Original Research Article

EVALUATION OF FOETAL CARDIOTHORACIC RATIO IN NORMAL PREGNANCY: CORRELATION WITH GESTATIONAL AGE, FOETAL WEIGHT AND ESTABLISHED NOMOGRAM

ABSTRACT

Background: An important sign of congenital heart disease (CHD), myocardial dysfunction and foetal congestive cardiac failure is cardiomegaly, which is detected using the assessment of the cardiothoracic (CT) ratio.

Objective: To evaluate the foetal CT ratio and its relationship with gestational age in the second half of pregnancy, and produce nomograms for the foetal CT ratio.

Subjects and Methods: This descriptive, cross-sectional study enrolled women with a normal pregnancy in their second and third trimesters at the two tertiary health facilities, one secondary facility and one radiodiagnostic facility in Bayelsa State, Nigeria. The study was conducted from April–December 2022. Pearson's correlation and logistic regression analyses were used to assess the relationship and correlation between the CT ratio, gestational age, and estimated foetal weight. The $p<0.05$ at 95%CI level of significance was set.

Results: The mean bi-parietal diameter estimated foetal weight and CT diameter ratio was 66.5 ± 18.3 mm, 1.24 ± 0.87 kg and 0.46 ± 0.02 cm respectively. The foetal CT ratio correlates very strongly with estimated gestational age (ɼ = 0.98; p – 0.001), bi-parietal diameter (ɼ = 0.96; p – 0.001), estimated foetal weight (ɼ = 0.92; p – 0.001), Maternal age (ɼ = 0.36; p – 0.001), maternal weight (ɼ = 0.19; p – 0.001) and maternal height (ɼ = 0.20; p – 0.001).

Conclusion: We have demonstrated that there does exist a very strong correlation between the foetal cardiothoracic ratio and the foetal gestational age, biparietal diameter and foetal weight, which slightly, but steadily increased throughout pregnancy.

Keywords: Cardiothoracic ratio, Cardiomegaly, Pregnancy, Gestational age, Foetal weight.

INTRODUCTION

The foetal cardiothoracic (CT) ratio is not routinely measured during obstetric ultrasound scans. However, it is measured when there is suspicion of foetal cardiac condition. On chest x-ray, the CT ratio is generally used to evaluate heart size in relation to the thorax in children and adults.[1] An important sign of congenital heart disease (CHD), myocardial dysfunction and foetal congestive cardiac failure is cardiomegaly, which is detected using the assessment of the CT ratio.[1–6] Measurement of heart size is a fundamental element in the screening for foetal cardiac diseases.[3] The normal heart size is about one-third of the human chest.[3]

An important method for assessing foetal heart size is the CT ratio. However, several recommendations for foetal sonographic cardiac evaluation do not suggest routine screening using CT ratio measurement.[3,6,7] Other methods are assessment of cardiac volume, cardiac area and circumference, estimation of gestational age, measurement of biparietal diameter and other foetal biometric indices.[1,4,8] There are three ways to calculate the CT ratio: by dividing the cardiac diameter by the thoracic diameter (also known as the CT diameter ratio), by dividing the cardiac circumference by the thoracic circumference (also known as the CT circumference ratio), and by dividing the cardiac area by the thoracic area (also known as the CT area ratio).

Some authors have reported that CT ratio values remain largely consistent during the course of gestation,[1,9–11] while others have reported that from the first trimester until the end of pregnancy, foetal CT ratios assessed using any method slightly increased with increasing GA.[8,12] The mean values for the CT diameter, circumference, and area ratios throughout the second and third trimesters are roughly 0.5, 0.51, and 0.3, respectively.[10,11,13,14] The cardiovascular profile score, which offers a semi-quantitative assessment of foetal heart health, also includes the foetal CT area ratio as one of its components.[2] Regardless of gestational age, this scoring method has a cut-off value of greater than 0.35 for foetal cardiomegaly.[2] Therefore, using GA-specific cut-off values rather than a universal cut-off value for diagnosing foetal cardiomegaly may be more accurate.[8]

There is presently no consensus in the literature on the best method for assessing foetal CT ratio that is least GA dependent. Therefore, we sought to evaluate the foetal CT ratio and its relationship with gestational age in the second half of pregnancy, and produce nomograms for the foetal CT ratio for our environment.

SUBJECTS AND METHODS

Study design and setting: This descriptive, cross-sectional study recruited and enrolled women with a normal pregnancy in their second and third trimesters at the radiology and obstetrics units of the Niger Delta University Teaching Hospital, Okolobiri, Federal Medical Centre, Yenagoa, Silhouette Radiodiagnostic Consultants, Yenagoa and Diete Koki Memorial Hospital, Yenagoa, all in Bayelsa State, Nigeria. The study was conducted between April 2022 and December 2022. The first two study centres are tertiary healthcare facilities that offer specialized gynaecological services to women in Bayelsa State and act as referral hubs for hospitals there and in the nearby Rivers and Delta States, both of which are located in South-South Nigeria. The largest radio diagnostic facility in Nigeria's Bayelsa State is the third study centre, while the fourth study centre is a secondary medical facility.

Ethics: The protocol for this study was approved by the Research and Ethics Committee of the Federal Medical Centre Yenagoa, Bayelsa State, Nigeria (FMCY/REC/ECC/2022/657).

Sample size calculation: This was calculated using the formula: $n = Z\alpha^2 \times \sigma^2 / \delta^2$ [15,16]

Where: Zα = 95% CI, which is 1.96, σ = mean of 4.8 cm from a previous study.[17] δ = level of precision for our study (σ/√511).

Calculation:

$n = (1.96)^2 \times 4.8^2 / \sigma/\sqrt{511}$

n = 3.8416 x 23.04 / 0.21

n = 88.51 / 0.21

n = 421.47

Considering attrition of 5% (21.07), n was adjusted to 442

For this study, 442 consecutive pregnant women were enrolled. The study included consecutive patients who visited our Obstetric Units.

Inclusion criteria: Uncomplicated singleton gestation in the second and third trimesters, absence of any foetal cardiac abnormalities.

Exclusion criteria: Structural and functional foetal heart abnormalities, pulmonary hypoplasia, skeletal dysplasia, major extracardiac abnormalities, chromosomal abnormalities, and abnormal foetal growth.

After counselling, written informed consent to participate was obtained from all the women enrolled in the study. For an obstetric ultrasound scan, they were referred to the radiology unit. Socioeconomic information was obtained, including the patient's age, marital status, occupation and any presenting complaints. With the patient standing on the Frankfort plane, the height of the patient was measured using a wall-mounted stadiometer. A weighing scale was used to determine weight. Patients were asked to take off their bulky outerwear and shoes and stand in the middle of the scale to evenly distribute their weight across both feet. Body mass index (BMI) was determined as the weight in kilograms (kg) divided by height in meters (m) squared. The last normal menstrual period, which corresponded with their first-trimester ultrasound scan, was used to determine the gestational age.

Procedure: Protocols for placing patients and scanning them as outlined by Vanderwerff and Winter were used.[18] All ultrasound examinations were performed transabdominally (by consultant radiologists with a special interest in foetal scans) using a 2012 Philips HD11 device with a 3.5 MHz curvilinear probe. As the patient lay supine on the examination couch, she was encouraged to expose the anterior abdominal wall for the procedure, and an adequate amount of ultrasound gel was applied to these exposed regions. The gel helped the transducer move more easily and removed air from the skin. With gain adjusted as necessary for acceptable image quality, it was moved back and forth on the skin and in orthogonal planes. The Foetal CT ratio was derived from a single ultrasound examination. At the level of the four-chamber view, 2-D cross-sectional images of the foetal chest were produced.

To optimize the image quality for CT ratio measurements, the entire thorax and ribs must be visible, and there should be a typical four-chamber view and an absence of abdominal contents in the view. Three cine-loops of the four-chamber view for each foetus were obtained to do an offline calculation. All measurements were made at the end-diastole. Frame-by-frame cine clips were assessed until the first downward systolic motion at the level of the atrioventricular valve annuli appeared to determine the end-diastole. The previous frame was chosen to depict end-diastole when this frame was in view.

The foetal CT diameter ratio (Figure 1) was used to determine the foetal CT ratio. Two imaginary lines of the cardiac axis and the anteroposterior axis of the chest were delineated. At the level of the atrioventricular valves, the cardiac diameter was measured from one outer edge to the other outer edge of the epicardium. The cardiac axis was parallel to this line. The thoracic diameter was then measured on the same image, perpendicular to the imaginary thoracic anteroposterior line, from one outer border to the other outer border of the ribs. The cardiac diameter was then divided by the thoracic diameter to automatically calculate the foetal CT diameter ratio.

Figure 1: Foetal thorax at the level of four-chamber view during end-diastole. The foetal CT diameter ratio was used to determine the foetal CT ratio (white dotted lines), using the 2-D cross-sectional images of the foetal chest.

Data analysis: Statistical Product and Service Solutions for Windows® version 25, SPSS Inc.; Chicago, USA, was used to enter and analyze the data after they had been collected using a proforma that had been pre-designed. After a normality (Shapiro-Wilk) test confirmed that the variables were normally distributed, the results were shown as frequencies and percentages for categorical variables and the mean and standard deviation for continuous variables. Pearson's correlation analysis was used to assess the relationship between the CT ratio, gestational age, and estimated foetal weight. After that, the correlation between the CT ratio and estimated foetal weight and CT ratio and gestational age was determined using logistic regression analysis. A nomogram was produced. Interobserver and intraobserver variations were calculated with the use of the intraclass correlation coefficient (ICC) and documented. The $p<0.05$ at 95%CI level of significance was set.

RESULTS

Baseline characteristics of study participants

The study involved 442 pregnant women, who had an average age of 29.1 ± 3.7 years. The modal (40.7%) age group was 30 – 34 years. Women aged 25 – 30 years constituted 36.0% of the sample population. The majority of the women were married (87.3%), had secondary education (72.9%) and were traders (60.4%). The mean weight, height and body mass index of the women were 67.2 ± 9.6 kg, 1.6 ± 0.1 m and 24.9 ± 3.2 kg/m^2, respectively (Table 1). Two hundred and eighty-five (64.5%) women had a normal body mass index, about a quarter (25.8%) were overweight, while slightly less than a tenth (9.7%) were obese. The average parity was 1, with a range between 0 and 5. Most (44.8%) women were primiparous women (Table 1).

Foetal characteristics

The mean gestational age was 27.2 ± 6.1 weeks. The mean bi-parietal diameter estimated foetal weight and cardiothoracic diameter ratio was 66.5 ± 18.3 mm, 1.24 ± 0.87 kg and 0.46 ± 0.02 cm respectively (Table 2).

Relationship between cardiothoracic ratio and maternal/foetal characteristics.

The foetal cardiothoracic ratio correlates very strongly with other foetal parameters like estimated gestational age (ɼ = 0.98; p – 0.001), bi-parietal diameter (ɼ = 0.96; p – 0.001) and estimated foetal weight (ɼ = 0.92; p – 0.001). Maternal features like maternal age (ɼ = 0.36; p – 0.001), maternal weight (ɼ = 0.19; p – 0.001) and maternal height (ɼ = 0.20; p – 0.001) also had a significant relationship with foetal cardiothoracic ratio (Table 3). Tables 4 and 5 show estimated centile reference intervals for cardiothoracic diameter ratio across the biparietal diameter and gestational age, respectively, while Table 6 reports the interobserver and intraobserver intraclass correlation coefficient results.

Table 1: Maternal characteristics

Characteristics	Frequency, n = 442	Percent (%)
Age group (years)		
20 – 24	56	12.7

25 – 30	159	36.0
30 – 34	180	40.7
35 – 39	47	10.6
Age (years) – Mean ± SD	29.1 ± 3.7	
Marital status		
Single	56	12.7
Married	386	87.3
Level of education		
Primary	13	2.9
Secondary	322	72.9
Tertiary	107	24.2
Occupation		
Professionals	13	2.9
Civil servant	67	15.2
Trader	267	60.4
Unemployed	95	21.5
Weight in kg – Mean ± SD	67.2 ± 9.6	
Height in metres – Mean ± SD	1.6 ± 0.1	
Body mass index – Mean ± SD	24.9 ± 3.2	
Weight		
Normal weight	285	64.5
Overweight	114	25.8
Obese	43	9.7
Parity		
Nulliparity	148	33.5
Primiparous	198	44.8
Multiparous	81	18.3
Grand-multiparous	15	3.4
Parity – Median (range)	1 (0 – 5)	

Table 2: Foetal characteristics

Characteristics	Mean ± SD
Gestational age	27.2 ± 6.1
Biparietal diameter	66.5 ± 18.3
Estimated foetal weight	1.24 ± 0.87
Cardiothoracic diameter ratio	0.46 ± 0.02

Table 3: Correlation between foetal cardiothoracic ratio and maternal/foetal characteristics

Characteristics	Correlation coefficient - ɼ (p-value)
Maternal features	
Maternal age	0.36 (0.001*)
Maternal weight	0.19 (0.001*)

Maternal height	0.20 (0.001*)
Body mass index	0.08 (0.080)
Foetal features	
Gestational age	0.98 (0.001*)
Biparietal diameter	0.96 (0.001*)
Estimated foetal weight	0.92 (0.001*)

Table 4: Estimated centile reference intervals for cardiothoracic diameter ratio across biparietal diameter in centimetres.

BPD	CT diameter ratio					BPD	CT diameter ratio				
(cm)	5th	10th	50th	90th	95th	(cm)	5th	10th	50th	90th	95th
4.1	0.42	0.43	0.47	0.51	0.52	6.7	0.45	0.46	0.50	0.54	0.55
4.2	0.42	0.43	0.47	0.51	0.52	6.8	0.45	0.46	0.50	0.54	0.55
4.3	0.42	0.43	0.47	0.51	0.52	6.9	0.46	0.47	0.50	0.54	0.55
4.4	0.42	0.43	0.47	0.51	0.52	7.0	0.46	0.47	0.51	0.55	0.56
4.5	0.42	0.43	0.47	0.51	0.52	7.1	0.46	0.47	0.51	0.55	0.56
4.6	0.43	0.44	0.47	0.51	0.52	7.2	0.46	0.47	0.51	0.55	0.56
4.7	0.43	0.44	0.47	0.51	0.52	7.3	0.46	0.47	0.51	0.55	0.56
4.8	0.43	0.44	0.48	0.52	0.53	7.4	0.46	0.47	0.51	0.55	0.56
4.9	0.43	0.44	0.48	0.52	0.53	7.5	0.47	0.48	0.51	0.55	0.56
5.0	0.43	0.44	0.48	0.52	0.53	7.6	0.47	0.48	0.51	0.55	0.56
5.1	0.43	0.44	0.48	0.52	0.53	7.7	0.47	0.48	0.51	0.55	0.56
5.2	0.43	0.44	0.48	0.52	0.53	7.8	0.47	0.48	0.52	0.56	0.57
5.3	0.44	0.45	0.48	0.52	0.53	7.9	0.47	0.48	0.52	0.56	0.57
5.4	0.44	0.45	0.49	0.53	0.54	8.0	0.47	0.48	0.52	0.56	0.57
5.5	0.44	0.45	0.49	0.53	0.54	8.1	0.47	0.48	0.52	0.56	0.57
5.6	0.44	0.45	0.49	0.53	0.54	8.2	0.48	0.49	0.53	0.57	0.58
5.7	0.44	0.45	0.49	0.53	0.54	8.3	0.48	0.49	0.53	0.57	0.58
5.8	0.44	0.45	0.49	0.53	0.54	8.4	0.48	0.49	0.53	0.57	0.58
5.9	0.44	0.45	0.49	0.53	0.54	8.5	0.48	0.49	0.53	0.57	0.58
6.0	0.44	0.45	0.49	0.53	0.54	8.6	0.49	0.50	0.53	0.57	0.58
6.1	0.44	0.45	0.49	0.53	0.54	8.7	0.49	0.50	0.54	0.58	0.59
6.2	0.45	0.46	0.49	0.53	0.54	8.8	0.49	0.50	0.54	0.58	0.59
6.3	0.45	0.46	0.50	0.54	0.55	8.9	0.49	0.50	0.54	0.58	0.59
6.4	0.45	0.46	0.50	0.54	0.55	9.0	0.49	0.50	0.54	0.58	0.59
6.5	0.45	0.46	0.50	0.54	0.55	9.1	0.50	0.51	0.54	0.58	0.59
6.6	0.45	0.46	0.50	0.54	0.55	9.2	0.50	0.51	0.55	0.59	0.60

CT – Cardiothoracic; BPD – Biparietal diameter; cm – centimeters.

Table 5: Estimated centile reference intervals for cardiothoracic diameter ratio across gestational age in weeks

Characteristics	Frequency (%)	5th	10th	50th	90th	95th
GA (weeks)						
17	17 (3.8)	0.42	0.43	0.47	0.51	0.52
18	37 (8.4)	0.42	0.43	0.47	0.51	0.52

19	24 (5.4)	0.43	0.44	0.47	0.51	0.52
20	16 (3.6)	0.44	0.45	0.48	0.52	0.53
21	13 (2.9)	0.44	0.45	0.49	0.53	0.54
22	13 (2.9)	0.45	0.46	0.49	0.53	0.54
23	13 (2.9)	0.45	0.46	0.50	0.54	0.55
24	16 (3.6)	0.45	0.46	0.50	0.54	0.55
25	13 (2.9)	0.46	0.47	0.50	0.54	0.55
26	17 (3.8)	0.46	0.47	0.51	0.55	0.56
27	55 (12.4)	0.46	0.47	0.51	0.55	0.56
28	13 (2.9)	0.47	0.48	0.51	0.55	0.56
29	17 (3.8)	0.47	0.48	0.51	0.55	0.56
30	16 (3.6)	0.47	0.48	0.51	0.55	0.56
31	38 (8.6)	0.48	0.49	0.53	0.57	0.58
32	26 (5.9)	0.48	0.49	0.53	0.57	0.58
33	17 (3.8)	0.48	0.49	0.53	0.57	0.58
34	17 (3.8)	0.49	0.50	0.54	0.58	0.59
35	17 (3.8)	0.49	0.50	0.54	0.58	0.59
36	17 (3.8)	0.50	0.51	0.54	0.58	0.59
37	30 (6.8)	0.50	0.51	0.55	0.59	0.60

GA – Gestational age

Table 6: Inter-observer and intra-observer intraclass correlation coefficient results

Ultrasound parameter	**Intraclass correlation coefficient**	
	Inter-observer	**Intra-observer**
Cardiothoracic diameter ratio	0.99 (95% CI 0.51–0.99)	0.99 (95% CI 0.55–0.99)

Table 7: Results of mean cardiothoracic diameter ratio compared among previous studies across the globe conducted in the second half of pregnancy and present study.

Author	**Location**	**Sample size**	**GA (weeks)**	**CT diameter ratio**
Garrett (1970)[19]	London, Europe	96	32 – 40	0.52 ± 0.05
Filkins (1981)[14]	USA, North America	30	16 – 36	0.50 ±0.028
Chaoui (1994) [5]	Germany, Europe	143	20 – 40	0.44 (20 weeks) 0.52 (40 weeks)
Sompagdee (2021)[17]	Thailand, Asia	511	17 – 37	0.48 ± 0.04
Present study	Nigeria, Africa	442	17 – 37	0.46 ± 0.02

DISCUSSION

This study sought to evaluate the relationship between foetal CT ratio with gestational age in the second half of pregnancy, and produce nomograms for foetal CT ratio in our locale. This study demonstrated that the CT diameter ratio increased slightly but steadily during the second and third trimesters. Our finding is consistent with what has been reported by earlier studies in other parts of the globe.[5,14,17,17,19] We report a mean CT diameter ratio of 0.46 ± 0.02 which is very similar to the 0.48 ± 0.04 in the study by

Sompagdee *et a*l.,[17] but was lower than the 0.50 to 0.52 reported by studies in the Europe[5,19] and North America[14], respectively. The variations may be attributable to differences in their relatively smaller sample sizes and techniques in measuring the CT diameter ratios which may not have revealed the significance of small changes in CT ratios.

The present study showed that the foetal CT ratio measurement technique had a very strong linear correlation with gestational age (0.98), biparietal diameter (0.96), and also the estimated foetal weight (0.92) with all p-values (<0.001). This was comparable with findings from other studies which was conducted in both earlier and later gestations.[8,14,17,19–21]

Despite the lack of similar studies in sub-Saharan Africa, this study has attempted to establish the nomogram of CT diameter ratios for each gestational week in the second half of pregnancy (17–37 weeks GA). Our data are highly reliable because gestational age was ascertained by careful history taking and confirmed by sonography. Furthermore, the same high-resolution device was used for all sonographic tests, and all measurements were carried out by radiologists with extensive experience. This is buttressed by the Inter-observer and intra-observer intraclass correlation coefficients for cardiothoracic diameter ratio of 0.99 (95% CI 0.51–0.99) and 0.99 (95% CI 0.55–0.99) respectively, showing nearly perfect agreement. A value above 0.8 indicates nearly perfect agreement, with the standard range being 0 to 1.[22,23]

Yet another important benefit of this normative data displaying the 5^{th} to 95^{th} percentiles for CT diameter ratios presented here is the fact that it would beyond aiding in foetal gestational age and weight assessment, be helpful in the early detection of foetal cardiomegaly, as has been previously documented in other climes.[1,8,21] The particular usage of the CT diameter ratio has also been corroborated by the studies to be most valuable in detecting cardiomegaly when the CT ratio is above the 95^{th} percentile.[4]

Despite all efforts to ensure perfect measurements, we cannot exclude some errors probably due to unfavourable foetal positioning, acoustic shadowing caused by foetal bony structures and maternal habitus at later gestations. Other multi-centered studies would also be needful in future to further validate the nomogram of pregnancies with foetal cardiac complications.

CONCLUSION

We have demonstrated that there does exist a very strong correlation between the foetal cardiothoracic ratio and the foetal gestational age, biparietal diameter and foetal weight. These parameters slightly but steadily increased throughout pregnancy. The estimated centile reference intervals for cardiothoracic diameter ratio across the biparietal diameter and estimated centile reference intervals for cardiothoracic diameter ratio across gestational age were developed for the reference population respectively. These nomograms are thus simple and practical screening tools to help identify foetus with abnormal cardiac sizes.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

REFERENCES

1. Paladini D, Chita SK, Allan LD. Prenatal measurement of cardiothoracic ratio in evaluation of heart disease. Arch Dis Child. 1990;65(1):20-23. doi:10.1136/adc.65.1_spec_no.20

2. Huhta JC. Guidelines for the evaluation of heart failure in the fetus with or without hydrops. Pediatr Cardiol. 2004;25(3):274-286. doi:10.1007/s00246-003-0591-3

3. Carvalho JS, O'Sullivan C, Shinebourne EA, Henein MY. Right and left ventricular long-axis function in the fetus using angular M-mode. Ultrasound Obstet Gynecol. 2001;18(6):619-622. doi:10.1046/j.0960-7692.2001.00587.x

4. DeVore GR, Tabsh K, Polanco B, Satou G, Sklansky M. Fetal Heart Size: A Comparison Between the Point-to-Point Trace and Automated Ellipse Methods Between 20- and 40-Weeks' Gestation. J Ultrasound Med. 2016;35(12):2543-2562. doi:10.7863/ultra.16.02019

5. Chaoui R, Bollmann R, Göldner B, Heling KS, Tennstedt C. Fetal cardiomegaly: echocardiographic findings and outcome in 19 cases. Fetal Diagn Ther. 1994;9(2):92-104. doi:10.1159/000263915

6. Donofrio MT, Moon-Grady AJ, Hornberger LK, Copel JA, Sklansky MS, Abuhamad A, et al. Diagnosis and treatment of fetal cardiac disease: a scientific statement from the American Heart Association. Circulation. 2014;129(21):2183-2242. doi:10.1161/01.cir.0000437597.44550.5d

7. American Institute of Ultrasound in Medicine. AIUM Practice Parameter for the Performance of Fetal Echocardiography. J Ultrasound Med. 2020;39(1):E5-E16. doi:10.1002/jum.15188

8. Sirilert S, Tongprasert F, Srisupundit K, Tongsong T, Luewan S. Z Score Reference Ranges of Fetal Cardiothoracic Diameter Ratio. J Ultrasound Med. 2019;38(4):999-1007. doi:10.1002/jum.14786

9. Chanthasenanont A, Somprasit C, Pongrojpaw D. Nomograms of the fetal heart between 16 and 39 weeks of gestation. J Med Assoc Thai. 2008;91(12):1774-1778.

10. Respondek M, Respondek A, Huhta JC, Wilczynski J. 2D echocardiographic assessment of the fetal heart size in the 2nd and 3rd trimester of uncomplicated pregnancy. Eur J Obstet Gynecol Reprod Biol. 1992;44(3):185-188. doi:10.1016/0028-2243(92)90096-h

11. Sylwestrzak O, Respondek-Liberska M. Echocardiographic metods of fetal heart size assessment-heart to chest area ratio and transversal heart diameter. Prenat Cardio. 2019;2018(1):20-23.

12. Gembruch U, Shi C, Smrcek JM. Biometry of the fetal heart between 10 and 17 weeks of gestation. Fetal Diagn Ther. 2000;15(1):20-31. doi:10.1159/000020970

13. Siddiqi TA, Meyer RA, Korfhagen J, Khoury JC, Rosenn B, Miodovnik M. A longitudinal study describing confidence limits of normal fetal cardiac, thoracic, and pulmonary dimensions from 20 to 40 weeks' gestation. J Ultrasound Med. 1993;12(12):731-736. doi:10.7863/jum.1993.12.12.731

14. Filkins KA, Brown TF, Levine OR. Real time ultrasonic evaluation of the fetal heart. Int J Gynaecol Obstet. 1981;19(1):35-39. doi:10.1016/0020-7292(81)90036-9

15. Bolarinwa OA. Sample size estimation for health and social science researchers: The principles and considerations for different study designs. Niger Postgrad Med J. 2020;27(2):67-75. doi:10.4103/npmj.npmj_19_20

16. LaMorte WW. Sample Size for One Sample, Continuous Outcome. Boston University School of Public Health. Accessed October 26, 2022. Available: https://sphweb.bumc.bu.edu/otlt/mph-modules/bs/bs704_power/BS704_Power3.html

17. Sompagdee N, Anuwutnavin S, Burapasikarin C, Ruangvutilert P, Thongkloung P. Nomograms of fetal cardiothoracic ratio from 17 to 37 weeks' gestation as assessed by three different measurement techniques and their correlation with gestational age. Prenat Diagn. 2021;41(13):1658-1667. doi:10.1002/pd.6057

18. Vanderwerff B, Winter T. Renal failure. In: Sanders R, Winter T, eds. Clinical Sonography: A Practical Guide. 4th ed. Lippincott, Williams & Wilkins; 2007:162-187.

19. Garrett WJ, Robinson DE. Fetal heart size measured in vivo by ultrasound. Pediatrics. 1970;46(1):25-27.

20. Bronshtein M, Siegler E, Eshcoli Z, Zimmer E. Transvaginal Ultrasound Measurements of the Fetal Heart at 11 to 17 Weeks of Gestation. Amer J Perinatol. 1992;9(01):38-42. doi:10.1055/s-2007-994667

21. Tongsong T, Tatiyapornkul T. Cardiothoracic Ratio in the First Half of Pregnancy. Journal of clinical ultrasound. 2004;32(4):186-189.

22. Costa-Santos C, Bernardes J, Ayres-de-Campos D, Costa A, Costa C. The limits of agreement and the intraclass correlation coefficient may be inconsistent in the interpretation of agreement. Journal of Clinical Epidemiology. 2011;64(3):264-269. doi:10.1016/j.jclinepi.2009.11.010

23. Fernandez S, Figueras F, Gomez O, Martinez JM, Eixarch E, Comas M, et al. Intra- and interobserver reliability of umbilical vein blood flow. Prenatal Diagnosis. 2008;28(11):999-1003. doi:10.1002/pd.2092