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Heart Size Evaluation of Indonesian Domestic House Cat by Motion Mode Echocardiography Imaging

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Indonesian Domestic House Cats (DHC) are prone to various diseases, especially cardiovascular diseases. Physical examination alone is not enough to differentiate cardiac diseases, which is why further screening tests such as heart ultrasonography-echocardiography are needed. Since there has been no information regarding the heart size of Indonesian DHC, the purpose of this study was to determine the heart size of an anesthetized Indonesian DHC through Motion mode echocardiography imaging. Nine male cats weighing between 3.3-4.4 kg were anesthetized using zolazepam-tiletamine. Echocardiographic examinations were taken on the right parasternal short axis view at the papillary muscle and aorta level using a 7.5 MHz transducer. Result showed that the wall thickness, left ventricular internal diameter and fractional shortening of the Indonesian DHC were similar compared with those in other cat breeds with the same average weight. The left atrium internal diameter and the aorta diameter of the Indonesian DHC were relatively smaller. However, the left atrium and aorta diameter ratio were similar to the result in other cat breeds with the same average weight. Through this study, we also could specify the left ventricular volume, stroke volume, cardiac output and ejection fraction that not yet reported before.

Key words: heart, Indonesian domestic house cat, motion mode echocardiography, normal values

INTRODUCTION

The Indonesian Domestic House Cat (DHC) is a typical Indonesian short hair cat breed from the genus *Felis*. Cats are prone to various diseases, especially cardiovascular diseases (Mottet *et al.* 2012). The most common veterinary complaint in cats is the evaluation of heart murmur during auscultation. As is difficult to differentiate cardiac diseases using auscultation alone, further screening tests such as heart ultrasonography-echocardiography are needed. Echocardiography is defined as the examination of the heart using reflected ultrasound (Feigenbaum 2010). It gives a surrogate measure of the heart and is commonly performed on dogs and cats to detect acquired and congenital heart diseases (Coatney 2001; Adin & McCloy 2005; Abbott & MacLean 2006; Chetboul *et al.* 2006). Diseases detectable by ultrasonography include hypertrophic cardiomyopathy, congestive heart failure, and cardiac lyphoma (Scansen 2001; Ferasin *et al.* 2003; Shinohara *et al.* 2005; Trehiou-Sechi *et al*. 2012).

Knowledge of the heart size for a specific body weight can help to indicate the degree and direction of the change from normal when evaluating for cardiac diseases (Muzzi *et al.* 2006; Ghadiri *et al.* 2008). Data concerning heart-size values have been reported in a number of pedigree cats, such as in young adult Sphynx cat and DHC outside Indonesia (Mottet *et al.* 2012). However, lack of information concerning echocardiographic values of the Indonesian DHC has been reported. Echocardiographic values show significant breed variations which why the purpose of this study was to determine the echocardiographic reference values in anesthetized Indonesian DHC.

MATERIALS AND METHODS

This research was conducted at the Division of Surgery and Radiology, Department of Clinic, Reproduction and Pathology, Faculty of Veterinary Medicine, Bogor Agricultural University. Nine healthy male Indonesian Domestic House Cats weighing between 3.3 and 4.4 kg were kept under controlled conditions prior to ultrasonography. Cats were put in separate cages and given standard cat food, water (*ad libittum*) and a sandbox for defecation and urination. They were judged as having a normal cardiovascular system on the basis of history and

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physical examination (Allen 1982). A physical examination was performed before anesthesia on the cat's heart rate, respiratory rate, body temperature, and body weight. Cats were given premedication 0.02 mg/kg BW atropine sulfate intramuscularly. After fifteen minutes, cats were anesthetized using 8 mg/kg BW Zoletil® given intramuscularly. The target injection organs were the *semitendinosus* or *semimembranosus* muscles. Once the cat was anesthetized, the hair coat at the right lateral axillary area were clipped and shaved clean. Echocardiographic examination was performed from underneath with the cat on the right lateral recumbence. The probe was positioned at the fourth or fifth intercostal space. Ultrasonography was performed on the short axis view at the papillary muscle and aorta level on both brightness mode (B-mode) and motion mode (M-mode). Ultrasonography was performed by one operator using a 7.5 MHz transducer approximately 15 minutes after the cat was anesthetized. Data were taken until there were three representative data for each measurement. The M-mode right parasternal short axis reading at the papillary muscle level was used to measure the left ventricular wall (LVW) thickness during systole and diastole, the left ventricular internal diameter (LVID) during systole and diastole, and the interventricular septa wall (IVS) thickness during systole and diastole. The M-mode right parasternal short axis reading at the aorta level was used to measure the diameter of the aorta (AO) and the left atrium (LA) during diastole. Diastolic measurements were taken at the maximal left ventricular relaxation, while systolic measurements were taken at the maximal left ventricular contraction. The final value used was the average from the three measurements. Data were expressed as average $\pm$ standard deviation. Data obtained from the M-mode echocardiography were used to calculate the LA:AO ratio, left ventricular end diastolic volume (LVED), left ventricular end systolic volume (LVES), left ventricular stroke volume (SV), left ventricular cardiac output (CO), ejection fraction (EF), and fractional shortening (FS). Calculations are shown in Table 1. Heart measurements of the Indonesian DHC were compared to results of similar research on cats with the same average body weight.

RESULTS

Preliminary physical examination showed that the Indonesian DHC had an average body weight of 3.4 $\pm$ 0.4 kg, an average temperature of 38.1 $\pm$ 0.5 °C, an average heart rate of 180 $\pm$ 35 beats per minute (bpm) before anesthesia and 153 $\pm$ 19 bpm after anesthesia, and an average respiratory rate of 34 $\pm$ 5 times/minute (Table 2).

During echocardiography, cats were positioned at the right parasternal and ultrasonography was performed using a 7.5 MHz transducer. Brightness

Table 1. Equations for the measurement derivates

Parameter	Equation
Left ventricular end diastolic volume (LVED)	$\frac{7x\ LVIDd^3}{2.4 + LVIDd}$
Left ventricular end systolic volume (LVES)	$\frac{7\ x\ LVIDs^3}{2.4 + LVIDs}$
Stroke volume (SV)	LVED - LVES
Cardiac output CO)	SV x HR
Ejection fraction (EF)	$\frac{LVED - LVES}{LVED}$ x 100
Fractional shortening (FS)	$\frac{LVIDd - LVIDs}{LVIDd}$ x 100

LVIDd: left ventricular internal diameter during diastole, LVIDs: left ventricular internal diameter during systole, HR: heart rate; Source: Boon (2011).

Table 2. Physical examination result

Cat ID and color	BW (kg)	T (ºC)	HRa (bpm)	HRb (bpm)	RR (x/minute)
1 (grey-white)	3.5	38.5	240	128	36
2 (grey-white)	3	37.7	202	160	36
3 (grey-white)	3.8	37.7	202	192	28
4 (black)	3.3	37.5	202	156	36
5 (yellow)	4.3	37.4	142	160	28
6 (grey)	3	38	171	156	44
7 (grey)	3	38.5	142	156	32
8 (grey)	3	39	142	140	36
9 (black-white)	3.3	38	174	132	28
Mean $\pm$ Dev	3.4 $\pm$ 0.4	38.1 $\pm$ 0.5	180 $\pm$ 35	153 $\pm$ 19	34 $\pm$ 5
Reference*	-	37.7 – 39.4	140 – 240		20 – 24

*Source: Eldredge *et al.* (2008); BW: body weight, T: temperature, HRa: heart rate before anesthesia, HRb: heart rate after anesthesia, RR: respiratory rate, Mean $\pm$ Dev: mean $\pm$ deviation standard; bpm: beats per minute.

mode (B-mode) shows a two-dimensional projection of the cross section of the heart in real time. B-mode imaging at the papillary muscle level showed that the IVS, LVID, LVW, and the papillary muscles. The IVS and LVW were hypoechoic, appearing as various shades of grey, while the LVID was anechoic, appearing black. The papillary muscles were hyperechoic, apearing white (Figure 1A). Motion mode (M-mode) takes a linear projection of the B-mode relative to time. Figure 1B shows the M-mode projection of the short axis of the heart at the papillary muscle level. During systole, the ventricle wall and the interventricular septa moved closer while during diastole, the ventricular walls moved apart. The arrow a and b in Figure 1B shows the early contraction of the IVS compared to LVW. Figure 2A shows the B-mode short axis view of the aorta and left atrium while Figure 2B shows the M-mode projection of the aorta, left atrium, right ventricle, and right atrium. The wall of the aorta was hyperechoic while the lumen of the aorta and the left atrium were anechoic. Motion mode echocardiography images were used to calculate the heart wall thickness and the luminal diameter. Heart wall thickness of the Indonesian DHC is shown in Table 3. Result shows that the average LVW thickness during systole and diastole were 0.57 $\pm$ 0.03 cm and 0.35 $\pm$ 0.06 cm respectively, and the average IVS during systole and diastole were 0.56 $\pm$ 0.03 cm and 0.30 $\pm$ 0.05 cm respectively. Table 4 shows the internal dimension measurements of the Indonesian DHC. The average LVID during systole and diastole were 0.78 $\pm$ 0.11 cm and 1.48 $\pm$ 0.12 cm

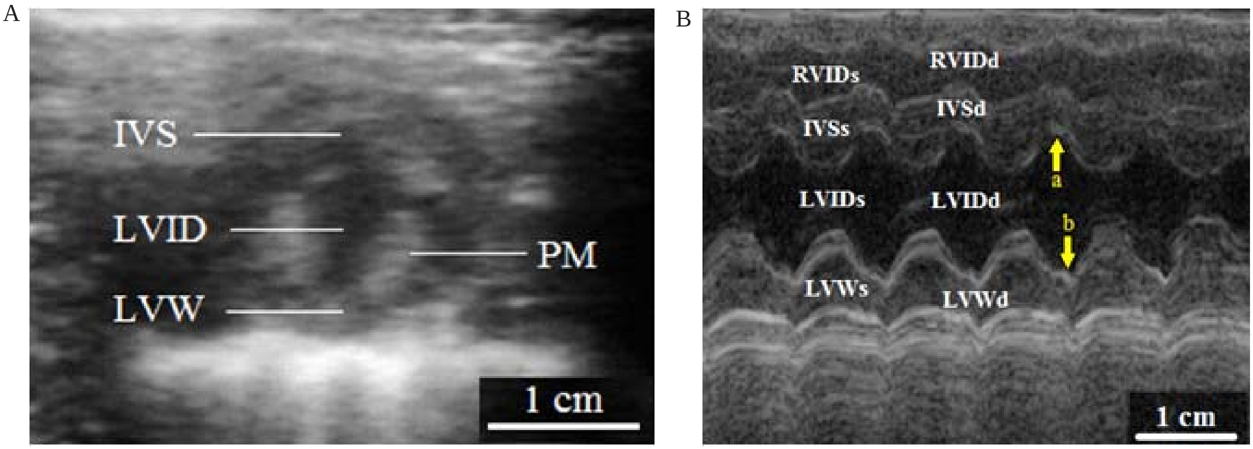

Figure 1. Sonogram view of the heart at the papillary muscle level (A) B-Mode view; IVS: interventricular septa, LVID: left ventricular internal diameter, LVW: left ventricular wall, PM: papillary muscle (B) M-Mode view; RVIDs: right ventricular internal diameter during systole, IVSs: interventricular septa during systole, LVIDs: left ventricular internal diameter during systole, LVWs: left ventricular wall during systole, RVIDd: right ventricular internal diameter during diastole, IVSd: interventricular septa during diastole, LVIDd: left ventricular internal diameter during diastole, LVWd: left ventricular wall during diastole, arrow: a slight lag between the IVS and LVW.

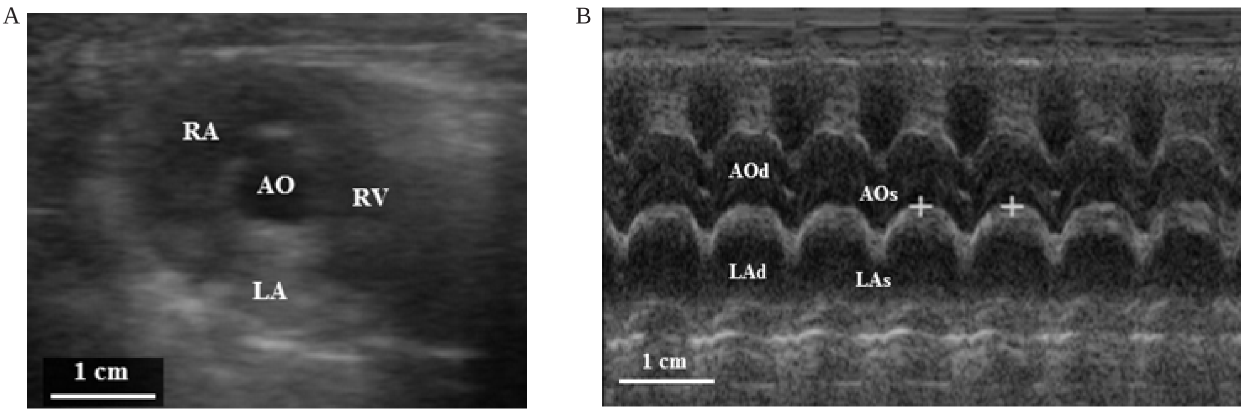

Figure 2. Sonogram view of the heart at the aorta level (A) B-Mode view; RA: right atrium, AO: aorta, RV: right ventricle, LA: left atrium; (B) M-mode view; AOd: aorta internal diameter during diastole, LAs: left atrium internal diameter during systole, AOs: aorta internal diameter during diastole, LAd: left atrium internal diameter during diastole.

Table 3. Heart wall thickness of Indonesian domestic house cat

Parameter	LVWs (cm)	LVWd (cm)	IVSs (cm)	IVSd (cm)
Mean $\pm$ SD	0.57 $\pm$ 0.03	0.35 $\pm$ 0.06	0.56 $\pm$ 0.03	0.30 $\pm$ 0.05

SD: standard deviation, LVWs: left ventricular wall thickness during systole, LVWd: left ventricular wall thickness during diastole, IVSs: interventricular septa during systole, IVSd: interventricular septa during diastole.

Table 4. Internal dimension measurements of Indonesian domestic house cat

Parameters	AOs (cm)	AOd (cm)	LAs (cm)	LVIDs (cm)	LVIDd (cm)	LA:AO
Mean $\pm$ SD	0.69 $\pm$ 0.06	0.67 $\pm$ 0.07	0.73 $\pm$ 0.04	0.78 $\pm$ 0.11	1.48 $\pm$ 0.12	1.07 $\pm$ 0.13

SD: standard deviation, AOs: aorta internal diameter during systole, AOd: aorta internal diameter during diastole, LAs: left atrial internal diameter during systole, LVIDs: left ventricular internal diameter during systole, LVIDd: left ventricular internal diameter during diastole.

Table 5. Derivative cardiac measurements of the Indonesian domestic house cat

Parameters	LVED (ml)	LVES (ml)	SV (ml)	CO (ml/minute)	EF (%)	FS (%)
Average $\pm$ SD	5.96 $\pm$ 1.17	1.08 $\pm$ 0.42	4.88 $\pm$ 0.87	865.18 $\pm$ 178.66	82.28 $\pm$ 4.64	47.81 $\pm$ 4.90
Range	4.47 – 7.21	0.57 – 1.77	3.42 – 5.97	659.13 – 1185.27	75.24 – 89.21	0.41 – 0.51

LVED: left ventricular end-diastolic volume, LVES: left ventricular end-systolic volume, SV: left ventricular stroke volume, CO: left ventricular cardiac output, EF: ejection fraction, FS: fractional shortening.

respectively. The Indonesian DHC had an average AOd of 0.67 $\pm$ 0.07 cm and an average LAs of 0.73 $\pm$ 0.04. Results show no significant difference in AOs and AOd, meaning that during the muscular contraction, the aorta diameter stayed the same. The AOd and LAs were used to calculate the LA:AO ratio. The average LA:AO ratio of Indonesian DHC was 1.07 $\pm$ 0.13.

Data obtained from M-mode echocardiography were used to calculate the left ventricular end diastolic volume (LVED), left ventricular end systolic volume (LVES), left ventricular stroke volume (SV), left ventricular cardiac output (CO), ejection fraction (EF), and fractional shortening (FS). The calculated data are shown in Table 5. The Indonesian DHC had an average FS of 47.81 $\pm$ 4.90%, an average LVED of 5.96 $\pm$ 1.17 ml and an average LVES of 1.08 $\pm$ 0.42 ml. The average EF was 82.28 $\pm$ 4.64% while the average SV was 4.88 $\pm$ 0.87 ml. The average CO was 865.18 $\pm$ 178.66 ml/minute.

DISCUSSION

Cats used in this study were nine healthy male Indonesian Domestic House Cats (DHC). Common clinical signs of heart disease in cats such as respiratory distress e.g. tachypnea and dyspnea, per acute paralysis or paresis, anorexia, lethargy, and depression were not observed in the cats used for ultrasonography. Preliminary physical examination before anesthesia shows that the average temperature and heart rate were still in the range for cats according to Eldredge *et al.* (2008).

There has been no information regarding the heart size in Indonesian DHC. For this reason, cardiac measurements of the Indonesian DHC in this study were compared to measurements in other cat breeds by Moise and Dietze (1986), Jacobs and Knight (1985), Fox *et al.* (1985), and Allen (1982). The study by Moize and Dietz (1986) was performed on 11 cats with a body weight of 4.3 $\pm$ 0.5 kg and an average heart rate of 182 $\pm$ 22 bpm. The study of Jacobs and Knight (1985) was performed on 30 cats with an average body weight and heart rate of 4.1 $\pm$ 1.1 kg and 194 $\pm$ 23 bpm respectively. Fox *et al.* (1985) did a study on 10 cats with an average body weight and heart rate of 3.91 $\pm$ 1.2 kg and 255 $\pm$ 36 bpm respectively, while Allen (1982) performed the study on 10 cats with an average body weight and heart rate of 3.64 $\pm$ 0.66 kg and 175 $\pm$ 20 bpm respectively. These data were used as a comparison because the cats had a similar average body weight.

M-mode echocardiography is commonly used to accurately quantify single dimensions of walls, chambers and valvular structures at a specific location (Gottdiener *et al.* 2004; Muzzi *et al.* 2006; Noviana *et al*. 2011; Petric *et al*. 2012). The M-mode image shows a slight lag between the IVS and LVW. This was because the IVS depolarizes a few milliseconds before the LVW (Burk & Feeney 2003). According to Wagner *et al.* (2010), the LVW of a cat should not be greater than 0.6 cm during systole, which shows that the LVW of the Indonesian DHC was still within the range for cats. The LVW was thinner when compared to the similar research done by Moise and Dietze (1986) (LVWs = 0.78 ± 0.10 cm) and Jacobs and Knight (1985) (LVWs = 0.68 ± 0.07 mm), but was quite similar to the results obtained by Fox *et al.* (1985) (LVWs = 0.55 ± 0.88 cm). The interventricular septum (IVS) is a muscular separation between the left and right ventricle (Factor *et al.* 2002). Bowles *et al.* (2010) stated that the IVS of a cat heart should not be greater than 0.6 cm during systole, which shows that the IVS obtained was still within the range for cats. The IVSs thickness of the Indonesian DHC was slightly thinner when compared to the IVSs obtained by Moise and Dietze (1986) (IVSs = 0.76 ± 0.12 cm) and Jacobs and Knight (1985) (IVSs = 0.58 ± 0.06 cm). Fox *et al.* (1985) did not calculate the IVS during systole but when the data was compared to the IVS during diastole, the Indonesian DHC had a similar IVS thickness. The slight difference in size between cats or breed may be caused by the morphologic adaptations made during training as well as other factors such as breed and body conformation (Muzzi *et al.* 2006). The IVS and LVW of the Indonesian DHC was thicker during systole than during diastole. This was because during diastole, the heart was filled with blood causing the walls to relax and thus become thinner (Nishimura & Tajik 1997). During systole, the contraction of the muscular walls increases the thickness of the walls. Normal diastolic function allows the heart to fill appropriately at normal filling pressure (Boon 2011).

The aorta lumen of the Indonesian Domestic House Cat was relatively small when compared to the aorta size obtained by Moise and Dietze (1986) (AO = 0.95 ± 0.15 cm), Jacobs and Knight (1985) (AO = 0.95 ± 0.11 cm), Fox *et al.* (1985) (AO = 0.94 ± 0.11 cm), and Allen (1982) (AO = 0.90 ± 0.07 cm). According to Schober and Todd (2010), the LA of a cat should be less than 1.6 cm. This shows that the Indonesian DHC had a LA size within the range for cats. However, when compared with the LA size obtained by Moise and Dietze (1986) (LA = 1.21 ± 0.18 cm), Jacobs and Knight (1985) (LA = 1.23 ± 0.14 cm), Fox *et al.* (1985) (LA = 1.03 ± 0.14 cm), and Allen (1982) (LA = 1.00 ± 0.07 cm), the Indonesian DHC had a smaller LA. Brown and Gaillot (2008) stated that the measurement of the LA derived from M-mode recordings include only a small portion of the atrial appendage structure and a variable thickness of adipose tissue that lies between the appendage and the aorta, causing room for error. Despite being simple and convenient, M-mode measurements of the LA are not reliably accurate because the LA is not symmetrical and enlargements don't always happen in a uniform area (Abhayaratna *et al.* 2006). The LVID during systole and diastole in the Indonesian DHC was similar to the LVID results obtained by Moise and Dietze (1986) (LVIDs = 0.69 ± 0.22 cm), Jacobs and Knight (1985) (LVIDs = 0.80 ± 0.14 cm), Fox *et al.* (1985) (LVIDs = 0.81 ± 0.16 cm), and Allen (1982) (LVIDs = 0.86 ± 0.16 cm). Dimensions of the LA and the AO have been used to calculate the LA:AO ratio for objective judgment of LA size. The ratio of LA:AO will increase with a dilatation in the LA or LV. A LA:AO ratio greater than 1.3 shows a dilatation in the LA (Boller 2010). The LA:AO ratio of the Indonesian DHC was similar to the results of previous researches.

Fractional shortening is affected by preload, afterload and contractility (Martin 1995; Muzzi *et al.* 2006). It is not significantly affected by age, sex, body surface area and weight but may be affected by heart rate (Boon 2011; Kealy *et al.* 2011). An increase in preload, a decrease in afterload and hypertrophy of the myocardium may increase the FS while a decrease in preload, increase in afterload, systolic dysfunction, and a reduction in ventricular contractility may decrease the FS (Martin 1995; Ferasin 2009; Boon 2011). FS in cats usually range from 29-55% or 45-55% and can elevate when excited and decrease when sedated (Martin 1995; Norsworthy 2012). The average FS of the Indonesian DHC was still within the average range for cats. The FS calculated was similar to the result obtained by Moise and Dietze (1986) (FS = 55.0 ± 10.2%), Jacobs and Knight (1985) (FS = 49.3 ± 5.3%), and Fox *et al.* (1985) (FS = 42.7 ± 8.1%), but was higher than the result by Allen (1982) (FS = 0.35 ± 0.25%).

Ejection fraction is described as the percentage volume reduction in the LVID from diastole to systole (Martin 1995). It is commonly used as an indication to determine heart diseases such as heart failure, coronary artery disease and to monitor the effects of drugs on the heart (Gottdiener *et al.* 2004). The lower the EF, the greater the reduction in systolic function (Tschope & Paulus 2009). Stroke volume can be obtained by deducting the LVED with the LVES and is determined by the interaction between preload, contractility and afterload. Cardiac output (CO) is the volume of blood pumped by the heart/minute and is the product of the HR and SV (Lavdaniti 2008).

Ultrasonography should be performed following clinical symptoms related to cardiovascular disease such as heart murmur, tachypnea, dyspnea, per acute paralysis or paresis, anorexia, lethargy, depression, and exercise intolerance. In order to obtain a good sonogram of echocardiography, cats need to be properly restrained. Through this research the wall thickness, luminal dimensions, valve structures and the derivative measurements of the heart can be obtained. Results of this present study is beneficial for all small animal veterinary practitioners as a reference to diagnose heart disease such as hypertrophic cardiomyopathy, dilated cardiomyopathy, endocardiosis, atrial, and aortic enlargement.

REFERENCES

Abbott JA, MacLean HN. 2006. Two-dimensional echocardiographic assessment of the feline left atrium. *J Vet Intern Med* 20:111-119. http://dx.doi.org/10.1111/j.1939-1676.2006.tb02830.x

Abhayaratna WP, Seward JB, Appleton CP, Douglas PS, Oh JK, Tajik AJ, Tsang TSM. 2006. Left atrial size physiologic determinants and clinical applications. *JACC* 47:2357-2363. http://dx.doi.org/10.1016/j.jacc.2006.02.048

Adin DB, McCloy K. 2005. Physiologic valve regurgitation in normal cats. *J Vet Cardiol* 7:9-13. http://dx.doi.org/10.1016/j.jvc.2004.10.001

Allen DG. 1982. Echocardiographic study of the anesthetized cat. *Can J Comp Med* 46:115-122.

Boller M. 2010. General Approach and Overview of Cardiac Emergencies. In: Drobatz KJ and Costello MF (eds). *Feline Emergency & Critical Care Medicine*. USA: Blackwell Scientific.

Boon JA. 2011. *Veterinary Echocardiography*. 2nd ed. UK: Blackwell Scientific.

Bowles DB, Coleman MG, Harvey CJ. 2010. Cardiogenic arterial thromboembolism causing non-ambulatory tetraparesis in a cat. *J Feline Med Sur* 12:144-150. http://dx.doi.org/10.1016/j.jfms.2009.06.004

Brown D, Gaillot H. 2008. Heart. In: Penninck D, Anjou MA (eds). *Atlas of Small Animal Ultrasonography*. USA: Blackwell Scientific.

Burk RL, Feeney DA. 2003. *Small Animal Radiology and Ultrasonography*. USA: Elsevier Science.

Chetboul V, Charles V, Nicolle A, Sampedrano CC, Gouni V, Pouchelon JL, Tissier R. 2006. Retrospective study of 156 atrial septal defects in dogs and cats. *J Vet Med A* 53:179-184. http://dx.doi.org/10.1111/j.1439-0442.2006.00813.x

Coatney RW. 2001. Ultrasound imaging: principles and applications in rodent research. *J ILAR* 42:233-247.

Eldredge DM, Carlson DG, Carlson LD, Griffin JM. 2008. In: Adelman B (ed). *Cat Owner's Home Veterinary Handbook*. 3rd ed. New Jersey: Wiley.

Factor SM, Lamberti MA, Abadi J. 2002. *Handbook of Pathology and Pathophysiology of Cardiovascular Disease*. New York: Kluwer Acad.

Feigenbaum H. 2010. Role of M-mode technique in today's echocardiography. *J Am Soc Echocardiogr* 23:240-257. http://dx.doi.org/10.1016/j.echo.2010.01.015

Ferasin L. 2009. Feline myocardial disese: classification, pathophysiology and clinical presentation. *J Feline Med Sur* 11:3-13. http://dx.doi.org/10.1016/j.jfms.2008.11.008

Ferasin L, Sturgess CP, Cannon MJ, Caney SMA, Gryffydd-Jones TJ, Wotton PR. 2003. Feline idiopathic cardiomyopathy: A restropective study of 106 cats (1994-2001). *J Feline Med Sur* 5:151-159. http://dx.doi.org/10.1016/S1098-612X(02)00133-X

Fox PR, Bond BR, Peterson ME. 1985. Echocardiographic reference values in healthy cats sedated with ketamine hydrochloride. *Am J Vet Res* 46:1479-1484.

Ghadiri A, Avizeh R, Rasekh A, Yadegari A. 2008. Radiographic measurements of vertebral heart size in healthy stray cats. *J Feline Med Surg* 10:61-65. http://dx.doi.org/10.1016/j.jfms.2007.06.015

Gottdiener JS, Bednarz J, Devereux R, Gardin J, Klein A, Manning WJ, Morehead A, Kitzman D, Oh J, Quinones M, Schiller NB, Stein JH, Weissman NJ. 2004. American Society of Echocardiography recommendations for use of echocardiography in clinical trials. *J Am Soc Echocardiogr* 17:1086-1119. http://dx.doi.org/10.1016/j.echo.2004.07.013

Jacobs G, Knight DH. 1985. M-mode echocardiographic measurements in non-anesthetized healthy cats: effects of body weight, heart rate, and other variables. *Am J Vet Res* 46:1705-1711.

Kealy JK, McAllister H, Graham JP. 2011. *Diagnostic Radiology and Ultrasonography of the Dog and Cat*. 5th ed. Missouri: Elsevier Science.

Lavdaniti M. 2008. Invasive and non-invasive methods for cardiac output measurements. *J Caring Sciences* 1:112-117.

Martin MWS. 1995. Small Animal Echocardiography. In: Goddard PJ (ed). *Veterinary Ultrasonography*. UK: CAB.

Moise NS, Dietze AE. 1986. Echocardiographic, electrocardiographic and radiographic detection of cardiomegaly in hyperthyroid cats. *Am J Vet Res* 47:1487-1494.

Mottet E, Amberger C, Doherr MG, Lombard C. 2012. Echocardiographic parameters in healthy young adult Sphynx cats. *Schweiz Arch Tierheilk* 154:1-5. http://dx.doi.org/10.1024/0036-7281/a000299

Muzzi RAL, Muzzi LAL, Araujo RB, Cherem M. 2006. Echocardiographic indices in normal German Shepherd dogs. *J Vet Sci* 7:193-198. http://dx.doi.org/10.4142/jvs.2006.7.2.193

Nishimura RA, Tajik AJ. 1997. Evaluation of diastolic filling of left ventricle in health and disease: doppler echoccardiographic is the clinician's Rosetta Stone. *J Am Coll Cardiol* 30:8-18. http://dx.doi.org/10.1016/S0735-1097(97)00144-7

Norsworthy GD. 2012. *Cardiology*. In: Schmeltzer LE, Norsworthy GD (eds). *Nursing the feline patient*. UK: Blackwell Scientific. p 155-163.

Noviana D, Paramitha D, Wulansari R. 2011. Motion mode two dimensional echocardiographic measurements of cardiac dimensions of Indonesian mongrel dogs. *Hayati J Biosci* 18:1-5. http://dx.doi.org/10.4308/hjb.18.1.1

Petric AD, Rishniw M, Thomas WP. 2012. Two-dimensionally-guided M-mode and pulsed wave Doppler echocardiographic evaluation of the ventricles of apparently healthy cats. *J Vet Cardiol* 14:423-430. http://dx.doi.org/10.1016/j.jvc.2012.04.004

Scansen BA. 2001. Interventional cardiology for the criticalist. *J Vet Emerg Crit Care* (San Antonio) 21:123-136. http://dx.doi.org/10.1111/j.1476-4431.2011.00623.x

Schober K, Todd A. 2010. Echocardiographic assessment of left ventricular geometry and the mitral valve apparatus in cats with hypertrophic cardiomyopathy. *J Vet Cardiol* 12:1-16. http://dx.doi.org/10.1016/j.jvc.2009.09.004

Shinohara N, Macgregor JM, Calo A, Rush JE, Penninck DG, Knoll JS. 2005. Presumptive primary cardiac lymphoma in cat causing pericardial effusion. *J Vet Cardiol* 7:65-69. http://dx.doi.org/10.1016/j.jvc.2005.02.004

Trehiou-Sechi E, Tissier R, Gouni V, Misbach C, Petit AMP, Balouka D, Sampedrano CC, Castaignet M, Pouchelon JL, Chetboul V. 2012. Comparative echocardiographic and clinical features of hypertrophic cardiomyopathy in 5 breeds of cats: a retrospective analysis of 344 cases. *J Vet Intern Med* 26:532-541. http://dx.doi.org/10.1111/j.1939-1676.2012.00906.x

Tschope C, Paulus WJ. 2009. Doppler echocardiography yields dubious estimates of left ventricular diastolic pressures. *J Circulation* 120:810-820. http://dx.doi.org/10.1161/CIRCULATIONAHA.109.869628

Wagner T, Fuentes VL, Payne JR, McDermott N, Brodbelt D. 2010. Comparison of auscultatory and echocardiographic findings in healthy adult cats. *J Vet Cardiol* 12:171-182. http://dx.doi.org/10.1016/j.jvc.2010.05.003