

Figure 1 Survey construction and overview of questions. Illustrations correspond to the five different echocardiographic methods evaluated in the survey. See Supplemental Document I for further details about the survey questions and answer alternatives. 2D: two-dimensional.

Phase 1: a group of subject-matter experts (n = 9), consisting of board-certified cardiologists and researchers working in academia or private clinical practice, from Canada, Sweden, Taiwan, the Netherlands, and the United States, reviewed the survey instrument with the goal of identifying perceived flaws and limitations, and stating recommended changes. Revisions were made according to the comments received.

Phase 2: a reference group (n = 12), consisting of echocardiographers who regularly performed echocardiograms in dogs and cats, but who were not working in academia and were not board-certified cardiologists, and who worked in various fields of veterinary medicine (cardiology, diagnostic imaging, emergency and critical care, and internal medicine) in different countries and territories (Australia, China, Hong-Kong, Japan, Singapore, Sweden, the Netherlands, the United States, and Zambia), tested the survey. Most echocardiographers (9/12) in the reference group were non-native English speakers. Revisions were made according to the comments received. Subject matter experts involved in phase 1 were not eligible to take part in phase 2.

Phase 3: the survey was tested and amended again by the nine subject-matter experts prior to distribution to potential respondents.

Data collection

Veterinary echocardiographers received an invitation to participate in the study, which was distributed through the following channels: (1)

Chairpersons of national veterinary organizations and key opinion leaders of veterinary internal medicine/cardiology associations in 34 countries; (**2**) American and European Colleges of Veterinary Internal Medicine — Cardiology ListServe, hosted by the Veterinary Information Network. The subscribers of the Listserve included veterinarians globally who had voluntarily registered to receive Listserve emails because of their interest in veterinary cardiology and included all American and European College of Veterinary Internal Medicine cardiology diplomates and candidates, as well as other interested veterinarians; (**3**) international cardiology virtual congresses. Reminders were sent out after 14 and 30 days to both groups (**1**) and (**2**).

Statistical analysis

Descriptive analyses of the survey results were performed. Response counts and percentages were calculated.

Results

A total of 949 individuals provided data, and of these, 702 (74%) completed the entire survey. The mean response time for the participants was 21 min and 18 s. Entries from 47 respondents were considered invalid and were excluded (Fig. 2), and results described below were accordingly based on analyses of responses from 655 respondents. Respondents (n = 3) from one country reported that they could not participate as the survey link could not be opened in their country (without access to a VPN).

Geographic, demographic, and professional information

Echocardiographers providing responses worked on six continents and in 54 countries (Supplemental Table A). Most echocardiographers (n = 633/655, 96.6%) self-reported that they performed echocardiograms regularly in the preceding 12 months (or portion of 12 months excluding COVID-19 restrictions, as relevant). Respondents' demographic and professional information is shown in Supplemental Figure I and Supplemental Table A. Respondents predominantly learned to perform echocardiograms from echocardiography courses (n = 419/655, 64.0%) and/or were self-taught (n = 293/655, 44.7%). Approximately half of respondents (n = 310/655, 47.3%) were the only echocardiographers regularly practicing echocardiography at their workplace.

Echocardiographic approaches for LA size assessment in cats

Respondents most commonly used linear 2D-based methods when assessing LA size, followed by subjective assessment, and MM-based methods (Fig. 3A). Most commonly, respondents combined linear 2D-based methods with subjective assessment, followed by using linear 2D-based methods alone, and, finally, by combining MM-based methods, linear 2D, and subjective assessment (Fig. 3B). Most respondents (n = 499/655, 76.2%) trusted linear 2D-based methods the most when assessing LA size. Virtually all respondents imaged cats in right lateral recumbency when obtaining either short-axis or long-axis views of the LA.

Quantitative assessment

Linear two-dimensional

Most of the 612 respondents who assessed LA size using linear 2D-based methods preferred the right parasternal short-axis view (Fig. 4). Similarly, most respondents preferred indexing the LA dimension to the aortic dimension, and most preferred timing the measurement at approximately ventricular end-systole/early-diastole by identifying the first frame after aortic valve closure. Of respondents using linear 2D, 34.3% had identical preferences regarding positioning of the cat during the examination, acquisition view, indexing method and identification of time point used for the measurements. Approximately 61% of respondents acquired repeat measurements over more than one cardiac cycle and subsequently averaged them.

M-mode

Most of the 175 respondents who assessed LA size using MM-based methods preferred the right parasternal short-axis view (Supplemental Figure II). Fifty percent of these respondents used anatomic MM. Most respondents preferred indexing the LA dimension to the aortic dimension, using echocardiographic guidance for timing the measurement of these two structures. For measuring the aortic dimension, most respondents identified the time point on the MM immediately before aortic valve opening. For measuring the LA dimension, most respondents identified the time point on the MM showing the maximal LA size. For respondents using MM, 11.4% had identical preferences regar ding positioning of the cat, acquisition view,

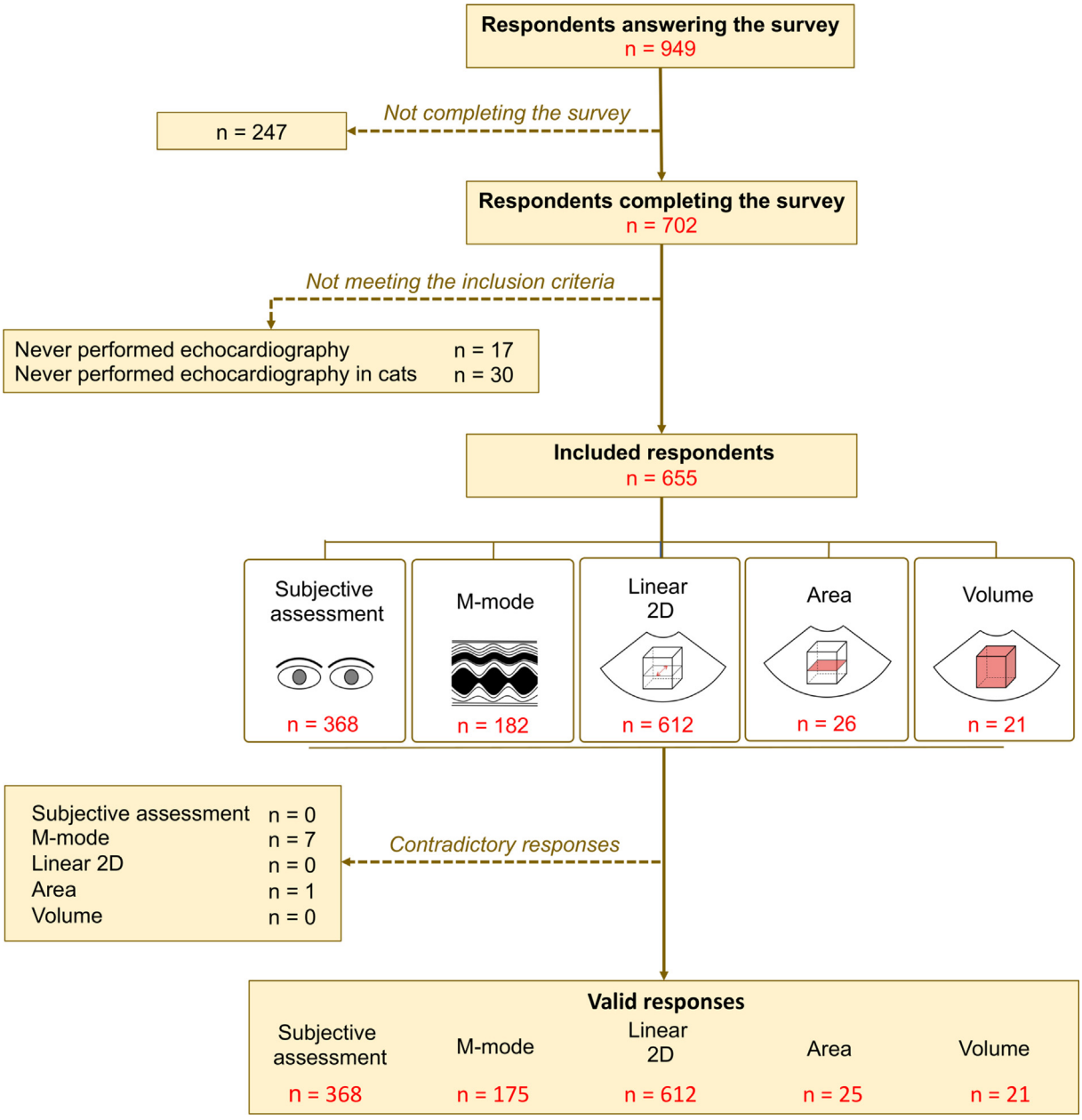

Figure 2 Flow chart demonstrating the process of extracting valid survey responses. Contradictory responses for an echocardiographic method led to exclusion of survey responses for that particular technique, whereas the remaining responses from these respondents were retained. 2D: two-dimensional.

indexing method, and identification of time point used for the measurements. Approximately two thirds of these respondents (66%) acquired repeat measurements over more than one cardiac cycle and subsequently averaged them.

Area

Most of the 25 respondents who assessed LA areas preferred the right parasternal short-axis view (Supplemental Figure III). Most respondents did not use any indexing method for LA area assessment and used 2D guidance for timing the measurement by identifying the image showing the maximal LA area. Forty percent of these respo ndents acquired repeat measurements over more than one cardiac cycle and subsequently averaged them.

Volume

Most of the 21 respondents who assessed LA volumes preferred the right parasternal long-axis four-chamber view, to which they applied a monoplane

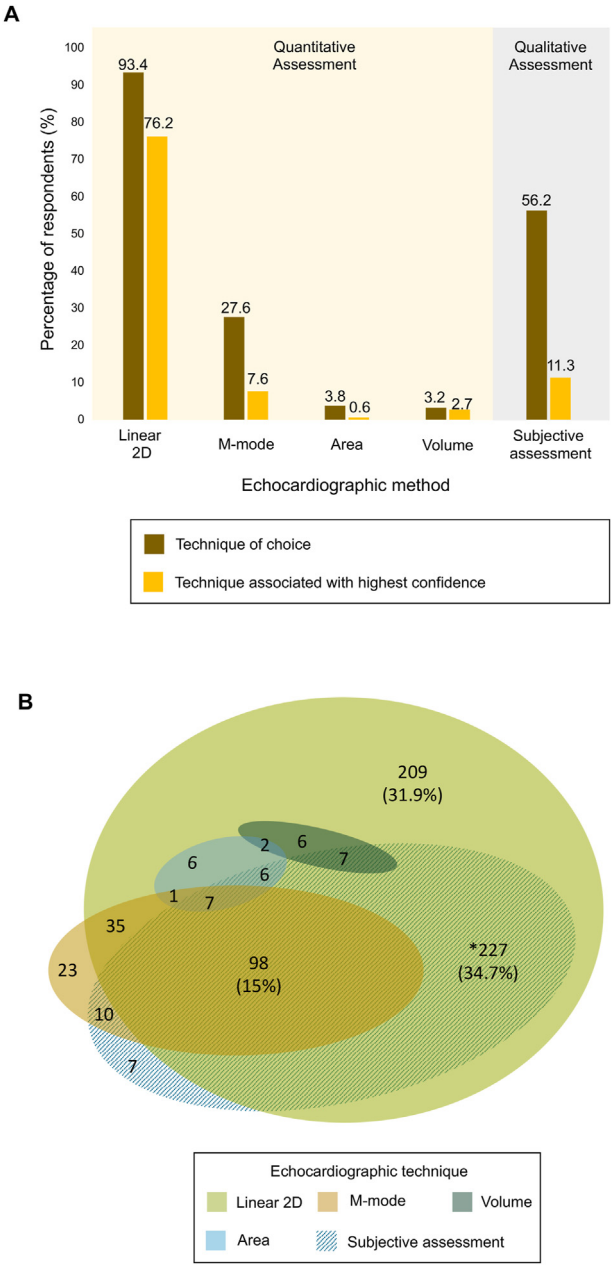

Figure 3 An overview of veterinary echocardiographers' preferences for left atrial size assessment in cats (n = 655), showing **(A)** the most commonly used (multiple-choice) and trusted (single-choice) echocardiographic technique for the purpose, and **(B)** demonstrates how echocardiographers combined different techniques for left atrial size assessment in cats and highlights the popularity of each combination. Respondents that used other echocardiographic techniques (n = 17) and other combinations (n = 5) were not included in (B). The size of the areas in (B) are approximately in proportion to the actual number of the responses for each technique, and the numbers represent the number of responses for each technique and the combination of techniques. *227 echocardiographers combined linear 2D-based methods and subjective assessment when assessing left atrial size in cats.

or biplane (modified) Simpson's method of discs (Supplemental Figure IV). Similarly, most respondents preferred indexing LA volume to body surface area or body weight, using 2D echocardiographic guidance for timing the measurement by visualizing maximal LA size or identifying the last frame before mitral valve opening. Thirty five percent of these respondents acquired repeat measurements over more than one cardiac cycle, and subsequently averaged them.

Qualitative assessment

Subjective assessment

Most of the 368 respondents who subjectively assessed LA size also used a quantitative assessment (Fig. 3B) and examined both right parasternal short-axis and long-axis four-chamber views (Supplemental Figure V).

Factors influencing choice of echocardiographic technique/method and respondents' willingness to change methods

Approximately two-thirds of the respondents stated that clinical studies and expert opinion had influenced their preferences for assessing LA size the most (Fig. 5). The echocardiographers' preferences were comparably similar across the groups based on geographic location, level of training, years performing echocardiography and type of practice, as shown in Supplemental Figures VI, VII and Supplemental Tables B and C. Most respondents were willing to change the method of use for assessing LA size in the future (Supplemental Table B).

Discussion

Our large survey-based study provides information about the methods cardiologists and other echocardiographers used to assess LA size in cats. Out of all respondents, 93% performed linear 2D echocardiographic measurements for LA size assessment in cats. This technique was the most trusted by 76% of all respondents. Common approaches were to acquire images from a right parasternal short-axis view with the cat positioned in right lateral recumbency, measuring the LA dimensions at approximately ventricular end-systole/early diastole, and indexing the LA size to the aortic dimension on the same image. However, considerable variability exists between respondents — among these approaches, only 34% of those using 2D imaging shared identical preferences. This suggests

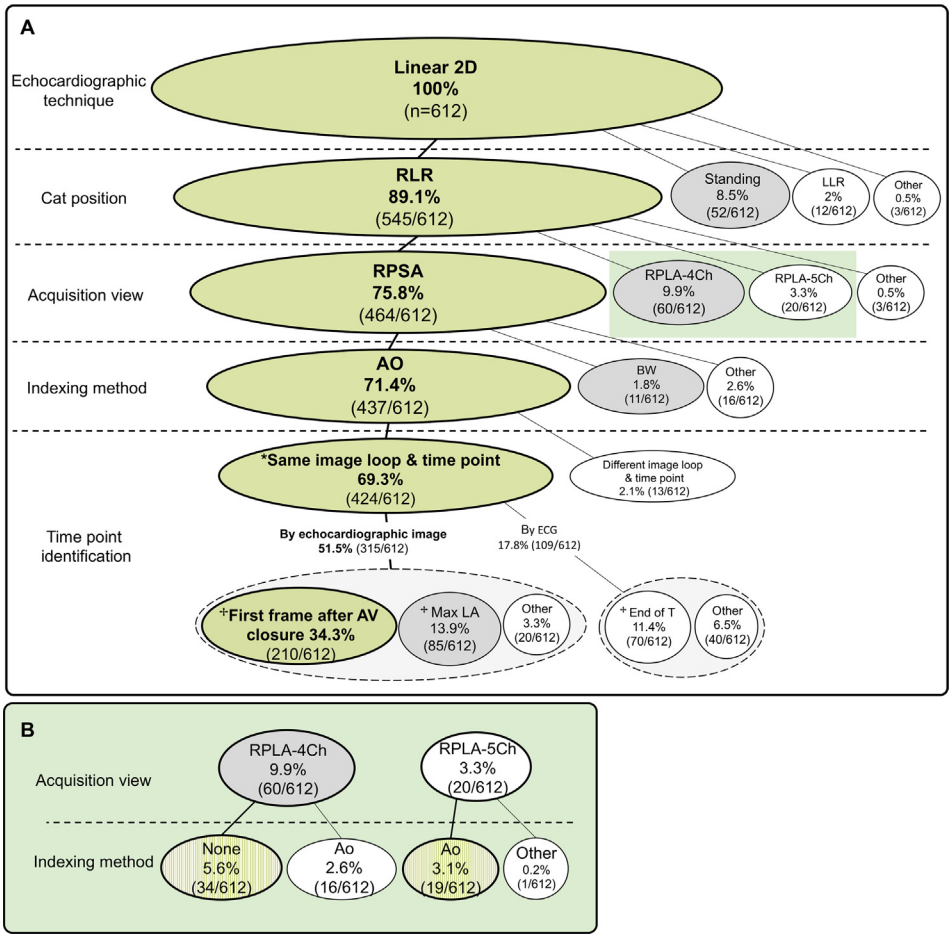

Figure 4 Linear two-dimensional preferences for assessment of left atrial size in cats based on responses from 612 veterinary echocardiographers preferences for assessment of left atrial size in cats based on responses from 612 veterinary echocardiographers. Questions regarding cat position, acquisition view, indexing method and time point identification for measurements had single discrete options for responding. The answers with the most (green) and the second most (gray) responses in each layer are marked. In (A), the branch was only extended from the answers with most responses in the previous question; therefore, totals at some individual levels can be less than the total on the previous level. (B) shows information regarding what indexing method were chosen by the respondents (the green square in A). Answer alternatives receiving less than 1.5% of the responses for the linear 2D method were grouped as 'other'. 2D: two-dimensional; Ao: aorta; AV: aortic valve; BW: body weight; LLR: left lateral recumbency; RLR: right lateral recumbency; RPSA: right parasternal short-axis view; RPLA-4Ch: right parasternal long-axis four-chamber view; RPLA-5Ch: right parasternal long-axis five-chamber view. *The respondents used the same image loop (acquisition view) and time point for both aortic and LA dimension for LA size assessment. +These time points were categorized as at the period approximately end-systole/early-diastole in the present study.

that considerable inconsistencies exist between respondents, underscoring the need for a more standardized approach (or approaches). For the assessment, linear 2D was often combined with subjective assessment.

For linear 2D methods, respondents acquired images from a right parasternal short-axis view (76%) much more commonly than from a right parasternal long-axis four-chamber view (10%). In the American College of Veterinary Internal Medicine consensus statement [6] and in other literature [22—24] concerning feline cardiology, it has been suggested that the LA dimension should be measured from a right parasternal short-axis view and be indexed to the Ao using the same frame; another common suggestion is to measure the LA dimension from a right parasternal long-axis four-chamber view, without indexing [25]. The LA and aortic dimensions have been reported to vary with body weight and sex in cats [26,27]. Accordingly, normalization of the LA size to either the Ao or by allometric scaling has been shown to

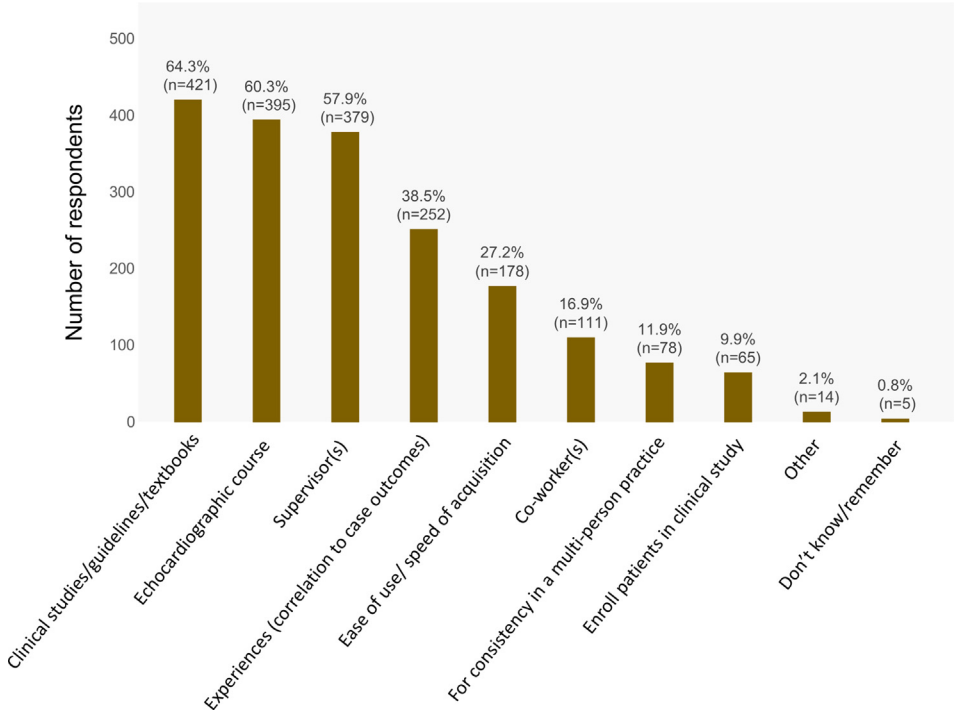

Figure 5 Factors that had impacted the 655 veterinary echocardiographers' preferences for left atrial size assessment in cats.

limit the impact of body weight [26,28]. Assessing LA size without indexing might be misleading with regards to the extent of LAE [26,28]. This might explain why the right parasternal long-axis four-chamber view was unfavored in the present study.

Of the respondents who shared comparably similar preferences regarding cat positioning, view of choice and indexing method in linear 2D, only one-third shared identical preferences in time point identification. More respondents timed their measurement at approximately ventricular end-systole/early-diastole, though they identified this period in the cardiac cycle using variable methods. For identifying ventricular end-systole/early-diastole, most respondents visualized aortic valve motion, but many also used either the size of LA or ECG gating. This suggests that some respondents experience difficulty in clearly visualizing the aortic commissures at ventricular early-diastole in some cats. Furthermore, different approaches (i.e. visualizing aortic valve motion, size of LA or ECG gating) [5,22,29] and different timings in the cardiac cycle have been reported in publications for LA measurement in cats, providing respondents with a range of options from which to choose their timing [29,30]. However, whether this has any clinical impact remains undetermined.

The most used approach for assessing LA size in cats was to combine subjective (qualitative) and linear 2D-based (quantitative) assessments rather than using linear 2D alone. A single linear measurement would not fully capture three-dimensional asymmetric LA dilation. As the left auricle in cats may sometimes be more prominently enlarged compared to the LA body [5], measuring LA size by this approach only might lead to underestimation of left auricular dilation, and could, accordingly, lead to underestimation of LAE. Combining the subjective assessment with linear 2D, to allow full inspection of the LA border, has been recommended for LA size assessment in cats [5]. In the present survey, assessing LA size subjectively was found to be the second most used method and was presented as the second most trusted when examining the LA in cats. One explanation might be that subjective assessment is intuitive and time-saving. Another explanation might be that enlargement of the LA in each feline cardiomyopathy stage was only described qualitatively [6], without quantification. These form the possible challenges of subjective assessment:

the consistency between different operators and accuracy in diagnosis and prognosis has never been systematically investigated in veterinary medi cine.

Respondents reported using MM less commonly than 2D methods. The prognostic value of LA size in feline cardiomyopathies was initially identified by using MM-based measurements [23]. The high temporal resolution of MM overcame some of the difficulties for visualizing rapid heart rate and small hearts in cats. However, with advances in imaging technology, frame rates and temporal resolution became less limiting in identifying appropriate measurement time-points. M-mode-based methods were more commonly performed for LA size assessment in one study concerning measurements in cats compared to dogs[1]. In cats, more than 1/4 of the respondents used MM-based methods, but only less than 1/10 of the total respondents trusted it the most. The MM technique was more frequently used by echocardiographers working in North and South America compared to the other continents, and by echocardiographers who had performed echocardiograms for $<$5 years or $>$20 years. A potential explanation for this finding is that respondents presumably had their habitual preferences, and beginners were willing to perform all the techniques taught by supervisors or outlined in textbooks.

Very few respondents used area- or volume-based methods for LA size assessment in cats. Using area- and volume-based methods for LA size assessment in cats has been reported to be time-consuming, and to have high sampling variation, low intra-operator repeatability, and low sensitivity for detecting LAE [27—31]. Moreover, the reference interval for normal LA volume reported in one study was established mainly based on measurements in cats of a single breed [32]. In the context of human medicine, evaluation of LA size and remodeling typically involves measurement of LA volume [33]. Unlike LA diameter, LA volume exhibits a more robust association with stronger prediction of outcomes in human [34]. Volumetric assessment in cats is likely constrained by the scarcity of dependable normal values of LA volume. Additionally, there is a lack of clinical studies demonstrating that intricate area- or volume-based methods offer superior prognostic value compared to simple linear estimates of LAE.

Survey research has developed into a rigorous branch of science that includes objectively tested strategies for obtaining representative samples [17,20,35,36]. In this study, we implemented an approach that has recently been utilized in human medicine to explore the divergences and commonalities in clinical imaging. By adopting similar methodology, we aimed to comprehensively address the obstacles encountered in a particularly contentious and intricate domain, namely the assessment of LA size in cats [11—13,37]. In addition to studying the preferred methods of examining LA size, the study also investigated the positioning of the cat, acquisition views, indexing methods, and identification of the time point used for the measurement for each method. We already know that the LA chamber assessed by echocardiography is a powerful clinical variable for disease assessment and prognostication [3—8,30]. We designed a survey instrument and used it to gather information from a wide range of veterinary echocardiographers worldwide. Accordingly, we find it of interest to evaluate current preferences amongst veterinary echocardiographers. This does not, however, indicate that methods assessed as being more accurate should be abandoned from future use systematically in favor of more efficient ones, but rather that the methods should be better described and optimized, to be practical in the hands of many. Obtaining information from this prospective exploratory study regarding 1) which and how specific techniques and methods are employed, 2) similarities and differences in LA size assessment in cats amongst veterinary echocardiographers, as well as 3) the underlying rationales for choosing the specific method for LA size assessment, can inform future developments in harmonization of LA size assessment in veterinary medicine.

Our study has some 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 [10—13,15]. No specific minimum number of participants was established for each category of geographic, demographic, or professional profiles, and the data that were analyzed and reported encompassed all valid responses. As in many other published survey studies, no inferential statistics were applied; only descriptive statistics were used, as inherent selection bias and other limitations could lead to inappropriate statistical conclusions. The survey was formulated in English, which might lead to misunderstanding or misinterpretation of the questions and answer alternatives to non-native English respondents. To overcome the language barrier and the respondents' potential differences in familiarity with

various echocardiographic terminologies, we invited 12 veterinarians (nine non-native English speakers) working in various fields and countries to validate the survey content. Only the respondents who had access to the internet and the survey 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 survey, and therefore might not be in proportion to the exact number of echocardiographers in any specific country. Respondents' preferences for echocardiographic LA size assessment in dogs and cats were investigated in the same survey[i]; thus, the respondents' answers for cats might be affected by their answers for dogs.

Conclusions

Most veterinary echocardiographers assessed LA size in cats using linear 2D-based methods. The majority of respondents employed the right parasternal short-axis view, indexed the LA to the aorta, and timed the measurement during end-systole/early-diastole. This approach was often combined with subjective assessment. Although the responses for linear 2D preferences appeared comparably homogeneous across respondents, less than one-third shared the exact same combination of preferences regarding position of the cat during the examination, acquisition view, indexing method, and identification of time point used for the measurements. The MM technique was used by one-third of echocardiographers and area- or volume-based method was infrequently used for assessment LA size in cats. Respondents' preferences were similar over geographic, demographic, and professional backgrounds.

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Conflict 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.2023.11.001.

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