Journal of Biosciences and Medicines, 2025, 13(10), 181-195
https://www.scirp.org/journal/jbm
ISSN Online: 2327-509X
ISSN Print: 2327-5081

Ultrasonography of Fetal Transcerebellar Measurements for Prediction of Gestational Age in Normal Sudanese Pregnancies

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How to cite this paper: Mohammed, A.H.A., Babeiker, K.E.E., Ali, T.O., Mustafa, M.O. and Alhassen, M.M.F. (2025) Ultrasonography of Fetal Transcerebellar Measurements for Prediction of Gestational Age in Normal Sudanese Pregnancies. *Journal of Biosciences and Medicines*, **13**, 181-195.
https://doi.org/10.4236/jbm.2025.1310016

Received: September 6, 2025
Accepted: October 17, 2025
Published: October 20, 2025

Abstract

Background: Prediction of gestational age (GA) based on sonographic fetal parameters is perhaps the cornerstone of modern obstetrics and continues to be an important component in the management of pregnancies with fetuses with growth disturbances. Trans cerebellar diameter is one of the parameters that can be used to estimate gestational age. **Objectives:** The study's objectives were to compare the accuracy of cerebellar measurement (transverse and median longitudinal (MLM) in determining GA between the 14th and 40th weeks to that of other fetal biometric parameters. **Material and Methods:** This was a prospective cross-sectional study conducted in Khartoum, Sudan, from August 2015 to January 2016. 385 healthy pregnant women with normal fetal ages ranging from 15 to 45 years were examined by ultrasound. The transcerebellar diameter (TCD), biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC), and femur length (FL) were measured using ultrasound to determine GA, and the data were collected and analyzed. **Results:** In normal pregnancy, TCD increases with advancing age, with a linear relationship between TCD and gestational age. The present study showed that the mean ± SD GA was (26.5 ± 6.8) weeks, and the mean ± SD TCD was 28.05 ± 7.6. Also, the correlation between the TCD and fetal age was 0.720, as well as between the TCD and other parameters (BPD, MLM, and HC), which were 0.819, 0792, and 0.763, respectively. **Conclusion:** According to the findings of this study, TCD and MLM are simple to identify and measure; they are the most accurate single parameters for estimating GA compared to other biometric indices, and they can be easily incorporated into models for estimating

GA. These charts will also assist radiologists and clinicians in predicting delivery dates, assessing fetal growth, and identifying intrauterine fetal insufficiency in the Sudanese population.

Keywords

Age Estimation, Cerebellar Measurement, Ultrasound, Radiograph, Sudan

1. Introduction

Gestational age (GA), according to the last menstrual period (LMP), is defined as the weeks beginning from the first day of LMP before conception. [1] The accurate knowledge of GA is a keystone in an obstetrician's ability to successfully manage the antepartum care of a patient and is of critical importance in antenatal tests and the successful planning of appropriate therapy or intervention. Failure can result in iatrogenic prematurity, which is associated with increased prenatal morbidity and mortality. [2] [3]

Accurate determination of GA is an important and potentially life-saving step in providing optimal medical care to pregnant women in the emergency department. Critical management decisions, such as the use of cesarean section, can be made confidently only when fetal viability can be assessed reliably. Traditionally, estimations of GA are based on the patient's recollection of her LMP; however, previous research suggests that this may be inaccurate. [4]

Ultrasonography of fetal measurements is highly reliable in the first and second trimester of pregnancy, but the reliability of any ultrasound method greatly diminishes as gestation advances. [5] In the third trimester, the reliability of any single ultrasound parameter is poor. [6]

Ultrasound (US) assessment for GA is becoming increasingly important. Many parameters can be used for establishing GA, for example, biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC), and femur length (FL). Recently, the evaluation of the posterior fossa of the fetal cranium has been accepted as part of routine obstetrical estimations; previously, the BPD had been described as a reliable method of determining GA. [7] [8] While the BPD was the first fetal parameter to be clinically utilized in the determination of fetal age in the second trimester, more recent studies have evaluated the use of several other biometric parameters, including HC, AC, FL, foot length, ear size, orbital diameters, cerebellum diameter, and others. [9]-[12] The fetal cerebellum grows progressively along with gestational age; therefore, ultrasonography examination can predict gestational age at any trimester. Parameters such as BPD are thought to compute gestational age more correctly when performed at an earlier gestation. [13] The transverse cerebellar diameter (TCD) provides a dependable measure for estimating gestational age in pregnancies affected by intrauterine growth restriction, showing close agreement with early dating ultrasound. This underscores its utility

as an alternative assessment tool when early dating scans are either unavailable or unreliable. [14] This study establishes transverse cerebellar diameter (TCD) as the most reliable biometric parameter for estimating gestational age (GA) in the second and third trimesters. Unlike other measures, TCD remains accurate even when the last menstrual period is unknown, no first-trimester scan is available, the assessment begins late, or fetal head shape is altered. [15] In late pregnancy, the fetal transcerebellar diameter (TCD) has been demonstrated to be a reliable biometric parameter, exhibiting a strong correlation with gestational age estimated from the last menstrual period. [16]

2. Materials and Methods

The study has been designed as a prospective cross-sectional (observational) study in Khartoum State, Sudan. The fetal cerebellum of 384 pregnant women was examined at various stages of pregnancy at Al Saudi Maternity Teaching Hospital, Al Rasheed Medical Center, and The National Ribat University Hospital. The study population consisted of 384 pregnant Sudanese women, ranging in gestational age from 5 to 40 weeks. And referred to an obstetric clinic. Aged between 15 and 45 years, all women who satisfied the inclusion criteria stated in this study had a regular menstrual cycle, certainty about the time of their last menstrual period, a normal pregnancy, and a viable singleton included in the study population. On the other hand, the study excluded those unsure of an accurate memory of the last menstrual period, fetal congenital abnormalities, failure to visualize/ measure the fetal cerebellum, pregnancy-induced hypertension, diabetes mellitus, cardiac diseases, thyroid disease, repeated cesarean section, intrauterine fetal death, chronic renal disease, and renal failure. The study population, representing different Sudanese tribes, was limited to the state of Khartoum. Trans cerebellar diameter was measured by identifying the cerebellum in the posterior fossa and measuring it from the outer to the outer extent. The thalamic plane used for the biparietal diameter was then obtained. The abdominal circumference was obtained from a transaxial view at the level of the junction of the umbilical vein and left portal vein. The main outcome measures noted were trans cerebellar diameter, other parameters noted were biparietal diameter, femur length, abdominal circumference, and head circumference.

2.1. Techniques and Equipment

All ultra-sonographic examinations of the present study were performed with a Toshiba (ECC CEE, SSA-340A) ultrasound machine with a 3.5 MHz convex transducer. Electronic calipers were used, and all measurements were obtained in millimeters; each fetus was included only once. The cerebellum was identified in the posterior fossa and measured in an outer-to-outer fashion. Patients were examined in the supine position. Multiple cross-sections of the uterus were made in longitudinal and transverse planes. In the course of ultrasonography, the fetal position and BPD are determined, and the cerebellum is localized (**Figure 1**).

Figure 1. Ultrasonographic machine (country/region: Japan).

2.2. Measurements of the Cerebellum

The cerebellum is located in the posterior cranial fossa and is visualized by a slight posterior and inferior rotation of the transducer at the level of the BPD. The measurement of TCD was obtained by placing the electronic calipers at the outer margins of the cerebellum. The landmarks of the thalami, cavum, septum pellucidum, and third ventricle were identified, thereby slightly rotating the transducer below the thalamic plane. The posterior fossa is revealed with the characteristic butterfly-like appearance of the cerebellum (Figure 2).

Figure 2. US image of fetal skull showing TCD & MLM of cerebellum.

Gestational Age Determination:

The GA was estimated by using the CRL, BPD, and HC from the tenth to the thirteenth week, BPD and HC from the thirteenth week to the twenty-fourth week, and BPD, FL, and AC from the 24th to the 40th week.

2.3. Data Collection

The specific sheet was designed to record biometric parameters and TCD during different antenatal care visits. It also included maternal age, anthropometric measurements, the state of origin, and the ethnic group.

2.4. Statistical Analysis and Computation

Data was analyzed using built-in procedures within the Statistical Package for Social Sciences (SPSS) version 20. Descriptive statistics were used to establish the nomogram for the measurements of the cerebellum. Values were expressed as mean ± standard deviation. Correlation and regression analysis were used to establish the relationship between measurements of the cerebellum and GA

3. Results

Reliability statistics have been made by using Cronbach's Alpha, for all (Fetal age per week depending on LNMP, TCD, and median longitudinal measurement), which was 0.879 and validity 0.938, for individual parameters, GA reliability 0.846 and validity 0.920, TCD reliability 0.802 and validity 0.896, and median longitudinal measurement reliability 0.834 and validity 0.913.

The mean fetal age, depending on LNMP per week, was 26.48 ± 6.824, and ranged between 13 and 41, as shown in Table 1. As well as the mean of TCD was (28.047 ± 7.6244), and ranged between (7.0 - 56.6) mm. Also, the mean of MLM was (16.870 ± 5.1149) and ranged between (2.6 - 33.0) mm. The mean FL was (63.369 ± 8.4450) and ranged between (18.0 - 82.0) mm. At the same time, the mean fetal BPD was (68.369 ± 17.3129) and ranged between 21.0 mm and 95.9 mm. The mean fetal head HC was 191.036 (±37.8012) and ranged between 91.0 mm and 262.0 mm. The mean fetal AC was 283.992 (±39.9485) and ranged between 116.0 mm and 364.2 mm, as shown in Table 1.

Table 1. Descriptive statistics of fetal biometric parameters.

Biometric Parameters	N	Minimum	Maximum	Mean	SD
LMP (weeks)	385	13	41	26.48	6.824
TCD (mm)	385	7.0	56.6	28.047	7.6244
MLM (mm)	385	2.6	33.0	16.870	5.1149
Fetal FL (mm)	219	18.0	82.0	63.914	8.4450
Fetal BPD (mm)	383	21.0	95.9	68.369	17.3129
Fetal HC (mm)	167	91.0	262.0	191.036	37.8012
Fetal AC (mm)	218	116.0	364.2	283.992	39.9485

This study showed that the predictor TCD has a linear correlation with FA depending on LMP (R = 0.720), R Square = 0.518. Adjusted R Square = 0.517 and

Standard error of the Estimate = 4.744, respectively. These results were obtained from ANOVA and correlation coefficients, as shown in Table 2, Table 3, and Figure 3.

Table 2. Analysis of variance (ANOVA) between TCD and FA depending on LMP.

Model	Sum of Squares	DF	Mean Square	F	Sig.
Regression	9261.929	1	9261.929	411.609	0.000
Residual	8618.175	383	22.502		
Total	17,880.104	384			

Table 3. Correlation coefficients between TCD and FA depending on LMP.

Model	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std. Error	Beta		
(Constant)	8.414	0.923		9.119	0.000
TCD	0.644	0.032	0.720	20.288	0.000

The GA, depending on the LMP period, could be obtained from the following equation by using TCD:

$$Y = 8.414 + 0.644 \times X$$

where Y = fetal age, X = transcerebellar diameter.

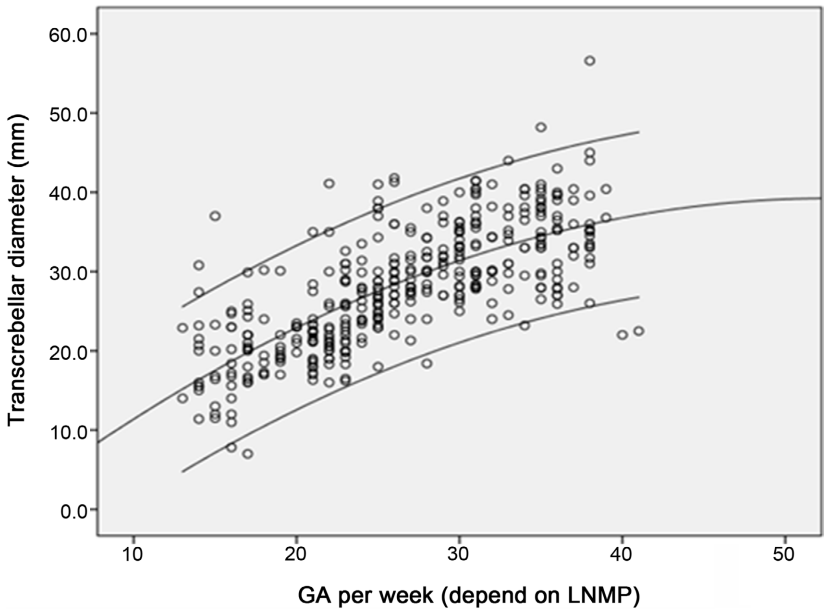

Figure 3. Scatter graph of gestational age with TCD.

The study showed that the predictor (TCD) has a linear correlation with FA, which, depending on LMP, R = 0.429, R Square = 0.184, Adjusted R Square = 0.180, and Standard error of the Estimate = 7.6463, respectively. These results were ob-

tained from ANOVA and correlation coefficients, as shown in Table 4, Table 5, and Figure 4.

Table 4. Analysis of variance (ANOVA) between TCD and fetal FL.

Model	Sum of Squares	DF	Mean Square	F	Sig.
Regression	2860.254	1	2860.254	48.922	0.000
Residual	12,687.045	217	58.466		
Total	15,547.299	218			

Table 5. Correlation coefficients between TCD and fetal FL.

Model	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std. Error	Beta		
(Constant)	42.198	3.147		13.407	0.000
TCD	0.659	0.094	0.429	6.994	0.000

The fetal ages, depending on the LMP, could be obtained from the following equation by using TCD:

$$Y = 42.198 + 0.659 \times X$$

where Y = fetal age, X = transcerebellar diameter.

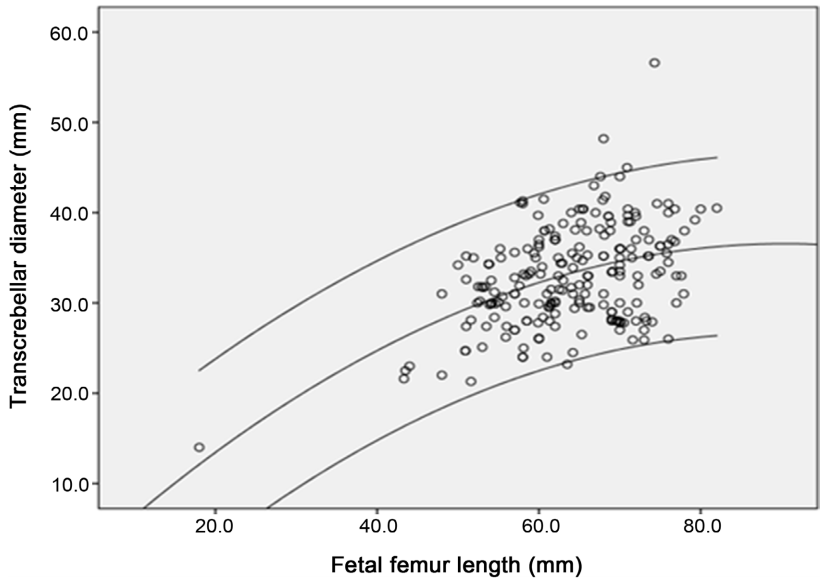

Figure 4. Scatter graph of fetal FL with TCD.

The study showed that the predictor TCD has a linear correlation with FA depending on LMP and fetal BPD: R = 0.819, R Square = 0.671, Adjusted R Square = 0.670, and Standard error of the Estimate = 9.9475, respectively. These results were obtained from ANOVA and correlation coefficients, as shown in Table 6, Table 7, and Figure 5.

Table 6. Analysis of variance (ANOVA) between TCD and fetal BPD.

Model	Sum of Squares	DF	Mean Square	F	Sig.
Regression	76,798.341	1	76,798.341	776.106	0.000
Residual	37,701.236	381	98.953		
Total	114,499.576	382			

Table 7. Correlation coefficients between TCD and fetal BPD.

Model	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std. Error	Beta		
(Constant)	15.959	1.949		8.189	0.000
TCD	1.865	0.067	0.819	27.859	0.000

The FA, depending on the LMP, could be obtained from the following equation:

$$Y = 15.959 + 1.865 \times X$$

where Y = fetal age, X = TCD.

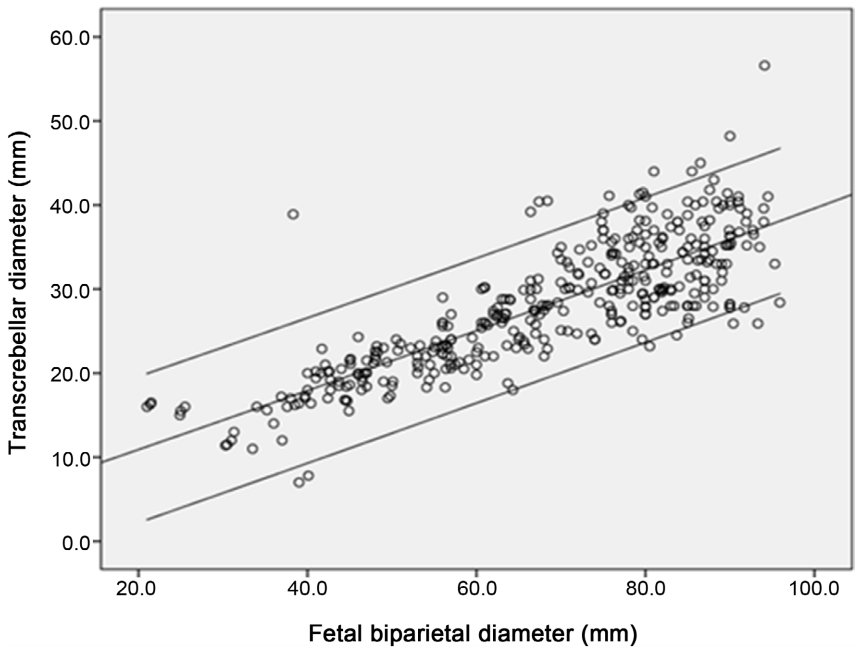

Figure 5. Scatter graph of fetal BPD with TCD.

The study showed that the predictor (TCD) has a linear correlation with FA depending on LMP and fetal HC: R = 0.763, R Square = 0.583, Adjusted R Square = 0.580, and Standard error of the Estimate = 24.4889. These results were obtained from ANOVA and correlation coefficients, as shown in **Table 8**, **Table 9**, and **Figure 6**.

The FA, depending on the LMP with HC, could be obtained from the following equation formula:

$$Y = 55.744 + 6.289 \times X$$

where Y = fetal age, X = TCD.

Table 8. Analysis of variance (ANOVA) between TCD and fetal HC.

Model	Sum of Squares	DF	Mean Square	F	Sig.
Regression	138,251.094	1	138,251.094	230.531	0.000
Residual	98,951.510	165	599.706		
Total	237,202.604	166			

Table 9. Correlation coefficients between TCD and fetal HC.

Model	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std. Error	Beta		
(Constant)	55.744	9.110		6.119	0.000
TCD	6.289	0.414	0.763	15.183	0.000

The FA, depending on the LMP, could be obtained from the following equation:

$$Y = 15.959 + 1.865 \times X$$

where Y = fetal age, X = TCD.

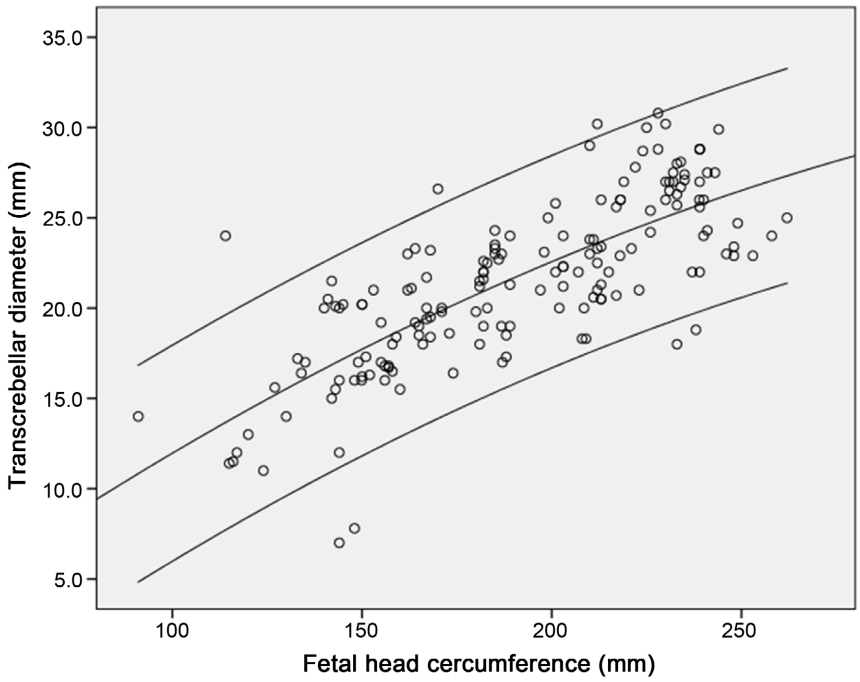

Figure 6. Scatter graph of fetal HC with TCD.

The study showed that the predictor (TCD) has a linear correlation with fetal

age depending on LMP and fetal AC: R = 0.336, R Square = 0.113, Adjusted R Square = 0.109, and Standard error of the Estimate = 37.7107, respectively. These results were obtained from ANOVA and correlation coefficients, as shown in Table 10, Table 11, and Figure 7.

Table 10. Analysis of variance (ANOVA) between TCD and fetal AC.

Model	Sum of Squares	DF	Mean Square	F	Sig.
Regression	39,133.550	1	39,133.550	27.518	0.000
Residual	307,172.887	216	1422.097		
Total	346,306.437	217			

Table 11. Correlation coefficients between TCD and fetal HC.

Model	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std. Error	Beta		
(Constant)	201.154	15.997		12.575	0.000
TCD	2.506	0.478	0.336	5.246	0.000

The FA, depending on the LMP with AC, could be obtained from the following equation:

$$Y = 201.154 + 2.506 \times X$$

where Y = fetal age, X = TCD.

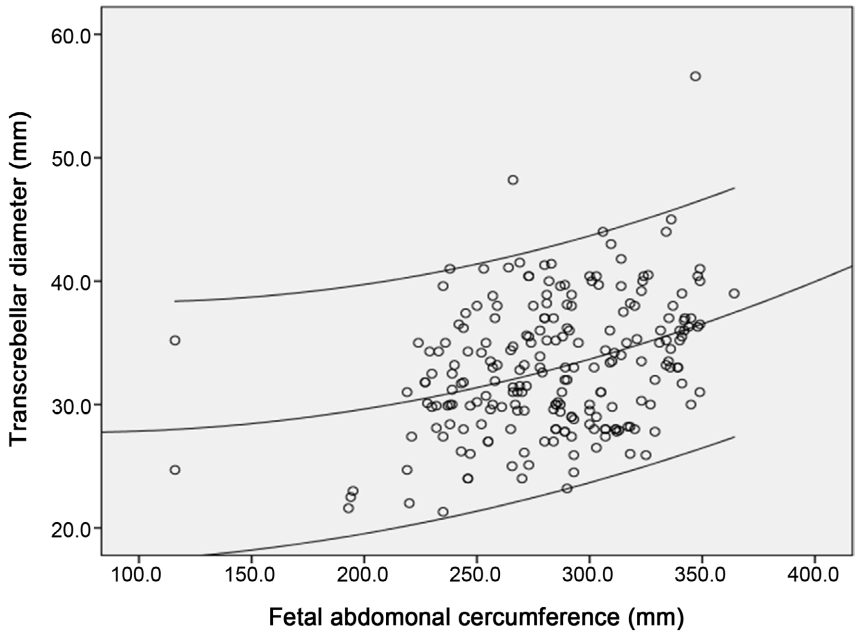

Figure 7. Scatter graph of fetal AC with TCD.

The study showed that the predictor (TCD) has a linear correlation with FA depending on LMP and MLM: R = 0.792, R Square = 0.628, Adjusted R Square = 0.627, and Standard error of the Estimate = 3.1238. These results were obtained from ANOVA and correlation coefficients, as shown in Table 12, Table 13, and Figure 8.

Table 12. Analysis of variance (ANOVA) between TCD and MLM.

Model	Sum of Squares	DF	Mean Square	F	Sig.
Regression	6308.842	1	6308.842	646.535	0.000
Residual	3737.285	383	9.758		
Total	10,046.126	384			

Table 13. Correlation coefficients between TCD and fetal HC.

Model	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std. Error	Beta		
(Constant)	1.960	0.608		3.225	0.001
TCD	0.532	0.021	0.792	25.427	0.000

The FA, depending on the LMP, could be obtained from the following equation by using TCD:

$$Y = 1.960 + 0.532 \times X$$

where Y = fetal age, X = transcerebellar diameter.

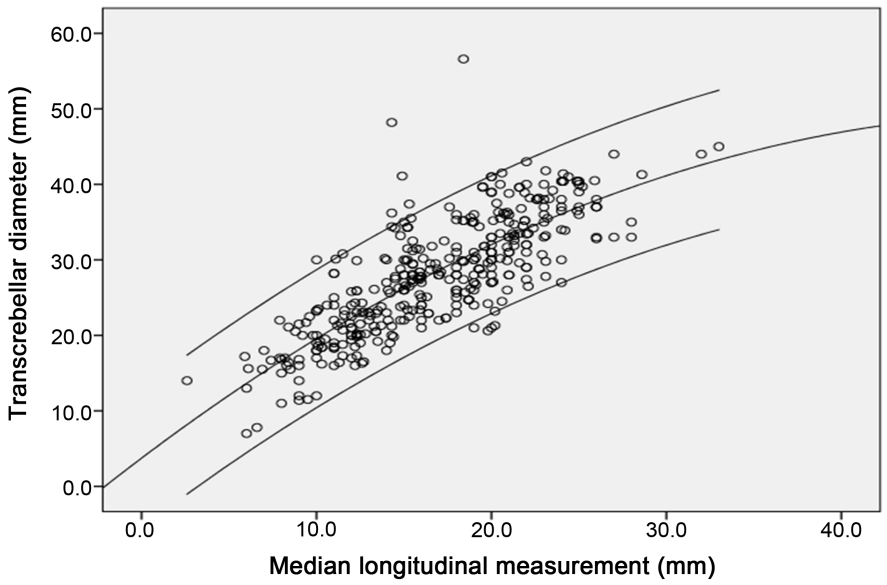

Figure 8. Scatter graph of fetal MLM with TCD.

4. Discussion

The present findings showed that the mean ± SD of the GA was (26.5 ± 6.8) weeks, similar to measurements obtained by Mahmoud *et al*., [17] who reported in their study that the mean ± SD of the GA was (26.8 ± 6.8) weeks. The present study showed the mean ± SD of the TCD was 28.05 ± 7.62; this disagrees with the result obtained by [18], who reported in their study that the mean TCD was 16.7 mm at 14 - 20 weeks, 23.2 mm at 21 - 27 weeks, and 30.6 mm at 28 - 34 weeks. In spite of the strong correlation between the TCD and GA as compared to the previous studies, the correlation coefficient (r = 0.720) in the present study was less as compared to [17] (r = 0.94), [19] (r = 0.972), [20] (r = 0.971), [18] (r = 0.946), [21] (r = 0.991), and [22] (r = 098). Several reasons could explain these differences. These include the type of study (longitudinal vs. cross-sectional), quality of the US machine (new vs. old), and characteristics of subjects (only uncomplicated pregnancies vs. all pregnancies).

Furthermore, there was a strong positive correlation in this study between the TCD and the other parameters, such as BPD (r = 0.819 and P = 0.000), MLM (r = 0.792 and P = 0.000), and HC (r = 0.763 and P = 0.000). However, the correlation was not that strong between TCD and FL (r = 0.429 and P =0.000) and AC (r = 0.336 and P = 0.000). The finding of the present study was lower than that of [20], who studied 301 pregnant women, and found the correlation of TCD with BPD was (r = 0.960), with HC (r = 0.979), with AC (r = 0.980), and with FL (r = 0.976).

Regarding the MLM of the cerebellum, [23] studied 10605 fetuses with GA ranging between 20 - 35 weeks, and they reported that the mean ± SD of the cerebellar vermis was 12.7 ± 1.6. Furthermore, the vermis longitudinal diameter showed a linear correlation with GA (r = 0.87). Our study observed less than the measurements obtained by [24], who studied 293 healthy fetuses between 19 and 34 weeks. They also reported a linear correlation with GA (r = 0.95; P = 0.001). In addition, [25] studied 328 normal singleton pregnancies between 18 and 33 weeks of gestation (r = 0.887, p = 0.0001). [26] A retrospective study examined 516 fetuses with a normal posterior cranial fossa, between 21 and 35 weeks of gestation, by using three different imaging modalities to measure vermis biometry: 2D ultrasound, 3D ultrasound, and MRI. The number of fetuses in the study group was 193 for 2D ultrasound, the mean was 19.28 mm (r = 0.839), 172 for 3D ultrasound, with the mean was 17.80 mm (r = 0.806), and 151 for MR imaging, the mean was 21.34 mm (r = 0.565), and (P = 0.001) for the three groups. Furthermore, measurements of the cerebellar vermis correlated linearly with BPD, HC, and TCD (r = 0.82, P = 0.0001) as reported by [27].

5. Conclusions and Recommendations

5.1. Conclusions

The estimation of GA using TCD is reliable because the cerebellar measurement correlates well with GA in normal pregnancies, with an accurate and significant value (r = 0.720; P = 0.000). The fetus's TCD and MLM in normal pregnancies

were correlated with FA depending on LMP, fetal BPD, FL, AC, and HC between 14 and 40 weeks' gestation. This study discovered a linear relationship between GA and TCD with MLM (r = 0.749, P = 0.000). Additionally, the linear relationship between TCD and BPD is highly significant (r = 0.819, r = 0.671, and P = 0.000).

So, in the second and third trimesters, cerebellar measurement is a reliable method of determining GA. In the final two trimesters of pregnancy, the US measurement of the fetal TCD could be a predictive biometric parameter of GA. The current findings provided the normal range of cerebellar measurements throughout gestation. These values may allow for intrauterine evaluation of cerebellar and posterior cranial fossa development.

5.2. Recommendations

- The measurements of the cerebellum by TCD and MLM, should be one of the routine and new parameters for the determination of GA.
- Although the correlation between TCD and BPD is highly significant, it is important to recommend using a combination of parameters to detect gestational age.
- Further studies about the correlation between the TCD with FL and the TCD with AC are needed to establish the age estimation.
- More studies about the role of the ethnic group in the estimation of GA are needed when using the measurement of the cerebellum, to detect the variations of the fetal TCD in different ethnic groups.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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