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Papers

Two-dimensional and M-mode echocardiographic reference values in healthy adult Saanen goats

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Echocardiography has become a routine non-invasive cardiac diagnostic tool in most species. Accurate measurement of cardiac dimensions requires reference values, which are poorly documented in goats. The aim of the present study was to test the inter-day repeatability and to establish the reference values of two-dimensional (2D-) and time-motion (M-) mode echocardiographic variables in healthy adult Saanen goats. Six goats were investigated three times by the same observer at one-day interval using a standardised 2D- and M-mode echocardiographic protocol. The intra-observer inter-day repeatability was tested using analysis of variance, calculation of the coefficient of variation and confidence intervals. A single echocardiographic examination was performed in six other goats, and values obtained in the 12 goats were used to establish the 2D- and M-mode echocardiographic reference values in healthy adult female Saanen goats. Statistical analysis revealed a good inter-day repeatability of the echocardiographic cardiac measurements. Echocardiographic reference values obtained in healthy adult Saanen goats seemed slightly higher than those reported in healthy Swedish domestic goats and were similar to those reported in healthy adult sheep.

IN the last 30 years, echocardiography has been developed for use in several domestic species including dogs (Mashiro and others 1976, Boon and others 1983, Lombard 1984), cats (Pipers and others 1979, Jacobs and Knight 1985), horses (Pipers and Hamlin 1977, Lescure and Tamzali 1984, Voros and others 1991, Long and others 1992), cattle (Pipers and others 1978, Amory and others 1991, Hallowell and others 2007) and sheep (Moses and Ross 1987, Kirberger and Van den Berg 1993). This technique has become a routine for the evaluation and diagnosis of heart disease in veterinary medicine. It proves as a non-invasive tool for the evaluation of cardiac morphology and function, and is a sensitive and accurate method to measure changes in chamber dimensions and thickness of the cardiac walls in response to a pathological or physiological process. Accurate measurement of cardiac dimensions and indices of cardiac function requires reference values following standardised measurement guidelines in the studied species (Boon 2011c).

Echocardiography has been demonstrated to be feasible in Philippine native goats (Acorda and others 2005) and in a pygmy goat (Gardner and others 1992). A quantitative echocardiographic study has also been realised in Swedish domestic goats to compare cardiovascular changes during pregnancy, lactation and dry period (Olsson and others 2001). To the best of the authors' knowledge, no studies of repeatability have been reported in goats. Goats are animals easy to handle with a body and heart size comparable with that of human beings. This makes goats an attractive candidate for the development of animal models for human cardiology research, especially chronic models including measurements in awake or exercising animals (Brice and others 1991, Remes and others 2008). The aim of the present study was to test the repeatability and to establish the reference values of echocardiographic measurements in unsedated standing adult goats.

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Materials and methods

Animals

Twelve adult nulliparous female Saanen goats, aged 22 to 28 months (mean age: 24.9±2.1 months) and weighing 51 to 83 kg (mean bodyweight: 66.1±9.4 kg) were studied. All animals included in the study were considered to be healthy on the basis of the history and the absence of pathological abnormalities on physical examination, cardiac auscultation, ECG, and on blood analysis including haematology, measurement of serum haptoglobin, fibrinogen, total protein content, and electrophoresis of serum proteins. A complete colour and pulsed Doppler echocardiography (from right and left side) has also been performed in each goat before starting the protocol to be sure that the studied goats were free of any cardiac disease, including any

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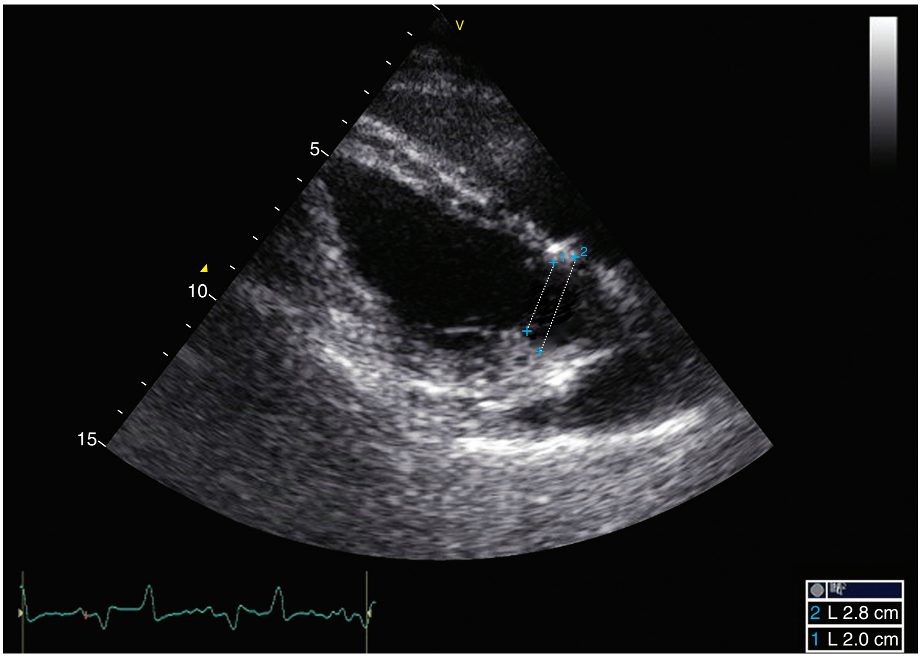

FIG 1: Right parasternal long-axis view of the left ventricular outflow tract used to measure the aortic diameter at the basis of the valves (1) and at the sinus of Valsalva (2)

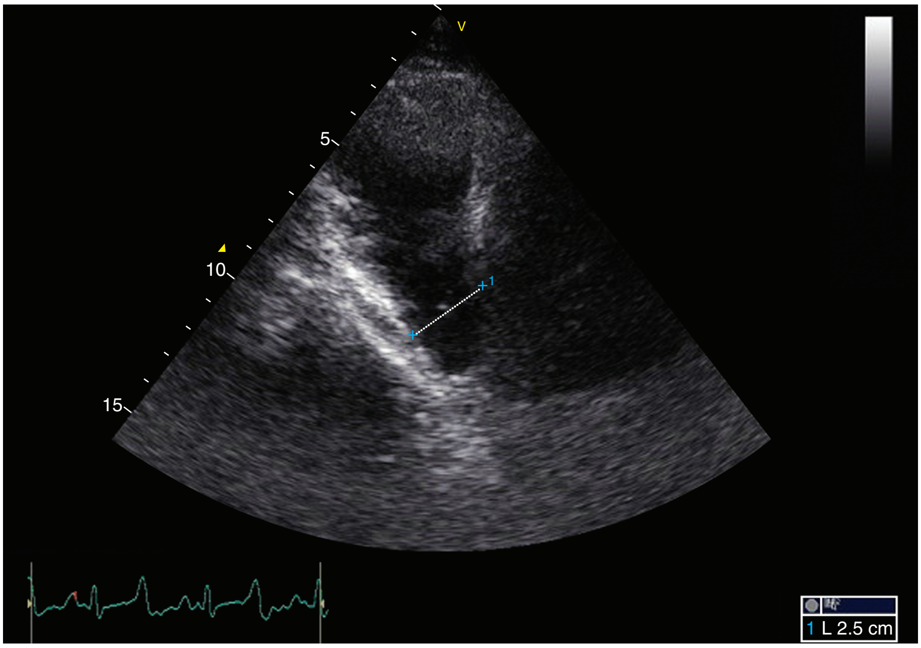

FIG 2: Right parasternal right ventricular inflow-outflow view used to measure pulmonary artery diameter at the pulmonary artery sinus (1)

valvulopathy. Before imaging, the hair was shaved from the third to the fifth right intercostal space just caudal to the right triceps muscle mass, from 3 to 5 cm below the right olecranon to 5 to 10 cm above it. The shaved area was then copiously rinsed with water and acoustic coupling was obtained using ultrasound gel.

Echocardiographic protocol

An ultrasound system (Vivid i, Software version 9.1.0, General Electric Healthcare Europe GMBH) equipped with colour flow mapping and spectral Doppler mode and with a 1.5 to 3.6 MHz phased array transducer (GE 3S-RS probe, General Electric Healthcare Europe GMBH) was used to perform the echocardiography. An ECG was recorded simultaneously with the echocardiographic images. All examinations were recorded digitally and measurements were realised off line using specific software (Echo Pac System for Vivid i, Software version 108.1.5, General Electric Healthcare Europe GMBH). Echocardiographic examination was only realised on the right side of the goats to minimise manipulations. All the echocardiographic recordings and measurements were performed by the first author. During echocardiographic examination, only cineloops of interesting images were recorded. Recordings were only identified using number codes chosen by an external observer. After all echocardiographic examinations were finished, off-line measurements were blindly performed on recordings. All variables were measured six times on six different non-consecutive cycles and average of these six measurements were calculated for each variable. Each cardiac cycle measured was chosen when the image quality was optimal and if no abnormal cardiac rhythm was observed just before or just after the measured cycle. Examinations were performed on standing animals with the right forelimb extended by an assistant as far forward as tolerated by the goat.

Heart rate (HR) was calculated from the ECG tracings from six successive cardiac cycles during the echocardiographic recordings. Echocardiographic measurements were only performed when HR was inferior to 120 beats per minute to decrease the stress effect.

Terminology and image orientation recommended by the Echocardiography Committee of The Specialty of Cardiology, American College of Veterinary Internal Medicine (Thomas and others 1993), were used. First, a right parasternal long-axis four-chamber view with chordae tendinae and clearly visible mitral valve was obtained in two-dimensional mode (2D-mode). From this view, the transducer was slightly turned forwards to obtain a right parasternal long-axis view of the left ventricular outflow tract and measurements of the aortic diameter at the basis of the valves (AoV) and at the sinus of Valsalva (AoS) were taken at end diastole (Fig 1). The pulmonary artery diameter at end diastole was also measured at the pulmonary artery sinus (Pu) from a right parasternal right ventricular inflow-outflow view obtained by directing the transducer slightly craniodorsally and by advancing it one intercostal space (Fig 2). The right parasternal long-axis four-chamber view was then tilted as vertically as possible to obtain an image of the entire left atrium in its largest dimensions and the mitral annulus diameter (MAD), left atrial diameter (LAD) and left atrial area (LAA) were measured at end diastole and at end systole, just before opening of the mitral valve (Schwarzwald and others 2007, Boon 2011a, b) (Fig 3). Restarting from the 2D-mode long-axis four-chamber reference view, the beam was then rotated clockwise toward the olecranon. In the produced transverse view, the beam was pivoted dorsally or ventrally until a 2D-mode right parasternal short-axis view of the left ventricle at the level of the chordae tendinae was obtained, in which the interventricular septum, the left ventricular free wall and the left ventricle were bisected at right angle and the left ventricle was circular. The papillary muscles and mitral valve leaflets were not visible while chordae tendinae were clearly visible. In this view, a time-motion mode (M-mode) right parasternal short-axis view of the left ventricle at the chordal level was obtained by placing the cursor at right angle through the left ventricle, dividing the left ventricle in symmetric halves. In this view, the right ventricular internal diameter (RVID) was measured at end diastole, and the interventricular septal

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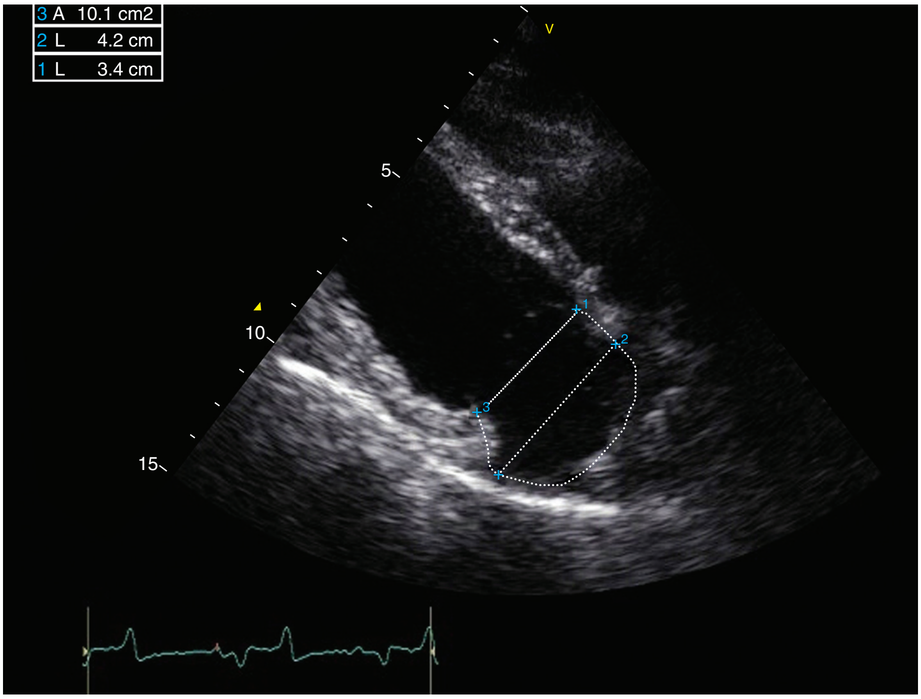

FIG 3: Right parasternal long-axis four-chamber view used to obtain an image of the entire left atrium in its largest dimensions and to measure the mitral annulus diameter (1), left atrial diameter (2) and left atrial area (3)

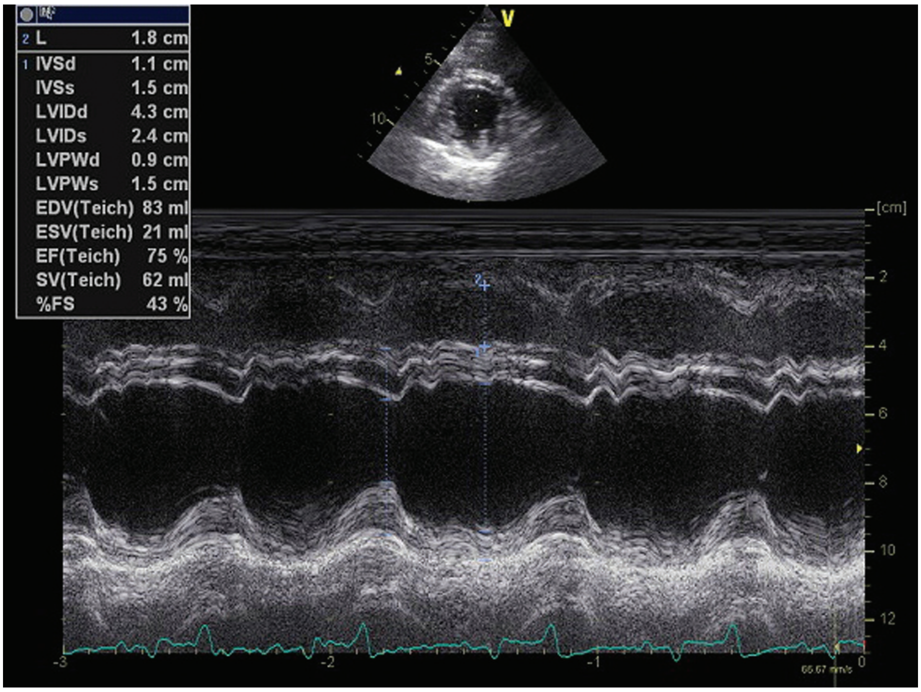

FIG 4: Time-motion mode right parasternal short-axis view of the left ventricle at the chordal level used to measure the right ventricular internal diameter (2), the interventricular septal and left ventricular free wall thicknesses (IVS and LVPW, respectively) and the left ventricular internal diameter (LVID)

and left ventricular free wall thicknesses (IVS and LVFW, respectively) and the left ventricular internal diameter (LVID) were measured at end diastole which was identified with ECG just before beginning of q wave and at peak systole which in turn was identified as the contraction peak in M-mode (Fig 4).

Calculations

Calculated variables included the ratios LAD/AoS and Pu/AoS and the fractional shortening of the left ventricle (FS), obtained as FS=((LVIDd-LVIDs)/LVIDd) x 100. End diastolic and end systolic left ventricular volume (LVVd and LVVs, respectively) were calculated using the Teichholz formula, as following:

$$LVVd=(7 \times (LVIDd)^3)/(2.4 + LVIDd)$$
$$LVVs=(7 \times (LVIDs)^3)/(2.4 + LVIDs)$$

The left ventricular ejection fraction (EF) and stroke volume (SV) were obtained using the following standard formulae:

$$EF=((LVVd–LVVs)/LVVd) \times 100$$
$$SV=LVVd–LVVs$$

The percentages of thickening of the interventricular septum and of the left ventricular free wall (IVS% and LVFW%, respectively) were calculated according to the standard following formulae:

$$IVS\%=(IVSs\text{-}IVSd/IVSd) \times 100$$
$$LVFW\%=(LVFWs\text{-}LVFWd/LVFWd) \times 100$$

The relative wall thickness (RWT) and the mean wall thickness (MWT) were calculated as follows:

$$RWT=(LVFWd + IVSd)/LVIDd$$
$$MWT=(LVFWd + IVSd)/2$$

Repeatability and statistical analysis

In six of the studied goats, the echocardiographic protocol was repeated three times with one-day interval by the same observer. Within each day, each variable was measured six times on six different nonconsecutive cardiac cycles. Observed means, standard deviations (sd), least square means, and standard errors (se) were calculated for each variable. A two-way ANOVA considering goats, days and interaction between goats and days as factors, allowed the determination of the intra-observer interday repeatability of the measurements. A P-value inferior to 0.05 was considered significant. The within-goat within-day variability was evaluated using the coefficient of variation ('Within-day CV') measured from se and observed means obtained from the two-way ANOVA for each variable. The within-goat between-day variability ('Between-day CV') meaning the variability of the same repeated measurements on the same goat independently of the day was measured from sd and observed means obtained in a one-way ANOVA considering only goats as a factor. The degree of variability of each measurement was defined arbitrarly according to Schwarzwald and others (2007), as followed: variables with a CV inferior to 5 per cent were considered to have very low variability, those with a CV between 5 and 15 per cent were considered to have low variability, those with a CV of between 15 and 25 per cent were considered to have moderate variability, and those with a CV of superior to 25 per cent were considered to have high variability. In addition to the CV, absolute variability was obtained by calculating confidence interval (CI) for each variable. This interval corresponding to the interval within the absolute value of the measurement has 95 per cent of probability to be included. Superior and inferior limits of this interval were obtained as follows: observed mean+1.96 x se and observed mean−1.96 x se.

After the study of repeatability, the same echocardiographic protocol was performed on six other female Saanen goats by the same observer and each variable was measured six times on six different cardiac cycles. The data were added to those obtained on the third day of the six first goats, and the observed mean, the sd and the range of

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TABLE 1: Within-day and between-day CV and CI of 2D- and M-Mode echocardiographic measurements performed in six healthy adult goats on three following days by the same observer

	Observed mean±sd	Within-day CV (%)	Between-day CV (%)	CI
AoS (cm)	2.84±0.08	2.97	2.79	2.81 to 2.86
AoV (cm)	1.95±0.10	5.04	4.95	1.92 to 1.99
Pu (cm)	2.44±0.09	3.84	3.61	2.41 to 2.6247
LADd (cm)	4.26±0.09	2.23	2.09	4.23 to 4.29
LADs (cm)	4.77±0.17	3.59	3.37	4.71 to 4.82
MADd (cm)	3.26±0.10	3.03	2.94	3.22 to 3.29
MADs (cm)	2.98±0.13	4.37	4.23	2.93 to 3.02
LAAd (cm^2)	10.77±0.68	6.56	6.51	10.54 to 11.00
LAAs (cm^2)	15.19±0.99	6.53	6.20	14.87 to 15.52
LADd/AoS	1.50±0.06	3.96	3.71	1.48 to 1.52
Pu/AoS	0.86±0.04	4.59	4.30	0.85 to 0.87
RVIDd (cm)	1.26±0.22	19.28	21.23	1.18 to 1.34
IVSd (cm)	0.93±0.08	9.01	8.33	0.90 to 0.95
IVSs (cm)	1.55±0.08	5.34	5.20	1.52 to 1.58
LVIDd (cm)	4.95±0.12	2.70	2.37	4.90 to 4.99
LVIDs (cm)	2.75±0.10	3.74	3.77	2.71 to 2.78
LVFWd (cm)	0.89±0.08	8.97	8.42	0.87 to 0.92
LVFWs (cm)	1.53±0.07	4.79	5.14	1.50 to 1.55
LVVd (ml)	115.90±6.60	6.61	5.55	113.39 to 118.40
LVVs (ml)	28.41±2.50	9.27	9.24	27.55 to 29.27
SV (ml/beat)	87.49±6.26	8.07	6.96	85.18 to 89.80
EF (%)	75.33±2.10	2.86	2.88	74.63 to 76.04
FS (%)	44.34±1.97	4.59	4.56	43.68 to 45.01
IVS% (%)	68.62±17.96	26.94	26.02	62.58 to 74.66
LVFW% (%)	72.53±14.49	21.11	20.84	67.53 to 77.54
RWT (cm)	0.37±0.02	5.88	5.90	0.36 to 0.38
MWT (cm)	0.91±0.05	5.63	5.68	0.89 to 0.93

CI Confidence interval, CV Coefficient of variation, d Measurement in diastole, s Measurement in systole. 2D-measurements: AoS Aortic diameter at the sinus of Valsalva, AoV Aortic diameter at the basis of the valves (aortic annulus), LAA Left atrial area, LAD Left atrial internal diameter, MAD Mitral annulus diameter, Pu Pulmonary artery diameter at the level of the sinus. M-mode measurements: EF Left ventricular ejection fraction, FS Fractional shortening of the left ventricle, IVS% Percentage of systolic thickening of the interventricular septum, IVS Interventricular septum thickness, LVID Left ventricular internal diameter, LVFW% Percentage of systolic thickening of LVFW, LVFW Left ventricular free wall thickness, LVV Left ventricular volume, MWT Mean wall thickness, RVID Right ventricular internal diameter, SV Left ventricular stroke volume, RWT Relative wall thickness

these measurements were calculated to establish the reference values of echocardiographic measurements in unsedated adult healthy female Saanen goats.

Results

The mean HR during the echocardiographic examination was 95.8±16.3 bpm and ranged from 68 to 120 bpm. The image quality was good in all except two goats, which were fatter and more restless than the 10 other studied goats. Some technical difficulties had also been encountered. It was especially difficult to obtain a good quality 2D right parasternal view of the heart base at the level of the pulmonary valves. For this view, the transducer had to be advanced far forward under the forelimb, which required an assistant pulling the right forelimb forward and upward during the examination. This procedure was not well tolerated by all the investigated animals. Moreover, at this level, the cardiac window often appeared to be narrow as observed in Swedish goats (Olsson and others 2001). Measurements in M-mode echocardiography were more difficult to perform than in other species like dogs and horses, because the edge between the left ventricular free wall and the pericardium and between the left ventricular endocardial edge and the chordae tendinae were not always easy to detect. Measurements of the left atrium were also more difficult to obtain in systole than in diastole because of loss of image quality in systole.

The least square mean value and the se to the mean of all echocardiographic measurements obtained on day 1, day 2 and day 3 and the ANOVA test including the effect of the day, the goat and the interaction between days and goats were calculated to evaluate the repeatability of the measurements. None of the mean values of these measurements showed significant differences between the days. Conversely, the effect of the goat was significant for all measurements while the interaction between goats and days was only significant for RVIDd, LVFWs and LVVs.

The variability of the echocardiographic measurements evaluated on the basis of the within-day and between-day CV and on the basis of CI is shown in Table 1. The within-day and between-day variability were closely similar. All 2D-mode measurements had a very low variability excepted for LAA. M-mode measurements had slightly higher variability but still had a very low to low variability, except for RVIDd and LVFW% that had a moderate variability and for IVS% that had a high variability.

The Table 2 compares the mean, the sd value and the range of each 2D- and M-mode echocardiographic measurement obtained in the 12 adult healthy unsedated female Saanen goats with previously reported echocardiographic measurements in adult healthy Swedish goats during the dry period (Olsson and others 2001) and in adult healthy sheep (Moses and Ross 1987).

Discussion

The results of this paper show that, as in most other animal species, 2D and M-mode echocardiography can be performed on standing unsedated goats. The goats' cardiac window appears to be quite similar to that of other animals (Boon and others 1983, Lescure and Tamzali 1984, Lombard 1984, Moses and Ross 1987, Amory and others 1991, Long and others 1992) and standardised imaging technique (Long and others 1992, Thomas and others 1993) can be easily adapted to goats. However, in comparison to other species the authors routinely perform echocardiography on (mostly equids and some bovine), it was more difficult to obtain a good quality 2D right parasternal view of the heart base at the level of the pulmonary valves and to perform the measurements in M-mode echocardiography. This problem could be a source of error of measurements and could explain the variability of the measurements in M-mode echocardiography showed in Table 2.

In the present study, the global variability and the within-day variability of the echocardiographic measurements were closely similar and showed a very low to low variability, but the M-mode measurements were slightly more variable than 2D-measurements. This has also been previously observed in dogs (Dukes-McEwan and others 2002, Chetboul and others 2004), cats (Simpson and others 2007) and horses (Young and Scott 1998, Buhl and others 2004). Only RVIDd, IVS% and LVFW% showed a moderate to high variability. A high variability of RVIDd has previously been reported in echocardiographic studies performed in most species (Moses and Ross 1987, Long and others 1992, Dukes-McEwan and others 2002, Chetboul and others 2004) and has been thought to be due to the non-circular geometry of the right ventricle or to the difficulty in aligning the M-mode cursor perpendicularly to the right ventricular endocardial surface. The present study also showed a good inter-day repeatability of 2D- and M-mode echocardiographic measurements. As already described in horses (Young and Scott 1998), this good repeatability and low variability should have connections with the conditions of examinations, since the investigated goats of the present study were fully accustomed to be handled and submitted to echocardiographic procedure. The conclusions reached in this study should thus be transposed with caution, to goats unaccustomed to be handled and examined for a clinical purpose. However, this bias is less problematic in goats, as echocardiography in this species is essentially performed in cardiovascular research on the contrary to dogs and horses, which are referred

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TABLE 2: Mean values of 2D- and M-Mode echocardiographic measurements obtained in 12 healthy adult Saanen goats and comparison with echocardiographic values previously reported in healthy adult Swedish goats during the dry period (Olsson and others 2001) and in healthy adult sheep of various breed (Moses and Ross 1987)

	Saanen goats		Swedish goats	Sheep	
	Mean±sd	Range	Mean±sd	Mean±sd	Range
Weight (kg)	66.1±9.4	51-83	51±2	73.5±11.3	55-95
Heart rate (bpm)	95.8±16.3	68-120	107±9	96.1±21.6	66-138
AoS (cm)	2.83±0.10	2.66-3.00	NR	NR	NR
AoV (cm)	2.03±0.10	1.88-2.17	NR	NR	NR
Pu (cm)	2.45±0.07	2.34-2.56	NR	NR	NR
LADd (cm)	4.15±0.22	3.71-4.35	2.69±0.3	NR	NR
LADs (cm)	4.76±0.22	4.52-5.27	NR	NR	NR
MADd (cm)	3.27±0.14	2.92-3.47	NR	NR	NR
MADs (cm)	2.98±0.11	2.86-3.25	NR	NR	NR
LAAd (cm^2)	10.90±1.06	9.27-12.58	NR	NR	NR
LAAs (cm^2)	15.06±1.71	12.74-18.25	NR	NR	NR
LADd/AoS	1.47±0.07	1.33-1.57	NR	NR	NR
Pu/AoS	0.87±0.03	0.82-0.90	NR	NR	NR
RVIDd (cm)	1.21±0.21	0.81-1.52	NR	2.03±0.56	1.26-3.35
IVSd (cm)	0.88±0.07	0.74-1.00	NR	0.94±0.17	0.62-1.36
IVSs (cm)	1.48±0.11	1.37-1.72	NR	1.41±0.22	1.02-1.86
LVIDd (cm)	4.81±0.37	4.12-5.37	4.06±0.1	5.17±0.74	3.73-6.33
LVIDs (cm)	2.74±0.24	2.32-3.11	2.4±0.8	3.23±0.46	2.48-4.05
LVFWd (cm)	0.94±0.09	0.79-1.1	0.68±0.03	0.89±0.20	0.62-1.39
LVFWs (cm)	1.53±0.09	1.37-1.67	1.29±0.06	1.53±0.11	1.14-2.73
LVVd (ml)	109.16±19.40	75.44-139.61	NR	NR	NR
LVVs (ml)	28.42±6.10	18.68-38.38	NR	NR	NR
SV (ml/beat)	80.73±15.17	55.48-106.36	NR	NR	NR
EF (%)	73.88±3.58	65.07-78.63	NR	NR	NR
FS (%)	43.01±3.11	35.71-47.1	40.6±1.2	37.2±5.7	27.3-49.0
IVS% (%)	68.81±10.08	49.99-88.87	NR	52.4±27.7	20.4-150.0
LVFW% (%)	65.54±13.74	42.17-89.01	NR	75.1±28.5	3.02-133.9
RWT (cm)	0.38±0.04	0.32-0.45	NR	NR	NR
MWT (cm)	0.91±0.06	0.83-1.01	NR	NR	NR

d Measurement in diastole, NR not reported, s Measurement in systole. 2D-measurements: AoS Aortic diameter at the sinus of Valsalva, AoV Aortic diameter at the basis of the valves (aortic annulus), LAA Left atrial area, LAD Left atrial internal diameter, MAD Mitral annulus diameter, Pu Pulmonary artery diameter at the level of the sinus. M-mode measurements: EF Left ventricular ejection fraction, FS Fractional shortening of the left ventricle, IVS% Percentage of systolic thickening of the interventricular septum, IVS Interventricular septum thickness, LVFW% Percentage of systolic thickening of LVFW, LVFW Left ventricular free wall thickness, LVID Left ventricular internal diameter, LVV Left ventricular volume, MWT Mean wall thickness, RVID Right ventricular internal diameter, RWT Relative wall thickness, SV Left ventricular stroke volume

to clinics to achieve a diagnostic and a prognosis (Chetboul and others 2004). The significant effect of the examined goat on all of these echocardiographic measurements was not surprising, since it has been shown in several species that 2D- and M-mode echocardiographic measurements are affected by various physiological factors such as body size (Morrison and others 1992, Slater and Herrtage 1995), breed (Morrison and others 1992), sex (Lonsdale and others 1998), growth process (Stewart and others 1984, Sisson and Schaeffer 1991), training (Lonsdale and others 1998, Young 1999) or pregnancy (Mesa and others 1999, Olsson and others 2001). None of the measurements were indexed to bodyweight, because the range of bodyweight of the investigated goats group was quite small, but this factor could explain why the effect of the goat was significant.

In the present study, LAD was measured from a 2D-mode right parasternal four-chamber view as previously described in the literature in dogs (Boon 2011b) and horses (Schwarzwald and others 2007). Two other methods are sometimes used to measure LAD in animal species. The first one, performed in a 2D- or M-mode right parasternal short-axis view of the aortic root and the left atrium, is mainly used with a good repeatability in small animals like dogs (Hansson and others 2002, Chetboul and others 2004) and cats (Simpson and others 2007). This method, also used on Swedish goats by Olsson and others (2001), seemed to produce higher variability as it has been reported in sheep (Moses and Ross 1987). The second method is to measure LAD from a 2D-mode left parasternal long-axis view. This latter view is often used in large domestic animals like horses (Voros and others 1991, Long and others 1992) and cattle (Hallowell and others 2007) and has been shown to allow measuring the greatest LAD in this species. The method used in the present study offers advantages such as allowing easy measuring of the mitral valve annulus and the true maximal LAD with a good repeatability. Furthermore, this method allowed performing the entire echocardiographic protocol from the right parasternal side. This shortened the echocardiographic procedure, which could be a priority in uncooperative animals such as goats not used to be handled or stressed animals.

The ratios LAD/Ao and Pu/Ao were calculate from AoS because, during measurements, AoV was qualitatively more difficult to measure than AoS, and the variability of AoV was higher than that of AoS. However, AoS might theoretically be more influenced by disease processes or changes in systemic blood pressures than AoV and its use in the LAD/Ao and Pu/Ao ratios could be a cause of error.

As showed in Table 2, echocardiographic values obtained from goats in the present study were slightly higher to corresponding values previously reported in Swedish domestic goats (Olsson and others 2001). This could be secondary to the effect of breed or more probably of bodyweight, since the M-mode echocardiographic values were closely comparable with corresponding values previously reported in sheep (Moses and Ross 1987) whose bodyweight was more similar to Saanen goats'. Echocardiographic measurements in the present study appeared to have a higher variability in sheep than what the authors observed in goats, with CV ranging from 10.1 to 38.9 per cent. As in the present study, problems were encountered in performing M-mode measurements in sheep because of difficulties to distinguish epicardial and pericardial edges.

In the present study, data were computed to determine the intra-observer inter-day repeatability of the echocardiographic measurements. To the authors' knowledge, repeatability test of echocardiographic measurements has not previously been reported in goats, which precludes comparison of such values with values obtained in this study.

In conclusion, the results of the study suggest a good inter-day repeatability and a low variability of 2D- and M-mode echocardiographic measurements in adult goats. Moreover, echocardiographic reference values in adult, healthy, non-pregnant, female goats of the Saanen breed have been established. However, the effects of the physiological factors that are known to significantly affect echocardiographic measurements in several species (Lombard and others 1984, Stewart and others 1984, Sisson and Schaeffer 1991, Morrison and others 1992, Slater and Herrtage 1995, Lonsdale and others 1998, Mesa and others 1999, Young 1999) were not investigated. For instance, effects of pregnancy and lactation have already been reported in Swedish domestic goats (Olsson and others 2001). In the future, it could thus be interesting to evaluate the effect of other physiological factors in order to establish fully documented echocardiographic reference values in this species.

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