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Echocardiographic parameters and indices in 23 healthy Maltese dogs

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Conflict of Interest

The authors declare no conflicts of interest.

Author Contributions

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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 Boredeaux [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.

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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, unsexed, 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, from 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

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 \pm 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-

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.

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