# Article

## Left atrial measurement in lateral *versus* sternal recumbency in cats undergoing focused cardiac ultrasound examination

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### Abstract

**Objective**
To compare left atrial measurements carried out by an emergency and critical care (ECC) clinician on cats in lateral and sternal recumbency.

**Animals and procedures**
A prospective observational study was conducted between December 2019 and January 2021 at the university teaching hospital at University of Liège. One hundred and two hospitalized cats were enrolled. Focused cardiac ultrasound (FOCUS) was performed in right lateral and sternal recumbency by a single FOCUS-trained ECC resident. Standard right parasternal long- and short-axis views were recorded. After randomization of the cineloops, the same blinded resident measured maximal left atrial dimension (LAD) and the ratio of left atrial to aortic diameter (LA:Ao). Reproducibility was assessed using the Bland-Altman method.

**Results**
The LA:Ao and LAD measurements in lateral (LA:Ao median: 1.37, range: 1.02 to 3.22; LAD median: 13.25, range: 7.90 to 32.90) and sternal (LA:Ao median: 1.38, range: 1.06 to 3.22; LAD median: 13.00, range: 8.00 to 32.90) recumbency were not significantly different (bias: −0.003, CI −0.014, 0.007; and bias: −0.101, CI −0.231, 0.029, respectively).

**Conclusions and clinical relevance**
The FOCUS technique was successfully applied in sternal recumbency in almost all cats. The LAD and LA:Ao measured in sternal and lateral recumbency were not significantly different. Cardiac left atrial measurements obtained using FOCUS can be reliably assessed in sternal recumbency in hospitalized, stable cats.

### Résumé

**Mesure de l'oreillette gauche en décubitus latéral *versus* sternal chez les chats soumis à une échographie cardiaque focalisée**

**Objectif**
Comparer les mesures de l'oreillette gauche effectuées par un clinicien des urgences et soins intensifs (ECC) sur des chats en décubitus latéral et sternal.

**Animaux et procédures**
Une étude observationnelle prospective a été menée entre décembre 2019 et janvier 2021 au CHU de l'Université de Liège. Cent deux chats hospitalisés ont été enrôlés. L'échographie cardiaque focalisée (FOCUS) a été réalisée en décubitus latéral droit et sternal par un seul résident ECC formé au FOCUS. Des vues parasternales droites grand et petit axe standards ont été enregistrées. Après randomisation des cineloops, le même résident en aveugle a mesuré la dimension auriculaire gauche maximale (LAD) et le rapport entre le diamètre de l'oreillette gauche et celui de l'aorte (LA:Ao). La reproductibilité a été évaluée à l'aide de la méthode de Bland-Altman.


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**Résultats**
Les mesures LA:Ao et LAD en décubitus latéral (LA:Ao médian : 1,37, intervalle : 1,02 à 3,22; LAD médian : 13,25, intervalle : 7,90 à 32,90) et sternal (LA:Ao médian : 1,38, intervalle : 1,06 à 3,22; médiane LAD : 13,00, intervalle : 8,00 à 32,90) n'étaient pas significativement différents (biais : −0,003, IC −0,014, 0,007; et biais : −0,101, IC −0,231, 0,029, respectivement).

**Conclusions et pertinence clinique**
La technique FOCUS a été appliquée avec succès en décubitus sternal chez presque tous les chats. Le LAD et LA:Ao mesurés en décubitus sternal et latéral n'étaient pas significativement différents. Les mesures de l'oreillette cardiaque gauche obtenues à l'aide de FOCUS peuvent être évaluées de manière fiable en décubitus sternal chez les chats hospitalisés et stables.

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## Introduction

In dyspneic cats, rapid identification of the underlying cause influences treatment. However, dyspneic cats may not tolerate thoracic radiography or comprehensive echocardiography. Interest in point-of-care ultrasound is growing in human and veterinary emergency medicine. In 2004, Boysen *et al* published a focused abdominal ultrasound protocol to detect free abdominal fluid in dogs suffering from polytrauma (1). Focused ultrasound is now widely used for targeted assessment and monitoring of companion animals (2–9). Focused thoracic ultrasound is thought to be a safer diagnostic tool for identifying pleural and pulmonary diseases, as it requires less restraint than other methods (2–9). Similarly, focused cardiac ultrasound (FOCUS), when used by non-cardiologists, may improve the clinician's ability to differentiate cardiac from respiratory causes of dyspnea in cats (10). Indeed, FOCUS can be used to detect occult heart disease in asymptomatic cats, particularly when marked disease is present (11). Assessment of the left atrial to aortic diameter ratio (LA:Ao) improves diagnostic accuracy in cats with respiratory distress compared to physical examination alone (10).

The American Society of Echocardiography defines FOCUS as "a focused examination of the cardiovascular system performed by a physician using ultrasound as an adjunct to physical examination to recognize specific ultrasound signs that represent a narrow list of potential diagnoses in a specific clinical setting" (12). Although a cardiologist performs a full, standardized echocardiogram, the veterinary emergency clinician preferably performs FOCUS, often with the animal in a sternal or standing position, which allows dyspneic animals to breathe more comfortably (13). A study by Smith and McEwan demonstrated that cutoff echocardiographic measurements of 16.5 mm for left atrial dimension [(LAD) measured by the right parasternal (RPS) long axis] and 1.5 for the LA:Ao (measured by the RPS short axis at the base of the heart) are indicative of left atrial dilation and are compatible with left-sided congestive heart failure (14). In that study, full echocardiographic examination was conducted in unsedated cats in right- and left-lateral recumbency (14). It is currently unknown whether these reference values can be applied to cats in sternal recumbency, which is the typical position in which to scan dyspneic cats — particularly in the emergent setting, for the reasons specified above.

The aim of this study was to compare the LAD and the LA:Ao obtained from non-dyspneic cats in sternal and lateral recumbency, with images acquired *via* FOCUS carried out by a FOCUS-trained emergency and critical care (ECC) clinician. We hypothesized that there are no differences between sternal and lateral measurements of LAD and LA:Ao when taken by the same observer.

## Materials and methods

### Patient population

A prospective, observational, single-center study was conducted between December 2019 and January 2021. The study protocol was approved by the Ethical Committee of the University of Liège. Cardiorespiratory stable cats hospitalized for various reasons at the university teaching hospital were enrolled. Breed, age, sex, and body weight were recorded for all cats. Cats were excluded if their condition prevented them from being comfortably placed in right lateral recumbency or if they required sedation to undergo FOCUS.

### Focused cardiac ultrasound (FOCUS) measurements

Before the study, an ECC resident was trained in FOCUS (including 1 h of didactic lecture and 2 h of practical sessions) by a Board-certified cardiologist. For 1 mo, FOCUS images were scanned from hospitalized cats not included in the current study and reviewed by the cardiologist to provide feedback on their quality and interpretation. The study was started after the cardiologist considered the resident to be capable of obtaining repeatable, high-quality images. The FOCUS-trained ECC resident undertook the FOCUS examination with a portable ultrasound machine (Logiq V2 equipped with a microconvex probe 4–10 MHz; GE Healthcare, SCIL Veterinary Excellence, France). Cats were first placed in right-lateral recumbency on a standard echocardiography table, and then in sternal position. Cats' fur was not clipped for the purpose of the study; rather, the hair was separated and alcohol was applied as a coupling agent. Each cat was restrained by 1 or 2 staff members, nurses, or veterinary students. Three-second video cineloops in B-mode for the RPS long-axis 4-chamber view and the RPS short-axis view (at the level of the heart base, to view the aorta and left atrium concurrently) were recorded to assess LAD and LA:Ao,

**Table 1.** Measurements of left atrial parameters.

| FOCUS views | Placement of the probe | Parameters assessed |
|---|---|---|
| RPS long-axis 4-chamber view | The microconvex probe is placed on the right lateral thoracic wall where the strongest apex beat is palpable and oriented with the marker pointing towards the spine. | Maximum LAD is measured at the end of ventricular systole (when the LA diameter is widest, just prior to mitral valve opening). |
| RPS short-axis (transaortic) view | From the right parasternal long-axis view, the probe is rotated 90 degrees clockwise and then angled cranially and dorsally to visualize the aorta. | The LA:Ao is measured at the end of ventricular systole (when the LA diameter is the widest, just after aortic valve closure). |

FOCUS — Focused cardiac ultrasound; LA — Left atrium; LA:Ao — Left atrial to aortic diameter ratio; LAD — Left atrial dimension; RPS — Right parasternal.

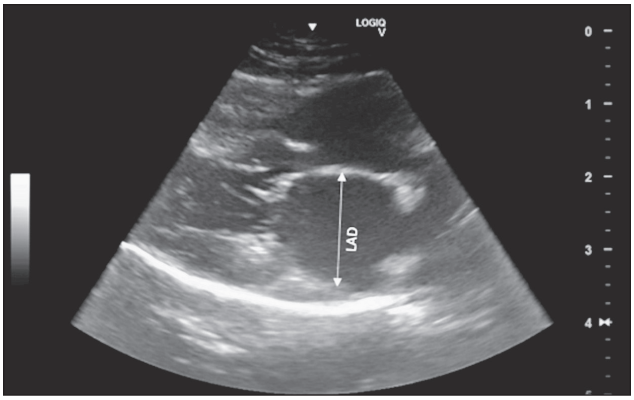


**Figure 1.** Right parasternal long-axis 4-chamber view. Measurement of the left atrial dimension (LAD) at the end of ventricular systole, when the left atrium is at its widest diameter.

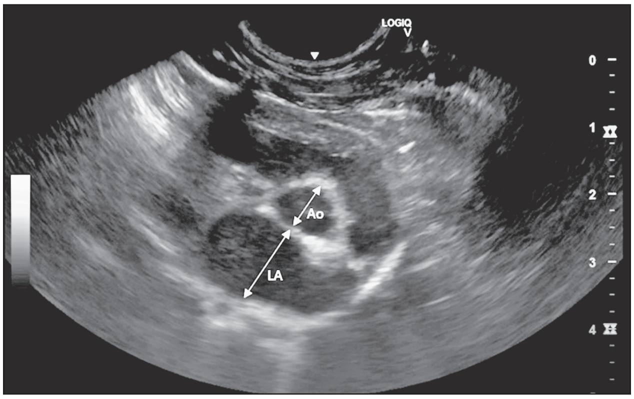


**Figure 2.** Right parasternal short-axis (transaortic) view. Measurement of the left atrial to aortic diameter ratio (LA:Ao).

respectively (Table 1; Figure 1 and Figure 2). The time taken for data acquisition was not recorded. Both measurements were made *a posteriori* on the recorded cineloops by the same ECC resident, who was blinded to the cats' identities and their positions.

## Statistical methods

Data were analysed using a commercial software program (XLSTAT, Addinsoft). A paired *t*-test was used to compare the means of the measurements in both positions. A value of $P < 0.05$ was considered statistically significant. The LAD and LA:Ao measured in the lateral *versus* sternal position during a FOCUS examination were highlighted using a scatterplot. The Bland-Altman method was used to assess agreement of left atrial measurements in each position. Bland-Altman analysis was used to determine systematic bias and 95% limits of agreement (LOA). In short, the 95% LOA describes the interval within which 95% of the differences between left atrial measurements performed in lateral and sternal positioning are evident. Quantitative variables were expressed as medians and ranges.

# Results

One hundred and two hospitalized cats were enrolled in this study. There were 9 different breeds: domestic shorthair (SH) (61/102, 59.8%); domestic longhair (LH) (23/102, 22.5%); Maine coon (6/102, 5.8%); Birman (4/102, 3.9%); Persian (3/102, 2.9%); British LH (2/102, 1.9%); and 1 (0.9%) each of Oriental SH, Siamese, and Russian blue. Male cats made up 53.9% (55/102) and female cats 46.1% (47/102) of the study population. The median age of the study population was 8 y (range: 0.6 to 17 y). The median body weight was 3.6 kg (range: 1.8 to 5.7 kg).

One hundred and two cats underwent FOCUS during the study period. The LA:Ao measurement was taken from recorded cineloops in both lateral and sternal recumbency in 100 cats and in sternal recumbency only in 1 cat, whereas it was not taken in either lateral or sternal recumbency in 1 cat. An LAD measurement was taken in both lateral and sternal recumbency in 98 cats and in sternal recumbency only in 4 cats. In 6 uncooperative cats, we were unable to determine left atrial measurements in both recumbencies, preventing the recording of the cineloops. The median values for each parameter with cats in both positions are presented in Table 2. The LAD obtained in lateral and sternal recumbency in cats is presented as a scatterplot in Figure 3. The mean of the differences in LAD between the 2 positions was not significantly different ($P = 0.125$). Figure 4 illustrates the results of Bland-Altman analysis for the LAD. The LAD was lower when measured in sternal compared to lateral recumbency, with excellent 95% LOA (−0.231 to 0.029 mm). The LA:Ao values obtained in lateral and sternal recumbency are presented in Figure 5. The mean of the differences in LA:Ao between the 2 positions was not significantly different ($P = 0.545$). Figure 6 illustrates the Bland-Altman analysis for LA:Ao. The LA:Ao was lower when measured in sternal compared to lateral recumbency, with excellent 95% LOA (−0.014 to 0.007). Table 3 summarizes the "between position" agreement for the same parameters.

Twelve cats (12/98, 12.2%) had left atrial measurements above established reference ranges, as shown in Table 4. An LAD > 16.5 mm was identified in both recumbencies in 12/98 (12.2%) cats. An additional 2 cats (2/98, 2.04%) exceeded this cutoff for LAD in lateral recumbency, but not in sternal (LAD lateral *versus* sternal: 16.6 *versus* 15.8 mm and 16.6 *versus* 16.5 mm, respectively). In the 4 cats for which LAD was completed only in sternal recumbency, the LAD was < 16.5 mm.

**Table 2.** Median (range) lateral and sternal recumbency left atrial measurements in cats obtained by one observer.

| | Lateral | Sternal |
|---|---|---|
| LAD (mm) | 13.25 (7.9 to 32.9) | 13.00 (8.00 to 32.9) |
| LA:Ao | 1.37 (1.02 to 3.22) | 1.38 (1.06 to 3.22) |

LA:Ao — Left atrial to aortic diameter ratio; LAD — Left atrial dimension.

One cat had LAD measured in sternal recumbency that was larger than LAD measured in lateral recumbency (21.7 *versus* 18.5 mm, respectively). An LA:Ao > 1.5 was identified in both recumbencies in 22/100 (22%) cats. An additional 5 cats (5/101, 4.95%) exceeded this cutoff for LA:Ao in sternal recumbency, but not in lateral (LA:Ao lateral *versus* sternal: 1.5 *versus* 1.51, 1.49 *versus* 1.54, 1.47 *versus* 1.75, 1.42 *versus* 1.51, 1.37 *versus* 1.7, respectively). In the cat for which LA:Ao was undertaken only in sternal recumbency, the LA:Ao was < 1.5.

## Discussion

This study compared LAD and LA:Ao measured in sternal *versus* lateral recumbency in cardiorespiratory stable cats by an ECC resident using FOCUS. There was no statistical difference between these 2 left atrial measurements taken in the 2 recumbencies. Considering the excellent 95% LOA (−0.231 to 0.029 mm for LAD; −0.014 to 0.007 for LA:Ao), the methods appear to be clinically interchangeable when carried out by the same observer.

In this study, an LAD > 16.5 mm was identified in both recumbencies in 12/98(12.2%) cats. An additional 2 cats (2/98, 2.04%) exceeded this cutoff for LAD in lateral recumbency, but not in sternal. By contrast, an LA:Ao > 1.5 was identified in both recumbencies in 22/100 (22%) cats. An additional 5 cats (5/101, 4.95%) exceeded this cutoff for LA:Ao in sternal recumbency, but not in lateral. However, all measured parameters aligned closely with the echocardiographic reference ranges reported for both LAD and LA:Ao measurements in cats (14). One (1/98, 1.02%) cat with an LAD above the established reference ranges had an LAD measured in sternal recumbency that was considerably higher than LAD measured in lateral recumbency (21.7 *versus* 18.5 mm). Measurements were completed by a FOCUS-trained ECC resident rather than a Board-certified cardiologist, which may have influenced the final LAD measurements recorded. However, regardless of position, both measurements are above cutoff reference limits and can be considered consistent with left-sided heart disease in this cat.

Currently, there is still no consensus on the optimal technique to assess left atrial size in companion animals. As cats in this study did not have full echocardiographic examinations done by a Board-certified cardiologist, it is not possible to confirm if they truly had left atrial parameters outside the reported reference ranges or if the measured results constitute measurement errors, including errors in image acquisition. In healthy dogs, Darnis (*et al,* 2019) showed that LA:Ao was mildly overestimated by non-cardiologists (15). More recently, Dickson (*et al,* 2022) did not identify a significant difference in LA:Ao sizes recorded by cardiologists *versus* non-cardiologists in dogs with myxomatous mitral valve disease [1.59 (1.09 to 2.46) *versus* 1.59 (1.20 to

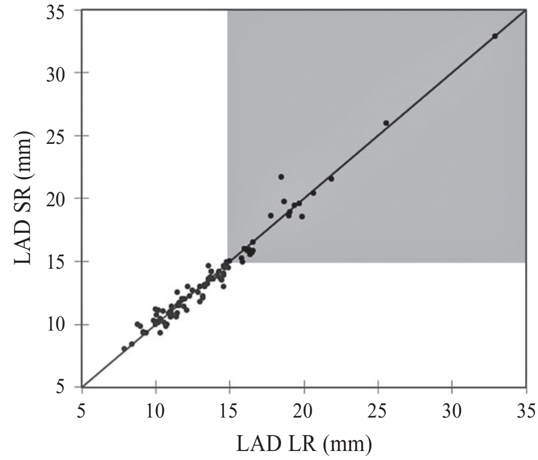


**Figure 3.** Scatterplot of LAD measured in lateral positioning *versus* LAD measured in sternal positioning, performed during a FOCUS examination. Results within the gray rectangular area of the graph correspond to LAD values above the previously reported LAD cutoff value of 16.5 mm (13).

FOCUS – Focused cardiac ultrasound; LAD – Left atrial dimension; LR – Lateral recumbency; SR – Sternal recumbency.

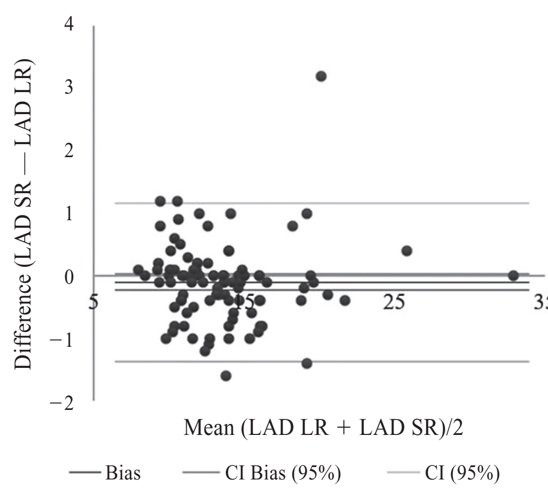


**Figure 4.** Bland-Altman plot of reproducibility between the LAD measured in lateral and in sternal recumbency. The means for the 2 methods are presented on the X-axis, and the difference between the methods on the Y-axis.

CI – Confidence interval; LAD – Left atrial dimension; LR – Lateral recumbency; SR – Sternal recumbency.

2.22); $P = 0.96$], although they did identify a significant difference in LAD, measured in short axis, with higher measurements taken by non-cardiologists [2.54 mm (1.22 to 3.61 mm) *versus* 2.76 mm (1.68 to 4.55 mm); $P < 0.001$] (16). Janson (*et al,* 2020) demonstrated moderate correlation between LA:Ao measured by FOCUS and by echocardiography (R = 0.646) in cats presenting with cardiac and noncardiac causes of respiratory distress (10). Interestingly, they showed a median LA:Ao of 2.05 (interquartile range: 0.13) in cats with left-sided congestive heart failure compared to cats whose signs were due to noncardiac disease [FOCUS LA:Ao median (interquartile range): 1 (0.13)] (10), which exceeded the previous reported reference ranges (14). Schober (*et al,* 2013) also evaluated left atrial size in cats with acute left-sided congestive heart failure, assessed by

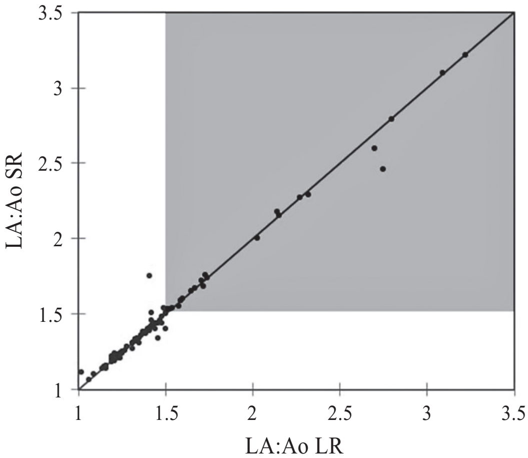


**Figure 5.** Scatterplot of LA:Ao measured in lateral positioning *versus* LA:Ao measured in sternal positioning, preformed during a FOCUS examination. Results within the gray rectangular area of the graph correspond to LA:Ao values above the previously reported LA:Ao cutoff value of 1.5 (13).

FOCUS – Focused cardiac ultrasound; LA:Ao – Left atrial to aortic diameter ratio; LR – Lateral recumbency; SR – Sternal recumbency.

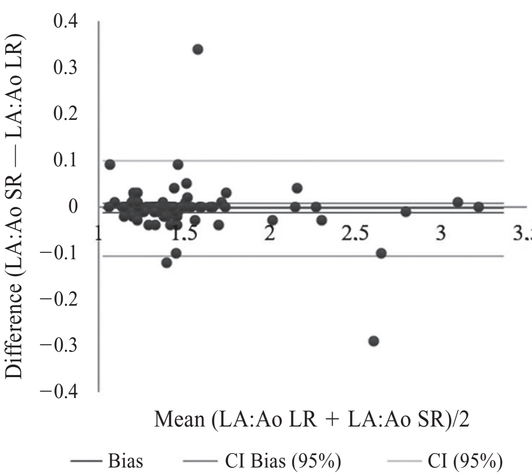


**Figure 6.** Bland-Altman plot of reproducibility between the LA:Ao measured in lateral and in sternal recumbency. The means for the 2 methods are presented on the X-axis, and the difference between the methods on the Y-axis.

CI – Confidence interval; LA:Ao – Left atrial to aortic diameter ratio; LR – Lateral recumbency; SR – Sternal recumbency.

a Board-certified cardiologist, and determined a median LAD of 19.8 mm (SD: 3.6 mm; range: 11 to 31.8 mm) (17). Ward (*et al,* 2018) identified that subjective assessment of left atrial enlargement during FOCUS in cats with respiratory distress was more reliable in predicting congestive heart failure (97% sensitivity, 100% specificity) than were left atrial measurements (18).

Our study assessed whether a FOCUS-trained ECC resident could obtain comparable left atrial measurements in lateral and sternal recumbency in cardiorespiratory stable cats. Given the excellent 95% LOA, the measurements were interchangeable between the 2 recumbencies. Whether measurements are similarly comparable in dyspneic cats is not known.

Although a prospective power analysis was not done to determine an effect of sample size, a retrospective power calculation was done to assess the validity of our findings. Based on previously published data, a 3-millimeter difference in LAD measurement (14) and a difference of 0.3 in LA:Ao (19) was considered clinically relevant. Based on these numbers, a sample size of 89 cats would be needed to achieve 80% power to detect a mean difference of 3 ± 5 mm for LAD and 0.3 ± 0.9 for LA:Ao with a significance level alpha = 0.025. Therefore, the sample size of 102 cats in the current study was considered sufficiently large to demonstrate the lack of a significant difference between measurements taken in sternal and lateral positions, given these statistical assumptions.

**Table 3.** Variability of LAD and LA:Ao based on patient position.

| LA measurements | Bland-Altman (bias, 95% LOA) |
|---|---|
| LAD (sternal — lateral) | −0.101 (−0.231 mm; 0.029 mm) |
| LA:Ao (sternal — lateral) | −0.003 (−0.014; 0.007) |

LA — Left atrium; LA:Ao — Left atrial to aortic diameter ratio; LAD — Left atrial dimension; 95% LOA — 95% limits of agreement.

**Table 4.** Left atrial measurements as a function of cutoff, based on patient positioning.

| Cutoff value | Lateral | Sternal |
|---|---|---|
| LAD ≤ 16.5 mm | 84/98 (85.7%) cats | 90/102 (88.2%) |
| LAD > 16.5 mm | 14/98 (14.3%) | 12/102 (11.8%) |
| LA:Ao ≤ 1.5 | 79/100 (79%) | 74/101 (73.2%) |
| LA:Ao > 1.5 | 22/100 (22%) | 27/101 (26.7%) |

LA:Ao — Left atrial to aortic diameter ratio; LAD — Left atrial dimension.

The fact that FOCUS cineloops were examined by only 1 FOCUS-trained ECC resident is a potential limitation of the current study. Chetboul (*et al,* 2004) reported interobserver agreement (between cardiologists) for echocardiographic measurements in cats and determined a coefficient of variation (CoV) for LA:Ao of 9.8% (20). Similarly, a more recent study in dogs reported lower CoV (4 and 7%) for LA:Ao measurements between a cardiologist and 2 trained non-cardiologists (15). Interobserver variability was not assessed in the current study. Although results of previous studies suggested non-cardiologists can gain proficiency in most cardiac measurements after undergoing a minimum of 3 h of FOCUS training (15,16,18), the fact than an independent person, preferably a Board-certified cardiologist, did not assess image quality may have biased the results of the current study.

Including only hospitalized, cardiorespiratory stable cats in the current study, without any time restrictions to obtain cineloops, was also a limitation. In addition, image acquisition time was not recorded. These results might not extrapolate to unstable cats presenting in the emergency setting. Stress for both the animal and the attending clinician, time constraints, and lack of available personnel for animal restraint may negatively affect the accuracy of image acquisition and measurement. In addition, our measurements were done retrospectively. These findings should be confirmed prospectively in a real-time setting. The initial recumbency for FOCUS was not randomized. Placing cats primarily in lateral recumbency may have induced anxiety and contributed to hemodynamic changes that may have influenced subsequent measurements obtained in sternal recumbency. The observer in this study had received advanced

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ultrasound training throughout their residency, which might not be representative of the average emergency clinician. The weight range of cats was 1.8 to 5.7 kg, and the findings in this study may not be applicable to larger or smaller cats, or to cats with extreme body condition scores. Similarly, only 2 cats ≤ 1 y of age were included and no cats < 6 mo of age were included, and extrapolation of findings to younger cats may not be applicable.

In conclusion, the LAD and LA:Ao measured by FOCUS in cats placed in sternal or lateral recumbency were not significantly different. To limit stress on animals, FOCUS exams can be done in sternal recumbency in almost all cardiorespiratory stable cats. CVJ

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