J Vet Sci. 2021 Sep;22(5):e60
https://doi.org/10.4142/jvs.2021.22.e60
pISSN 1229-845X·eISSN 1976-555X

Journal of Veterinary Science

Original Article
Medical Imaging

Check for updates

# Echocardiographic parameters and indices in 23 healthy Maltese dogs

**Chih-Hung Tsai** [1], **Chao-Chun Huang** [1], **Chia-Chi Ho** [1], **Marta Claretti** [2,*]

[1]Yu-Kang Animal Hospital, New Taipei City 220, Taiwan
[2]Department of Cardiology of Clinica Veterinaria Gran Sasso, 20131 Milano, Italy



**Received:** Jun 7, 2021
**Accepted:** Jun 29, 2021
Published online: Jul 12, 2021

***Corresponding author:**
**Marta Claretti**
Department of Cardiology, Clinica Veterinaria Gran Sasso, via Donatello 26, 20131 Milano, Italy.
E-mail: m_claretti@yahoo.com



**ORCID iDs**
Chih-Hung Tsai
https://orcid.org/0000-0002-6459-3576
Chao-Chun Huang
https://orcid.org/0000-0001-5921-1978
Chia-Chi Ho
https://orcid.org/0000-0001-7501-0770
Marta Claretti
https://orcid.org/0000-0001-6579-5033

**Conflict of Interest**
The authors declare no conflicts of interest.

**Author Contributions**
Conceptualization: Tsai CH, Claretti M; Data curation: Tsai CH, Huang CC, Ho CC; Formal analysis: Tsai CH, Huang CC, Ho CC; Investigation: Tsai CH, Huang CC, Ho CC; Methodology: Tsai CH; Project administration: Tsai CH, Claretti M; Resources: Tsai CH, Huang

## ABSTRACT

**Background:** Echocardiography is a primary tool used by veterinarians to evaluate heart diseases. In recent years, various studies have targeted standard echocardiographic values for different breeds. Reference data are currently lacking in Maltese dogs and it is important to fill this gap as this breed is predisposed to myxomatous mitral valve disease, which is a volume overload disease.
**Objectives:** To establish the normal echocardiographic parameters for Maltese dogs.
**Methods:** In total, 23 healthy Maltese dogs were involved in this study. Blood pressure measurements, thoracic radiography, and complete transthoracic echocardiography were performed. The effects of body weight, age and sex were evaluated, and the correlations between weight and linear and volumetric dimensions were calculated by regression analysis.
**Results:** The mean vertebral heart size was 9.1 ± 0.4. Aside from the ejection fraction, fractional shortening, and the left atrial to aorta root ratio, all the other echocardiographic parameters were significantly correlated with weight.
**Conclusion:** This study describes normal echocardiographic parameters that may be useful in the echocardiographic evaluation of Maltese dogs.

**Keywords:** Maltese dog; Echocardiography; Cardiovascular; Ultrasound; Canine

## INTRODUCTION

Echocardiography is a primary tool used to monitor heart dimensions and morphology, blood dynamics, and myocardial function. Numerous experienced cardiologists have applied ultrasonic techniques to the study and definition of echocardiographic measurement parameters [1-4]. Dogs of different breeds have different ventricular and atrial dimensions and morphologies [2]. In recent years, various studies have targeted standard echocardiographic values for different breeds of dogs, such as Beagles [5], Bull Terriers [6], Whippets [7], Border Collies [8], Labrador Retrievers [9], Indian Spitzes [2] and the Dogue de Boredaux [10], and many others. In addition to the aforementioned breed differences, diastolic function is influenced by factors including body shape, weight, body structure, heart rate, and sex [11-13]. Consequently, reference values for various echocardiography modes are required for different breeds for the clinical application of disease diagnosis, treatment, and prognosis tracking.

CC, Ho CC; Supervision: Claretti M; Validation: Tsai CH; Writing - original draft: Tsai CH; Writing - review & editing: Claretti M.

Studies have established that heart diseases that cause regression changes in valves are related to genetics and ageing [14-17]. Breeds with higher incidence include Cavalier King Charles Spaniels, Poodles, Miniature Schnauzers, Chihuahuas, Cocker Spaniels, and numerous small breeds [18]. Maltese dogs are common in Taiwan, and studies have indicated that they have genes that make them prone to mitral valve myxomatous mitral valve disease [19]. In Japan, Maltese dogs account for 23.5% of dogs with myxomatous mitral valve disease, and the morbidity rate among male dogs is 1.4 times that of female dogs [19,20]. Consequently, Maltese dogs were chosen as the sample in this study. The first aim of the study was to obtain normal echocardiographic variables and the second aim was to collect also radiographic and pressure variables.

## MATERIALS AND METHODS

Records of client-owned dogs that were presented at Yu Kang Veterinary Hospital in Banqiao District (New Taipei City) for cardiac evaluation between January 2019 and December 2019 were reviewed. The clinical presentation, history and physical examination data of each dog were reviewed.

Blood pressure measurements were performed with a USA Pet MAP graphic II Blood Pressure Measurement Device. The measurements were conducted in a quiet environment, away from other animals, before other procedures and only after the patients had been acclimated for 5 minutes. Blood pressure cuffs with a 30%–40% width of the tail root were selected [21]. The systolic, diastolic and mean arterial pressure and pulses were measured for six repetitions. The first measurement was discarded, and the average of five consecutive consistent measurements was recorded.

All of the dogs, with the consent of the owners, underwent haematological and biochemical tests, including heartworm antigen tests.

Thoracic radiography in right lateral and ventro-dorsal views was performed by Konica Minolta Regius Model 110 Computed Radiography. For evaluation of the heart size, the vertebral heart size (VHS) was measured according to the method published by Buchanan et al. [22].

Twelve-lead electrocardiography (ECG) in conscious, relaxed, unsedated, gently restrained dogs in right lateral recumbency was performed in a quiet environment, for five minutes, according to Santilli et al. [23]. The ECGs were acquired to rule out abnormal heart rhythm.

A complete transthoracic echocardiography (TTE) was performed in all animals without sedation. Echocardiography was performed using an Esaote Mylab Class C (Italy) with the PA-122 probe (Cardio Phased Array 8-3 MHz), following the published recommendations [24].

Left ventricle (LV) measurements were performed using standard right parasternal long-axis and short-axis views in B-mode and M-mode, through the Teicholz method. Variables measured included the left ventricular internal dimension at end systole (LVIDs) and at end diastole (LVIDd), the left ventricular posterior wall thickness at end systole (LVPWs) and at end diastole (LVPWd), and the interventricular septal thickness at end systole (IVSs) and at end diastole (IVSd) [24,25]. Then, the left ventricular fractional shortening (FS), ejection fraction (EF), and LV volumes (end-diastolic volume [EDV] and end-systolic volume

[ESV]) were calculated according to standard formula. The modified Simpson method was used to estimate the LV cavity, form the left parasternal four-chamber apical view [26-28]. Assessment of left atrial (LA) size was performed from the right parasternal short-axis view, and the left atrial-to-aortic ratio (LA/Ao) was calculated [29]. Concerning the Doppler examination, the peak velocity of early diastolic transmitral flow (E wave) and late diastolic transmitral flow (A wave), the ratio between both transmitral flow velocities (E/A ratio) and the E wave deceleration time (EDT) were recorded [30]. Tissue Doppler imaging was performed with the highest available transducer frequency to record the velocity of lateral mitral annular motion from the left apical four-chamber view, and the following variables were measured: the peak early diastolic velocity (E′ wave), peak late diastolic velocity (A′ wave), ratio between E′ and A′ waves, and ratio between E and E′ waves [1,31]. In addition, the heart rate was recorded.

All of the examinations were performed by the same experienced cardiologist. The inclusion criteria for our analysis were no abnormal findings upon physical examination, ECG measurements within reference limits, and no evidence of congenital and/or acquired heart disease in TTE.

### Statistical analysis

Statistical analysis was performed using SPSS Statistics Base 20 for Microsoft Windows.

The dogs were divided by weight (1–3 kg and 3–5 kg), sex (male and female), and age (less than 2 years and 2–6 years).

Independent variables analysed were sex, age and weight, while the dependent variables were echocardiographic parameters. Distributions of the echocardiographic parameters were tested for normality by the Shapiro Wilk tests, and a normal distribution was accepted if the $p$ value was greater than 0.05. The mean and SD of each variable were calculated for normally distributed data, whereas data that failed either test or both tests were presented as the median and range. Correlations between the independent variables (gender, age and weight) were also tested.

The Mann-Whitney test was used to assess the significance of differences for each parameter. The Spearman correlation test was used to determine correlations and establish the regression formula for weight and the echocardiographic parameters in B-mode and M-mode. Results with $p < 0.05$ were considered significant. For correlations, $r < 0.4$ was considered a low correlation, $r > 0.7$ was considered a high correlation, and the remaining values indicated a medium correlation. Simple linear regression was performed on variables that were determined to have significant correlations ($p < 0.05$) with body weight.

## RESULTS

Twenty-three of the 81 Maltese dogs underwent cardiologic consultation in 2019 and fulfilled the inclusion criteria, while 58 dogs were excluded from the study mainly due to the presence of heart apical murmurs and mitral valve degeneration in echocardiography.

Body weights ranged from 1.5 to 5.1 kg, with nine dogs included in the 1–3 kg group and 14 included in the second group. The Maltese dogs included 11 males (one of which was

Journal of Veterinary Science

neutered) and 12 females (none of which were spayed). Ages ranged from 7 to 67 months, and six dogs were less than two years of age.

There was no significant correlation between the independent variables (gender, age and weight; $p > 0.05$). The influences of weight, sex and age on the echocardiographic parameters were assessed. As expected, most of the parameters did not differ significantly in the age and sex groups ($p > 0.05$). Correlation analysis was performed to assess the relationship of weight with the echocardiographic parameters, and the results indicated a strong positive relationship ($p < 0.01$) for most of them, with linear correlations. For each parameter, the SD and 95% confidence interval, in addition to the upper and lower parts of the reference range, were established.

**Table 1** shows the blood pressure measurements, heart rate, and VHS of the 23 healthy Maltese dogs included in our study. The mean VHS was 9.1 ± 0.4 (range: 8.5–9.8).

Variables determined from 2D and M-mode echocardiography are presented in **Table 2**.

**Table 3** shows the values (mean ± SD) of left ventricular diastolic function parameters upon Doppler examination and tissue Doppler echocardiography for all dogs.

**Tables 4** and **5** list the correlation results for weight with LV measurements and volume based on M-mode and B-mode echocardiography, respectively. Apart from EF, FS, and the LA/Ao ratio, all parameters were highly positively correlated with weight ($p < 0.01$).

**Table 1.** Blood pressure, heart rate, and VHS in 23 healthy Maltese dogs

| Parameters | Mean | Median | SD | 95% CI | Range |
|---|---|---|---|---|---|
| SBP (mmHg) | 127 | 125 | 10.5 | 122–131 | 110–150 |
| MAP (mmHg) | 99 | 101 | 6.5 | 96–102 | 83–111 |
| DBP (mmHg) | 86 | 85 | 8.1 | 82–89 | 65–105 |
| HR (bpm) | 107 | 100 | 16 | 100–114 | 75–135 |
| VHS | 9.1 | 9.1 | 0.3 | 8.9–9.3 | 8.5–9.8 |

CI, confidence interval; DBP, diastolic blood pressure; HR, heart rate; MAP, mean arterial pressure; SBP, systolic blood pressure; VHS, vertebral heart size.

**Table 2.** M-mode and 2D echocardiographic measurements of LA, aortic, and left ventricular dimensions from 23 healthy Maltese dogs

| Parameters | Mean | Median | SD | 95% CI | Range |
|---|---|---|---|---|---|
| MM LVIDd (mm) | 20.53 | 20.3 | 3.04 | 19.29–21.78 | 15.80–29.40 |
| MM LVIDs (mm) | 12.18 | 12.3 | 2.25 | 11.26–13.12 | 8.30–19.00 |
| MM IVSd (mm) | 5.16 | 5.2 | 0.83 | 4.82–5.50 | 3.70–6.50 |
| MM IVSs (mm) | 8.25 | 8.0 | 1.21 | 7.76–8.75 | 5.50–10.10 |
| MM LVPWd (mm) | 4.86 | 4.9 | 0.68 | 4.58–5.14 | 3.70–6.20 |
| MM LVPWs (mm) | 7.34 | 7.3 | 1.13 | 6.88–7.80 | 5.60–9.40 |
| AoD (mm) | 10.39 | 10.3 | 1.35 | 9.84–10.94 | 7.50–13.00 |
| LA (mm) | 11.40 | 11.6 | 1.75 | 10.68–12.12 | 6.60–15.00 |
| LA/Ao | 1.10 | 1.09 | 0.13 | 1.04–1.15 | 0.75–1.3 |
| LVIDs (mm) | 12.63 | 12.6 | 2.44 | 11.64–13.63 | 8.30–19.00 |
| LVIDd (mm) | 21.15 | 20.4 | 3.20 | 19.84–22.46 | 16.20–28.50 |
| IVSd (mm) | 4.98 | 5.3 | 0.77 | 4.67–5.29 | 3.70–6.00 |
| LVPWd (mm) | 4.78 | 4.9 | 0.78 | 4.46–5.10 | 3.70–6.80 |
| EDV (mL) | 5.92 | 5.6 | 1.83 | 5.18–6.67 | 2.40–9.60 |
| ESV (mL) | 1.66 | 1.5 | 0.66 | 1.39–1.92 | 0.73–3.60 |
| EF% | 72.35 | 73.0 | 4.81 | 70.38–74.31 | 63.00–82.00 |
| FS% | 39.17 | 39.0 | 3.95 | 37.56–74.31 | 31.00–47.00 |

AoD, aortic diameter; CI, confidence interval; EF%, ejection fraction; FS%, fractional shortening; EDV, end-diastolic volume of the left ventricle; ESV, end-systolic volume of the left ventricle; IVSd, interventricular septal thickness at end diastole; IVSs, interventricular septal thickness at end systole; LA/Ao, left atrial to aorta root ratio; LA, left atrial; LVIDd, left ventricular internal diameter at end diastole, LVIDs, left ventricular internal diameter at end systole; MM, motion mode; LVPWd, left ventricular posterior wall at end diastole; LVPWs, left ventricular posterior wall at end systole.

**Table 3.** Spectral Doppler measurements

| Parameters | Mean | Median | SD | 95% CI | Range |
|---|---|---|---|---|---|
| E wave (cm/s) | 72.26 | 74.0 | 11.73 | 67.46–77.06 | 43.00–88.00 |
| A wave (cm/s) | 57.13 | 56.0 | 11.58 | 52.40–61.86 | 42.00–83.00 |
| E/A ratio | 1.29 | 1.33 | 0.15 | 1.22–1.35 | 1.03–1.55 |
| EDT (ms) | 74.39 | 76.0 | 12.54 | 69.27–79.52 | 46.00–99.00 |
| IVRT (ms) | 45.91 | 46.0 | 6.57 | 43.23–48.60 | 35.00–56.00 |
| TDI E′ (cm/s) | 8.04 | 8.0 | 1.22 | 7.54–8.54 | 6.00–10.00 |
| TDI A′ (cm/s) | 5.83 | 6.0 | 1.03 | 5.40–6.25 | 4.00–8.00 |
| E′/A′ ratio | 1.40 | 1.38 | 0.19 | 1.32–1.47 | 1.17–1.74 |
| E/E′ ratio | 9.13 | 8.93 | 1.86 | 8.37–9.89 | 5.60–12.38 |

CI, confidence interval; A wave, peak velocity of the late transmitral flow signal; E wave, peak velocity of the early transmitral flow signal; EDT, early transmitral flow velocity deceleration time; IVRT, isovolumic relaxation time; TDI A′, tissue Doppler imaging peak myocardial velocities in late diastole at the lateral mitral annulus; TDI E′, tissue Doppler imaging peak myocardial velocities in early diastole at the lateral mitral annulus.

**Table 4.** Linear regression and correlation analysis for weight with the left ventricular, aorta, and LA size in M-mode echocardiography

| Echocardiographic parameters | Regression (y=) | Correlation | ($r^2$) | *p* value |
|---|---|---|---|---|
| LVIDd (mm) | 2.185x + 13.84 | 0.6513 | 0.4574 | 0.0004*** |
| LVIDs (mm) | 1.364x + 7.999 | 0.4767 | 0.3233 | 0.0107* |
| IVSd (mm) | 0.5128x + 3.592 | 0.4963 | 0.3342 | 0.0080** |
| IVSs (mm) | 0.8115x + 5.767 | 0.5588 | 0.3925 | 0.0028** |
| LVPWd (mm) | 0.4514x + 3.476 | 0.5531 | 0.3834 | 0.0031** |
| LVPWs (mm) | 0.8278x + 4.804 | 0.6197 | 0.4765 | 0.0008*** |
| AoD (mm) | 1.077x + 7.086 | 0.6476 | 0.5648 | 0.0004*** |
| LA (mm) | 1.461x + 6.919 | 0.6243 | 0.6138 | 0.0007*** |
| LA/Ao | 0.03488x + 0.9891 | 0.2865 | 0.0674 | 0.0925 |

AoD, aortic diameter; IVSd, interventricular septal thickness at end diastole; IVSs, interventricular septal thickness at end systole; LA/Ao, left atrial to aorta root ratio; LA, left atrial; LVIDd, left ventricular internal diameter at end diastole, LVIDs, left ventricular internal diameter at end systole; LVPWd, left ventricular posterior wall at end diastole; LVPWs, left ventricular posterior wall at end systole.
*Correlation and regression values are significantly ($p < 0.05$) related to the echocardiographic parameter.
**Correlation and regression values are highly significantly ($p < 0.01$) related to the echocardiographic parameter.
***Correlation and regression values are extremely significantly ($p < 0.001$) related to the echocardiographic parameter.

**Table 5.** Linear regression and correlation analysis for weight with the left ventricular size, volume, and systolic functions in B-mode echocardiography

| Echocardiographic parameters | Regression (y=) | Correlation | ($r^2$) | *p* value |
|---|---|---|---|---|
| LVIDd (mm) | 2.599x + 13.18 | 0.7419 | 0.5842 | < 0.0001*** |
| LVIDs (mm) | 1.81x + 7.082 | 0.5952 | 0.4882 | 0.0014** |
| IVSd (mm) | 0.5575x + 3.27 | 0.6307 | 0.4671 | 0.0006*** |
| LVPWd (mm) | 0.3593x + 3.68 | 0.4377 | 0.1887 | 0.0184* |
| EDV (mL) | 1.65x + 0.8605 | 0.7896 | 0.7221 | < 0.0001*** |
| ESV (mL) | 0.5902x − 0.1546 | 0.7358 | 0.7187 | < 0.0001*** |
| EF% | 0.1025x + 72.03 | 0.07109 | 0.0004 | 0.3736 |
| FS% | 0.3597x + 38.07 | 0.1334 | 0.0073 | 0.2720 |

EDV, left ventricular end-diastolic volume; EF%, ejection fraction; ESV, left ventricular and systolic volume; FS%, fractional shortening; IVSd, interventricular septal thickness at end diastole; LVIDd, left ventricular internal diameter at end diastole; LVIDs, left ventricular internal diameter at end systole, LVPWd, left ventricular posterior wall at end diastole.
*Correlation and regression values are significantly ($p < 0.05$) related to the echocardiographic parameter.
**Correlation and regression values are highly significantly ($p < 0.01$) related to the echocardiographic parameter.
***Correlation and regression values are extremely significantly ($p < 0.001$) related to the echocardiographic parameter.

## DISCUSSION

Several studies have established echocardiographic reference ranges in dogs using various allometric scaling techniques [7,32,33], and a number of breed-specific reference ranges have been developed to further improve echocardiographic assessments and clinical decision-


https://doi.org/10.4142/jvs.2021.22.e60

making [5,6,8,10,34-37]. To the best of the author's knowledge, this study is the first to provide an echocardiographic parameter in healthy Maltese dogs.

In previous studies, the mean VHS of approximately 98% of healthy dogs was ≤ 10.5. However, this value differs between breeds. For example, the VHS of Miniature Schnauzers can be up to 11; some deep-chested dogs, such as Dachshunds, have a standard VHS value of approximately 9.5; and the standard value of the Beagle is approximately 10.3 ± 0.5 [38,39]. VHS values differ according to the animals' growth condition and age, and the direction of the X-ray (i.e., left or right recumbency position) also influences the VHS results [40], as malformations of the thoracic vertebrae or fat infiltration of the mediastinum or pericardial area. In our study, the mean VHS was 9.1 ± 0.4 for Maltese dogs.

Concerning the M-mode echocardiography standard values reported in literature, in a study of Whippets, because the heart weight and weight ratio of female dogs were higher than those of male dogs, the LVID differed significantly between the sex groups ($p < 0.05$) [7]. In addition, in studies of Beagles and German Shepherds, the LVPW differed significantly between sexes ($p < 0.05$) [5,16]. Conversely, the LA/Ao ratio and the EF and FS did not differ significantly ($p > 0.05$). Similarly, according to the standard echocardiography values for Beagles, the LA/Ao ratio, EF, and FS are not influenced by sex, weight, or age [5]. Therefore, these heart systolic functions are not influenced by weight and age; however, the EF was negatively correlated with weight in some breeds with similar structures [34].

The LVID increased with weight in our findings, as reported in previous studies [2,9,35]. However, according to the studies on Corgis and Afghan Hounds, weight changes are not correlated with the LVID [16]. In addition, in studies of Indian Spitzes, Beagles, and Labrador Retrievers, the IVS and LVPW were not correlated with weight [2,5,9]. In a study of Labrador Retrievers, the left ventricular systolic and diastolic volumes were significantly correlated with weight ($p < 0.01$) [9].

The results of our study were as expected. The parameters related to blood dynamics, E waves, A waves, the E/A wave ratio, the EDT, E′ waves, A′ waves, the E′/A′ ratio, EF%, and FS% exhibited no significant differences in weight ($p > 0.05$).

In contrast, for parameters related to heart size, such as the LVID, LVPW, LA, IVS, AoD, and left ventricular volume, correlation analysis revealed that these parameters were almost all extremely correlated with weight ($p < 0.01$). Based on the results of this study, linear regression calculations were performed to analyse the relationship of weight with the aforementioned parameters related to heart size to obtain formulas.

Several limitations of this study must be considered. The sample size is the major limitation of our study. Reference intervals should ideally be established from a minimum of 120 healthy individuals; however, as there is not such a caseload in our clinic and there are no reference ranges, according to the authors' knowledge, we wanted to pave the way on this breed.

The small sample size of the group could have affected the association between gender and reference values and made the association between the parameters and gender unreliable. Further studies in a larger population of Maltese dogs are warranted to confirm the findings from this study. Furthermore, the population in this study was not randomly selected, and the possibility of selection bias should be considered. A multicentre study is desirable.

Given these limitations, we believe that our findings are likely representative of a healthy population of Maltese dogs, but further studies in a larger population are warranted to confirm the findings of this study.

The Maltese is the dog breed with the highest incidence of heart disease in Taiwan.

There is a high prevalence of mitral valve insufficiency within this population of dogs, although it appears to be generally mild to moderate in nature. This study provides breed-specific echocardiographic parameters for normal Maltese dogs, and these data may be useful in echocardiographic evaluations.

## ACKNOWLEDGMENTS

The authors thank Dr. Claudio Bussadori for the scientific consultation.

## REFERENCES

1. Appleton CP, Firstenberg MS, Garcia MJ, Thomas JD. The echo-Doppler evaluation of left ventricular diastolic function. A current perspective. Cardiol Clin. 2000;18(3):513-546.
PUBMED | CROSSREF
2. Bodh D, Hoque M, Saxena AC. Echocardiographic study of healthy Indian Spitz dogs with normal reference ranges for the breed. Vet World. 2019;12(6):740-747.
PUBMED | CROSSREF
3. Bonagura JD, Miller MW. Doppler echocardiography. II. Color Doppler imaging. Vet Clin North Am Small Anim Pract. 1998;28(6):1361-1389.
PUBMED | CROSSREF
4. Pedersen F, Raymond I, Madsen LH, Mehlsen J, Atar D, Hildebrandt P. Echocardiographic indices of left ventricular diastolic dysfunction in 647 individuals with preserved left ventricular systolic function. Eur J Heart Fail. 2004;6(4):439-447.
PUBMED | CROSSREF
5. Crippa L, Ferro E, Melloni E, Brambilla P, Cavalletti E. Echocardiographic parameters and indices in the normal beagle dog. Lab Anim. 1992;26(3):190-195.
PUBMED | CROSSREF
6. O'Leary CA, Mackay BM, Taplin RH, Atwell RB. Echocardiographic parameters in 14 healthy English Bull Terriers. Aust Vet J. 2003;81(9):535-542.
PUBMED | CROSSREF
7. Bavegems V, Duchateau L, Sys SU, De Rick A. Echocardiographic reference values in whippets. Vet Radiol Ultrasound. 2007;48(3):230-238.
PUBMED | CROSSREF
8. Jacobson JH, Boon JA, Bright JM. An echocardiographic study of healthy Border Collies with normal reference ranges for the breed. J Vet Cardiol. 2013;15(2):123-130.
PUBMED | CROSSREF
9. Gugjoo MB, Hoque M, Saxena AC, Shamsuz Zama MM, Dey S. Reference values of M-mode echocardiographic parameters and indices in conscious Labrador Retriever dogs. Majallah-i Tahqiqat-i Dampizishki-i Iran 2014;15(4):341-346.
PUBMED
10. Locatelli C, Santini A, Bonometti GA, Palermo V, Scarpa P, Sala E, et al. Echocardiographic values in clinically healthy adult dogue de Bordeaux dogs. J Small Anim Pract. 2011;52(5):246-253.
PUBMED | CROSSREF
11. Schober KE, Baade H. Comparability of left ventricular M-mode echocardiography in dogs performed in long-axis and short-axis. Vet Radiol Ultrasound. 2000;41(6):543-549.
PUBMED | CROSSREF

12. Schober KE, Fuentes VL. Effects of age, body weight, and heart rate on transmitral and pulmonary venous flow in clinically normal dogs. Am J Vet Res. 2001;62(9):1447-1454.
PUBMED | CROSSREF

13. Visser LC, Ciccozzi MM, Sintov DJ, Sharpe AN. Echocardiographic quantitation of left heart size and function in 122 healthy dogs: a prospective study proposing reference intervals and assessing repeatability. J Vet Intern Med. 2019;33(5):1909-1920.
PUBMED | CROSSREF

14. Buchanan JW. Chronic valvular disease (endocardiosis) in dogs. Adv Vet Sci Comp Med. 1977;21:75-106.
PUBMED

15. Das KM, Tashjian RJ. Chronic mitral valve disease in the dog. Vet Med Small Anim Clin 1965;60(12):1209-1216.
PUBMED

16. Morrison SA, Moise NS, Scarlett J, Mohammed H, Yeager AE. Effect of breed and body weight on echocardiographic values in four breeds of dogs of differing somatotype. J Vet Intern Med. 1992;6(4):220-224.
PUBMED | CROSSREF

17. Meurs KM, Friedenberg SG, Williams B, Keene BW, Atkins CE, Adin D, et al. Evaluation of genes associated with human myxomatous mitral valve disease in dogs with familial myxomatous mitral valve degeneration. Vet J. 2018;232:16-19.
PUBMED | CROSSREF

18. Boswood A, Häggström J, Gordon SG, Wess G, Stepien RL, Oyama MA, et al. Effect of pimobendan in dogs with preclinical myxomatous mitral valve disease and cardiomegaly: the EPIC study-a randomized clinical trial. J Vet Intern Med. 2016;30(6):1765-1779.
PUBMED | CROSSREF

19. Lee CM, Song DW, Ro WB, Kang MH, Park HM. Genome-wide association study of degenerative mitral valve disease in Maltese dogs. J Vet Sci. 2019;20(1):63-71.
PUBMED | CROSSREF

20. Kageyama TW, Wakao Y, Sawa K, Muto M, Watanabe T, Miyata Y, et al. Echocardiographic findings of mitral regurgitation in Maltese dogs. Adv Anim Cardiol. 1994;27:70-76.

21. Acierno MJ, Brown S, Coleman AE, Jepson RE, Papich M, Stepien RL, et al. ACVIM consensus statement: guidelines for the identification, evaluation, and management of systemic hypertension in dogs and cats. J Vet Intern Med. 2018;32(6):1803-1822.
PUBMED | CROSSREF

22. Buchanan JW. *Textbook of Canine and Feline Cardiology*. 2nd ed. Philadelphia: WB Saunders; 1999.

23. Santilli RA, Porteiro Vázquez DM, Gerou-Ferriani M, Lombardo SF, Perego M. Development and assessment of a novel precordial lead system for accurate detection of right atrial and ventricular depolarization in dogs with various thoracic conformations. Am J Vet Res. 2019;80(4):358-368.
PUBMED | CROSSREF

24. Thomas WP, Gaber CE, Jacobs GJ, Kaplan PM, Lombard CW, Moise NS, et al. Recommendations for standards in transthoracic two-dimensional echocardiography in the dog and cat. Echocardiography Committee of the Specialty of Cardiology, American College of Veterinary Internal Medicine. J Vet Intern Med. 1993;7(4):247-252.
PUBMED | CROSSREF

25. Sahn DJ, DeMaria A, Kisslo J, Weyman A. Recommendations regarding quantitation in M-mode echocardiography: results of a survey of echocardiographic measurements. Circulation. 1978;58(6):1072-1083.
PUBMED | CROSSREF

26. Smets P, Daminet S, Wess G. Simpson's method of discs for measurement of echocardiographic end-diastolic and end-systolic left ventricular volumes: breed-specific reference ranges in Boxer dogs. J Vet Intern Med. 2014;28(1):116-122.
PUBMED | CROSSREF

27. Lang RM, Bierig M, Devereux RB, Flachskampf FA, Foster E, Pellikka PA, et al. Recommendations for chamber quantification: a report from the American Society of Echocardiography's Guidelines and Standards Committee and the Chamber Quantification Writing Group, developed in conjunction with the European Association of Echocardiography, a branch of the European Society of Cardiology. J Am Soc Echocardiogr. 2005;18(12):1440-1463.
PUBMED | CROSSREF

28. Kosaraju A, Goyal A, Grigorova Y, Makaryus AN. *Left Ventricular Ejection Fraction*. Treasure Island: StatPearls; 2020.

29. Hansson K, Häggström J, Kvart C, Lord P. Left atrial to aortic root indices using two-dimensional and M-mode echocardiography in cavalier King Charles spaniels with and without left atrial enlargement. Vet Radiol Ultrasound. 2002;43(6):568-575.
PUBMED | CROSSREF

30. O'Sullivan ML, O'Grady MR, Minors SL. Assessment of diastolic function by Doppler echocardiography in normal Doberman Pinschers and Doberman Pinschers with dilated cardiomyopathy. J Vet Intern Med. 2007;21(1):81-91.
PUBMED | CROSSREF

31. Nagueh SF, Bachinski LL, Meyer D, Hill R, Zoghbi WA, Tam JW, et al. Tissue Doppler imaging consistently detects myocardial abnormalities in patients with hypertrophic cardiomyopathy and provides a novel means for an early diagnosis before and independently of hypertrophy. Circulation. 2001;104(2):128-130.
PUBMED | CROSSREF

32. Cornell CC, Kittleson MD, Della Torre P, Häggström J, Lombard CW, Pedersen HD, et al. Allometric scaling of M-mode cardiac measurements in normal adult dogs. J Vet Intern Med. 2004;18(3):311-321.
PUBMED | CROSSREF

33. Misbach C, Lefebvre HP, Concordet D, Gouni V, Trehiou-Sechi E, Petit AM, et al. Echocardiography and conventional Doppler examination in clinically healthy adult Cavalier King Charles Spaniels: effect of body weight, age, and gender, and establishment of reference intervals. J Vet Cardiol. 2014;16(2):91-100.
PUBMED | CROSSREF

34. della Torre PK, Kirby AC, Church DB, Malik R. Echocardiographic measurements in greyhounds, whippets and Italian greyhounds--dogs with a similar conformation but different size. Aust Vet J. 2000;78(1):49-55.
PUBMED | CROSSREF

35. Kayar A, Gonul R, Or ME, Uysal A. M-mode echocardiographic parameters and indices in the normal German shepherd dog. Vet Radiol Ultrasound. 2006;47(5):482-486.
PUBMED | CROSSREF

36. Lobo L, Canada N, Bussadori C, Gomes JL, Carvalheira J. Transthoracic echocardiography in Estrela Mountain dogs: reference values for the breed. Vet J. 2008;177(2):250-259.
PUBMED | CROSSREF

37. Vollmar AC. Echocardiographic measurements in the Irish wolfhound: reference values for the breed. J Am Anim Hosp Assoc. 1999;35(4):271-277.
PUBMED | CROSSREF

38. Kraetschmer S, Ludwig K, Meneses F, Nolte I, Simon D. Vertebral heart scale in the beagle dog. J Small Anim Pract. 2008;49(5):240-243.
PUBMED | CROSSREF

39. Buchanan JW, Bücheler J. Vertebral scale system to measure canine heart size in radiographs. J Am Vet Med Assoc 1995;206(2):194-199.
PUBMED

40. Bodh D, Hoque M, Saxena AC, Gugjoo MB, Bist D, Chaudhary JK. Vertebral scale system to measure heart size in thoracic radiographs of Indian Spitz, Labrador retriever and Mongrel dogs. Vet World. 2016;9(4):371-376.
PUBMED | CROSSREF