



## Normal Echocardiographic Parameters in Egyptian Nubian Goats

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### Abstract

THE reference parameters for echocardiography are poorly documented in goats and undocumented in Egyptian Nubian goats. This study aimed to establish reference ranges for echocardiographic indices using M-mode and Doppler techniques in Egyptian Nubian goats. Echocardiographic parameters were measured in 25 healthy Egyptian goats aged 3 to 4 years, weighing 40-50 kg, in lateral recumbency position. The parameters included left ventricular end-systolic and end-diastolic diameters, interventricular septum thickness in systole and diastole, left ventricular free wall thickness in systole and diastole, heart rate, final diastolic volume, final systolic volume, cardiac output, stroke volume, fractional shortening, and ejection fraction. Additionally, aortic root diameter, left atrial diameter, and the left atrial-to-aortic root ratio were reported. Doppler echocardiography was used to assess blood flow velocities in the pulmonary artery and aorta: peak velocity and pressure gradient. Parameters of left ventricular diastolic function, including early (E<sub>max</sub>) and late (A<sub>max</sub>) velocities, and the E<sub>max</sub>/A<sub>max</sub> ratio, were obtained from the mitral flow profile. Several differences in echocardiographic dimensions were found in Egyptian goats compared to previous studies in other goat breeds.

In conclusion, echocardiographic parameters can be reliably evaluated in Egyptian goats, and our study has provided normal reference ranges that may be useful in accurately assessing cardiac structures and functions to aid in diagnosing heart diseases. These findings can also benefit experimental studies on the heart and blood vessels in goats used for human research purposes.

**Keywords:** Doppler, M-mode echocardiography, Normal Egyptian goats, Reference values.

### Introduction

Nowadays, the researches on goats has been expanded as it is considered one of the productive animals, so researcher used echocardiography, as a practicable method used to assess the functions of the heart. Echocardiographic procedures including Doppler in goats are not totally described before so it needs further investigations. The use of echocardiography is clinically restricted in farm animals and limited only to scientific researches. Accordingly, animals with heart diseases are usually discarded not treated due to lack of proper diagnosis. The echocardiographic dimensions are varied among different breeds and there are no earlier documentations of the echocardiographic measurements in Egyptian native breeds of goats [1, 2].

From many years, echocardiography is widely used in evaluation and diagnosis of different heart diseases as a routinely diagnostic tool in pets and human practices. Also, it offers feasible, non-

invasive and consistent standards needed to evaluate the drug safety, effectiveness, and practicability also the possible hazards [3].

Recently, different animals have been used as a model in researches of cardiovascular abnormalities as well as goats. The widely use of these models designed for early prediction, diagnosis and proper treatment of CVD in both animals and humans, which is the main aim of the researchers in CVD to decrease the spreading of the CVD [4, 5].

The cardiologist used small ruminant like goats in the researches on heart diseases especially in experiments that need complete wake or active animals, flow dynamic research, and atrial fibrillation [6]. Moreover, goats are easily handled and managed animal and have a heart and body size nearly similar to those in humans [7].

Echocardiography is a feasible method used to evaluate structures, dimensions and functions of the

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heart, chambers and myocardium. Doppler, Two dimensional, and also M-mode echocardiography are continuously used to detect the cardiovascular abnormalities in humans and animals practices [8, 9]. Providing the echocardiography apparatus with digital raw data storage offers images of high-quality of hearts in many species at variable dimensions. Normal dimensions and reference ranges for echocardiographic parameters have been documented in a lot of species [8].

Scarce documentations were found on echocardiography in normal small animals. Only little researches are now focus on echocardiography in apparently normal adult goats, this is mainly due to rare detection of heart diseases in the goats. Scarce documentations of cardiac dimensions abnormalities in goats is little surprising as it represents an attractive and continuous animal model for CVD in humans that mainly used in atrial fibrillation, chronic heart failure, valve replacement, and artificial hearts' experiments [10].

Lack of detailed clinical evaluation of this species or may be their relative resistant to heart abnormalities, goats are rarely clinically identified with structural heart diseases. Endocarditis has not been documented in this species before. Also, myocarditis due to different infectious causes as *Clostridium spp*, FMD, or even monensin toxicity could be present but without real documentation [11].

Echocardiography is an applied diagnostic tool in goats, although a small acoustic window makes it difficult to attain some images in some animals [12].

Thus, this work aimed to establish the baseline information normal echocardiographic findings of Egyptian Nubian goats and to compare the recorded values with those reported by other researchers in other breeds of goats.

## **Material and Methods**

### *Animals*

Twenty-five adult goats, 3-4 years old, and a body weight of 40-50 kg were included in our work. In the Faculty of Veterinary Medicine, Cairo University, Egypt, the goats were housed, they were fed pelleted feed and wheat straw as a regular regime 2 times per day, and water available freely. The animals were in non-pregnant and in non-lactating states. Neither of them were used any medications in the last month before joining the study.

Intensive clinical evaluation was achieved on all animals which were considered clinically sound depend on the medical record. In all goats the findings of echocardiography were documented and compared with the reference ranges of different breeds of same the species [13].

### *Conventional Echocardiography*

Full conventional echocardiography was performed on all Egyptian goats to detect the normal interval ranges. The documented dimensions were gained from 5 frequent heart cycles as an average. The animal was handled by 2 assistants in a wake state in the lateral recumbent position while performing the echocardiographic investigation. The precordial areas were shaved on both sides and covered with an ultrasonic gel provided by a sector probe of 2-4 MHz and an electrocardiographic observing system was used (EDAN AX8, USA). The documented dimensions and image positioning were lined to the American Society of Echocardiography standards [11].

As detailed by [14], a complete conservative M-mode and Doppler echocardiography from the regular right and left parasternal assessments was conducted on all animals. First of all, the right parasternal long axis (RPLAV) four-chamber and five-chamber views were imagined, after that the dimensions of the LV functions including: LV end-diastolic and end-systolic diameters (LVIDd, LVIDs), interventricular septal thickness in diastole and systole (IVSTd, IVSTs), LV free wall thickness in diastole and systole (LVPWd, LVPWs), heart rate (HR), end diastolic volume (EDV), end systolic volume (ESV), cardiac output (CO), stroke volume (SV), fraction shortening (FS), and ejection fraction (EF) was taken by M-mode of the short-axis view at the papillary muscle level. Then aortic root diameter (AoR), left atrium diameter (LAD), and the left atrium/ aortic diameter ratio (LAD/AoR) were detailed as shown in Figs. (1 and 2).

### *Doppler echocardiography*

Also, the Doppler echocardiography was used for evaluation of the pulmonary artery blood flow with a 2.0 mm sample volume. Then, the position of the animal was transformed to achieve the echocardiography from the left side. From the left apical four-chamber view, the LV diastolic parameters including early ( $E_{max}$ ) and late ( $A_{max}$ ) velocities and,  $E_{max}/A_{max}$  ratio, were gained from the trans-mitral flow profile using Doppler. Also, for the evaluation of trans-aortic blood flow, the transducer was slightly moved anteriorly to gain the left apical 5-chamber view.

The pulmonary and aortic flow Doppler measurements have been assessed including: Peak velocity (PV) and pressure gradient (PG) according to [9, 15] as shown in Figs. (3, 4, and 5).

### *Statistical analysis*

Finally the gained data were analyzed by the Independent-Samples T-test, the SPSS software package for Windows Ver. 20.0 (SPSS Inc., Chicago, IL, USA) and detailed in tables as mean value  $\pm$  SD for echocardiography. Echocardiography

measurements were taken by a specialized observer with seven years of experience in veterinary Echocardiography and were conducted using the device built-in software.

### **Results**

While performing our study and during echocardiography process, all the presented goats were have both normal heart rate and sounds with average heart rate  $128.20 \pm 12.7$  bpm compared to reference range (70-90 bpm). M-mode, and Doppler echocardiographic measurements are summarized in Tables 1 and 2 in normal Egyptian Nubian goats.

### **Discussion**

The present study has documented an easy and valuable method for cardiac dimensions' reference values that can be gained from M-Mode, and Doppler echocardiography for Egyptian Nubian goats, that have not been documented before. Reference ranges for internal cardiac dimensions for adult goats should improve detection, assessment and evaluation of heart abnormalities in the goats [16].

Our study showed differences in ventricular dimensions in Nubian Egyptian goats when compared to previous studies [2, 16, 17, 18, and 19] as summarized in Table 3 as mean  $\pm$  SD. These differences may relate to the difference in bodyweights, breeds and genetics variations of the goats used in these studies.

In the Egyptian goats, Fractional shortening was lowered to reference value of [16, 17] but slight higher to reference value recorded by [2, 18]. Ejection fraction is higher in our Egyptian goats compared to previous studies of [2, 16, 17, 18, and 19]. This may be due to weight, breeds and genetic differences.

Doppler echocardiography showed Mitral valve  $E_{\max}$  values were lower than that of  $A_{\max}$  with low  $E_{\max}/A_{\max}$  ratio Egyptian goats. This result is contrary to what reported by [17] but agreed with [11] who reported lower  $E_{\max}/A_{\max}$  ratio in merino ewes.

Aortic valve  $V_{\max}$  and pulmonary valve  $V_{\max}$  values were lower in goats of our study ( $0.79 \pm 0.25$  and  $0.73 \pm 0.11$ ) than that recorded by [17] ( $1.05 \pm 0.14$  and  $0.99 \pm 0.12$ ) in Saanen goats. Also, [18] reported higher values of Aortic valve  $V_{\max}$  and  $PG_{\max}$  and Pulmonary valve  $V_{\max}$  and  $PG_{\max}$  in Polish White Improved (PWI) and Polish Fawn Improved (PFI) goats.

### **Conclusion**

This study provides an echocardiographic reference values for Egyptian Nubian goats in clinically healthy animals which can be useful in future researches and help in detection of cardiac diseases.

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### *Authors' contributions*

The idea and methodology of the study were performed by all authors. Data collection and preparation of materials were performed by Mohamed El-said and Mohamed El-sherif. Laboratory work and data analysis were conducted by Mohamed Oraby, and Alaa Jaheen. The manuscript was written by Mohamed Oraby and Alaa Jaheen, and, Mohamed El-said and Mohamed El-sherif revised the manuscript, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

### *Funding statement*

No financial issues to disclose.

### *Declaration of Conflict of Interest*

None.

### *Ethical of approval*

This study was performed according to guidelines of the Institutional Animal Care and Use committee of the Cairo University (IACUC) (Ethics approval number: Vet CU 2305 2022471).

**TABLE 1. M-mode echocardiographic parameters of normal Egyptian Nubian goats.**

Parameters	Nubian goats (n=25)
	Mean± SD
IVSTd (cm)	0.73 ± 0.20
IVSTs (cm)	1.10 ± 0.28
LVIDd (cm)	2.95 ± 0.40
LVIDs (cm)	1.68 ± 0.09
LVPWd (cm)	0.85 ± 0.18
LVPWs (cm)	1.10 ± 0.28
HR (bpm)	128.20 ± 12.7
EDV (ml)	34.66 ± 11.2
ESV (ml)	8.22 ± 1.1
SV (ml)	26.44 ± 10.3
CO (l/min)	3.44 ± 1.4
EF %	74.55 ± 6.4
FS %	42.31 ± 5.9
LAD (cm)	2.63 ± 0.38
AoR (cm)	1.95 ± 0.23
LAD/AoR	1.35 ± 0.01

IVSTd: Interventricular septal thickness at end-diastole; IVSTs: Interventricular septal thickness at end-systole LVIDd: Left ventricular internal diameter at end-diastole; LVIDs: Left ventricular internal diameter at end-systole; LVPWd: Left ventricular posterior wall thickness at end-diastole; LVPWs: Left ventricular posterior wall thickness at end-systole; HR: Heart rate; EDV: End-diastolic volume; ESV: End-systolic volume; SV: Stroke volume; CO: Cardiac output; EF: Ejection fraction; FS: Fractional shortening; LAD: left atrial diameter; AoR: Aortic root diameter; LAD/AoR: Ratio of left atrial diameter to aortic root diameter at end- diastole.

**TABLE 2. Doppler echocardiography of normal Egyptian Nubian goats.**

Parameters	Nubian goats (n=25)
	Mean± SD
MV E <sub>max</sub> (m/s)	0.60 ± 0.07
MV A <sub>max</sub> (m/s)	0.66 ± 0.15
E <sub>max</sub> /A <sub>max</sub> (m <sup>2</sup> )	0.95 ± 0.22
PV(V <sub>max</sub> ) (m/s)	0.73 ± 0.11
PV (PG <sub>max</sub> ) (mmHg)	2.21 ± 7.09
AV (V <sub>max</sub> ) (m/s)	0.79 ± 0.25
AV (PG <sub>max</sub> ) (mmHg)	2.76 ± 2.14

MV E<sub>max</sub>: Mitral valve E wave velocity; MV A<sub>max</sub>: Mitral valve A wave velocity; E<sub>max</sub>/A<sub>max</sub>: Ratio between E and A waves to locate maximal flow velocity; PV(V<sub>max</sub>): Pulmonary valve maximal blood velocity; PV(PG<sub>max</sub>): Pulmonary valve maximal pressure gradient; AV(V<sub>max</sub>): Aortic valve maximal blood velocity; AV(PG<sub>max</sub>): Aortic valve maximal pressure gradient.

**TABLE 3. Compare between cardiac dimensions from this study with previous ones represented by mean ± SD.**

Parameters	Nubian goats- current study	Goat as in study of [16]	Goat as in study of [17]	PWI Goats as in study of [18]	PFI Goats as in study of [18]	Zarabi Goats as in study of [2]
IVSTd (cm)	0.73 ± 0.20	0.98 ± 2.1	0.88 ± 0.7	0.88±0.14	0.81±0.13	0.881±0.12
IVSTs (cm)	1.10 ± 0.28	1.32 ± 3.2	1.48±1.1	1.10±0.19	1.03±0.15	1.002±0.11
LVIDd (cm)	2.95 ± 0.40	3.74 ± 4.8	4.81±3.7	4.29±0.49	4.07±0.43	3.211±0.32
LVIDs (cm)	1.68 ± 0.09	2.11± 3.1	2.74 ± 2.4	2.57±0.36	2.4±0.39	2.413±0.21
LVPWd (cm)	0.85 ± 0.18	0.79 ± 0.7	0.94 ± 0.9	0.91±0.19	0.84±0.14	0.721±0.06
LVPWs (cm)	1.10 ± 0.28	1.22 ± 1.9	1.53 ± 0.9	1.21±0.21	1.11±0.18	0.941±0.12
HR (bpm)	128.20 ± 12.7	87.1 ± 3.2	95.8 ± 16.3	NR	NR	75±8
EDV (ml)	34.66 ± 11.2	NR	NR	NR	NR	NR
ESV (ml)	8.22 ± 1.1	NR	NR	NR	NR	NR
SV (ml)	26.44 ± 10.3	NR	NR	NR	NR	NR
CO (l/min)	3.44 ± 1.4	NR	NR	NR	NR	NR
EF %	74.55 ± 6.4	73.6 ± 5.4	73.9 ± 3.58	70.48±7.04	71.81±7.68	57.5±4.1
FS %	42.31 ± 5.9	45.2 ± 5.9	43.0 ± 3.11	40.02±6.07	41.05±6.45	24.5±2.71
LAD(cm)	2.63 ± 0.38	4.06 ± 5.4	NR	3.36±0.40	3.26±0.41	NR
AoR (cm)	1.95 ± 0.23	NR	NR	2.80±0.28	2.64±0.22	1.24±0.18
LAD/AoR	1.35 ± 0.01	NR	NR	1.21±0.13	1.24±0.14	NR

Table 3 is displaying mean  $\pm$  standard deviation for cardiac dimensions in Egyptian Nubian goats obtained in this study. These have then been compared with dimensions reported from five previous studies in other breeds of goats. Abbreviations: IVSTd: Interventricular septal thickness at end-diastole; IVSTs: Interventricular septal thickness at end-systole LVIDd: Left ventricular internal diameter at end-diastole; LVIDs: Left ventricular internal diameter at end-systole; LVPWd: Left ventricular posterior wall thickness at end-diastole; LVPWs: Left ventricular posterior wall thickness at end-systole; HR: Heart rate; EDV: End-diastolic volume; ESV: End-systolic volume; SV: Stroke volume; CO: Cardiac output; EF: Ejection fraction; FS: Fractional shortening; LAD: left atrial diameter; AoR: Aortic root diameter ; LAD/AoR: Ratio of left atrial diameter to aortic root diameter at end- diastole; NR: not recorded, PWI: Polish White Improved goats; PFI: Polish Fawn Improved goats

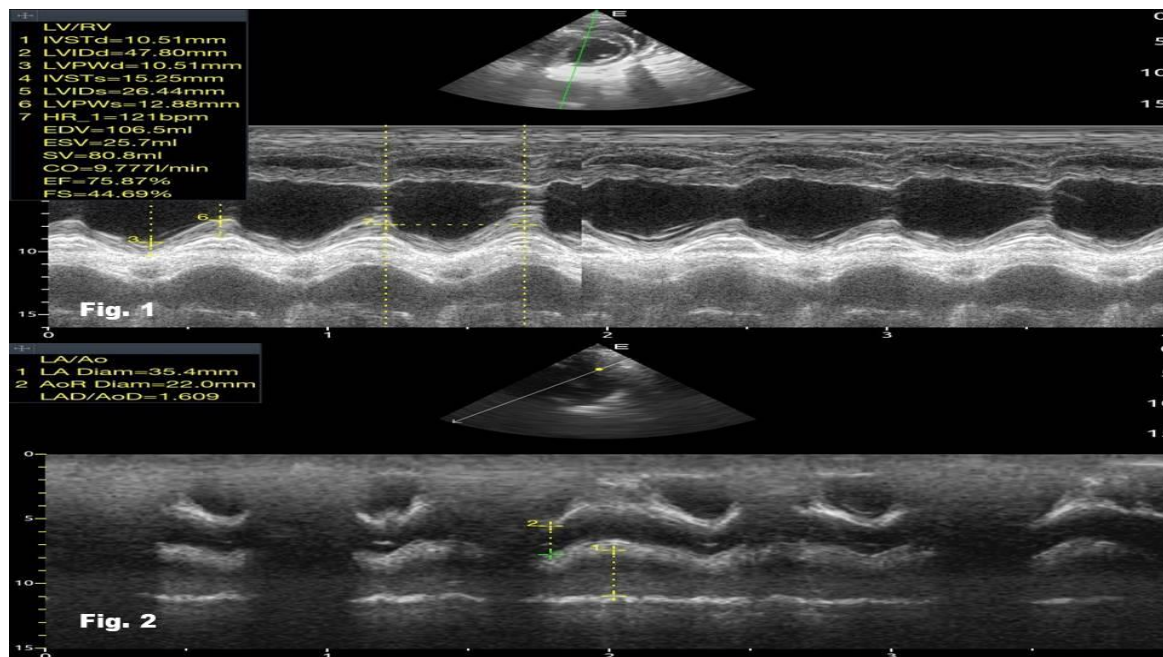


Fig. 1 and 2. Represent M-mode of the short-axis view at the papillary muscle level to record the measurements of the LV functions. This includes LV end-diastolic and end-systolic diameters (LVIDd, LVIDs), interventricular septal thickness in diastole and systole (IVSTd, IVSTs), LV free wall thickness in diastole and systole (LVPWd, LVPWs), heart rate (HR), end diastolic volume (EDV), end systolic volume (ESV), cardiac output (CO), stroke volume (SV), fraction shortening (FS), and ejection fraction (EF). Then aortic root diameter (AoR), left atrium diameter (LAD), and the left atrium/ aortic diameter ratio (LAD/AoR) were reported.



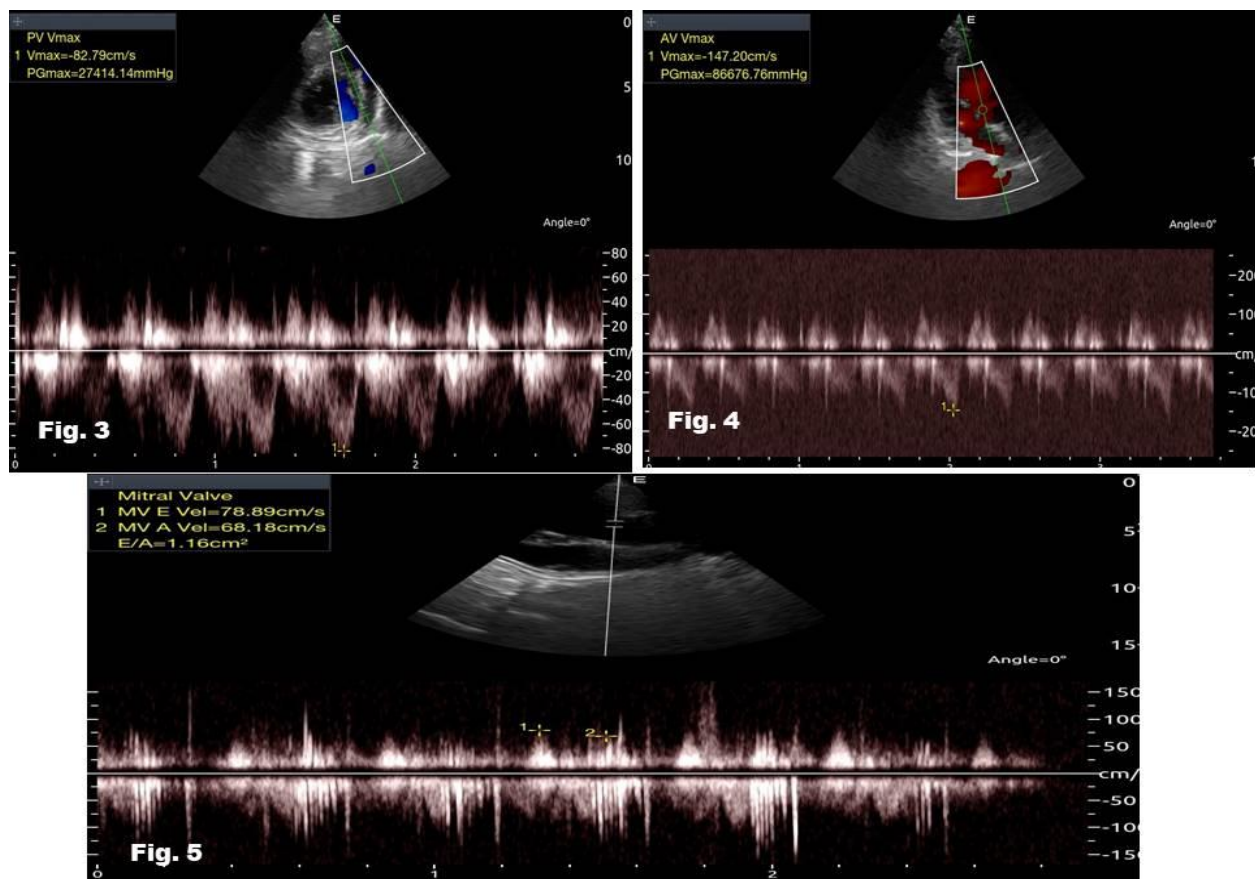


Fig. 3, 4, and 5 Represent Doppler echocardiography of pulmonary, aortic and mitral valve blood flow respectively. From the left apical four-chamber view, the LV diastolic parameters including early ( $E_{max}$ ) and late ( $A_{max}$ ) velocities and,  $E_{max}/A_{max}$  ratio, were obtained from the trans-mitral flow profile using Doppler. Also, the transducer was slightly moved anteriorly to obtain the left apical 5-chamber view for Doppler evaluation of the trans-aortic blood flow. Doppler parameters of the pulmonary and aortic flow have been addressed: peak velocity (PV) and pressure gradient (PG).

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### قياسات صدى القلب الطبيعية في الماعز النوبي المصري

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#### الملخص

المعايير المرجعية لفحص القلب بواسطة التصوير بالصدى غير موثقة بشكل جيد في الماعز بشكل عام وغير موجودة في الماعز النوبية المصرية خصوصاً. كان هدف هذه الدراسة تحديد النطاقات المرجعية لمؤشرات الصدى القلبي باستخدام تقنيات M- mode والدوبلر في الماعز النوبية المصرية. تم قياس معايير الصدى القلبي في ٢٥ من الماعز المصرية السليمة تتراوح أعمارها بين ٣ و ٤ سنوات ووزنها بين ٤٠ و ٥٠ كجم، أثناء وضعها على جنبها. شملت المعايير القطر الانبساطي والانقباضي للبطين الأيسر، سمك الحاجز البين البطيني في الانقباض والانبساط، سمك جدار البطين الأيسر في الانقباض والانبساط، معدل ضربات القلب، حجم الانقباضي النهائي، حجم الانقباضي النهائي، الناتج القلبي، حجم السكتة الدماغية، تقصير الكسر، ونسبة الانقباض. بالإضافة إلى ذلك، تم تحديد قطر جذر الأبهري، وقطر الأذين الأيسر، ونسبة قطر الأذين الأيسر إلى جذر الأبهري. تم استخدام تقنية الدوبلر في التصوير بالصدى لتقييم سرعات تدفق الدم في الشريان الرئوي والأبهري: سرعة الذروة وتدرج الضغط. تم الحصول على معلمات وظيفية البطين الأيسر في مرحلة الانبساط، بما في ذلك سرعات Emax و Amax ونسبة Emax/Amax، من ملف تدفق الدم عبر الصمام الإبهامي. تم العثور على اختلافات عدة في أبعاد الصدى القلبي في الماعز النوبية المصرية مقارنة بالدراسات السابقة في سلالات أخرى. في الختام، يمكن تقييم معايير الصدى القلبي بشكل موثوق في الماعز النوبية المصرية، وقد قدمت دراستنا نطاقات مرجعية طبيعية قد تكون مفيدة في تقييم هياكل القلب ووظائفه بدقة للمساعدة في تشخيص أمراض القلب. يمكن أن تعود هذه النتائج أيضاً بالفائدة على الدراسات التجريبية حول القلب والأوعية الدموية في الماعز المستخدمة لأغراض بحثية في الإنسان.

**الكلمات المفتاحية:** الدوبلر، تخطيط صدى القلب بوضع M، الماعز المصري الطبيعي، القيم المرجعية.