Original Article

Fetal Gestational Age Estimation Using Ultrasonic Transverse Cerebellar Diameter in a Sub-Saharan African Population

Akeem Olajide Adelabu[1], Temitope Olugbenga Bello[1], Bukunmi Michael Idowu[2]*, Victor Olufemi Oyedepo[1]

[1]Department of Radiology, College of Health Sciences, Ladoke Akintola University of Technology, Ogbomoso, Oyo, Nigeria, [2]Department of Radiology, Union Diagnostics and Clinical Services Plc, Lagos, Nigeria

Abstract

Background: To explore the relationship between fetal Transverse Cerebellar Diameter (TCD) and menstrual gestational age (GA) and to generate normative references (nomogram) of the fetal TCD in some pregnant women in Southwest Nigeria. **Methods:** Four hundred pregnant women with a singleton fetus between 14 and 38 weeks GA were enrolled. The TCD and other biometric parameters (biparietal diameter, head circumference, abdominal circumference, and femur length) as well as the cerebellar appearance were analyzed and correlated with the GA. **Results:** The mean TCD increased from 13.3 ± 0.3 mm at 14 weeks to 52.3 ± 3.3 mm at 38 weeks of pregnancy. A strong positive correlation was observed between TCD and GA, which was best represented by a linear regression equation: Predicted GA = 0.557 × TCD + 8.840. The regression analysis indicated a statistically significant strong positive relationship between TCD and GA (r = 0.972 and P < 0.001). The cerebellar appearance based on shape and echogenicity was graded into Grade I: 230 fetuses (57.5%); Grade II: 74 fetuses (18.5%) and Grade III: 96 fetuses (24.0%). Median GA and TCD were 21 weeks and 21.2 mm for Grade I; 29 weeks and 35.5 mm for Grade II; and 35 weeks and 48.1 mm for Grade III, respectively. **Conclusion:** The TCD increased in a linear fashion with advancing GA in the evaluated fetuses. The TCD is, therefore, a good marker for GA estimation. There is a gradual ultrasonographic change in fetal cerebellar appearance with advancing gestation.

Keywords: Fetal biometry, gestational age, pregnancy, transverse cerebellar diameter, ultrasonography

Introduction

An accurate knowledge of the fetal gestational age (GA) is crucial to the antenatal care of pregnant women. Erroneous GA estimation can result in iatrogenic prematurity which is associated with increased perinatal morbidity and mortality.[1] Furthermore, reliable dating of pregnancy is also a prerequisite for the prenatal diagnosis of fetal anomalies because the correct interpretation of some structural abnormalities seen on ultrasonography depends on accurate dating of pregnancy.[2,3]

Ultrasonographic fetal biometry is now the mainstay of estimating GA and monitoring fetal growth and development. Many fetal parameters can be measured with ultrasonography and have been correlated with GA.[4,5] Among the various clinical criteria, the last menstrual period (LMP) preceded by a normal cycle is known to correlate best with the GA. However, it is not reliable when a woman is unsure of her LMP. Similarly, sonographic biometric parameters such as biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC), and femur length (FL) have their limitations. For instance, FL is unreliable in cases of femur achondroplasia. The BPD is also unreliable in conditions that alter the shape of the skull such as in breech presentation and oligohydramnios. Due to mild skull deformation, breech babies were shown to have smaller mean BPD neonatally compared with that of a matched group of vertex babies.[6] Moreover, these parameters cannot provide accurate dating of GA in late pregnancy due to the increasing biologic variability with advancing GA.[4] They are highly reliable in the first and second trimesters of pregnancy but their reliability diminishes greatly

Address for correspondence: Dr. Bukunmi Michael Idowu, Department of Radiology, Union Diagnostics and Clinical Services Plc, Yaba, Lagos, Nigeria.
E-mail: ibmcontacts@gmail.com

Received: 02-12-2022 **Revised:** 08-03-2023 **Accepted:** 21-03-2023 **Available Online:** 02-06-2023

Access this article online

Quick Response Code:

Website: https://journals.lww.com/jmut

DOI: 10.4103/jmu.jmu_116_22

How to cite this article: Adelabu AO, Bello TO, Idowu BM, Oyedepo VO. Fetal gestational age estimation using ultrasonic transverse cerebellar diameter in a Sub-Saharan African population. J Med Ultrasound 2024;32:41-7.

as gestation advances. In the third trimester, the reliability of any single ultrasound parameter is poor.[1]

The cerebellum is a suprasegmental portion of the brain located within the posterior cranial fossa. The cerebellum can be sonographically visualized as early as 9–10 weeks. From the second trimester, it grows rapidly in a linear relationship with GA. The sonographic appearance of the cerebellum can be categorized into three grades based on shape and echogenicity.[7] In grade I, the cerebellar hemisphere is rounded and lacks echogenicity, the vermis is poorly developed giving the cerebellum the appearance of an "eyeglass." This appearance is seen predominantly up to 27 weeks of gestation [Figure 1]. In grade II, the vermis is more prominent and appears as an echogenic rectangular tissue connecting both hemispheres. The cerebellar hemisphere is oval and the central portion is more echogenic than the peduncles but less echogenic than the circumferential margin of the hemisphere. The cerebellum has a "dumbbell" appearance-this is seen predominantly from 28 to 32 weeks of gestation [Figure 2]. In grade III, the cerebellar hemispheres become triangular or "fan-shaped," the echo pattern from the central portion of the hemisphere is now similar to the margin of the vermis, and the cerebellum now looks more solid than cystic. This appearance is seen predominantly after 32–33 weeks of gestation [Figure 3].

Since the cerebellum is located inside the posterior fossa and is surrounded by the dense petrous ridges and the occipital bone, it withstands deformation by extrinsic pressure better than the parietal lobe. The Transverse Cerebellar Diameter (TCD) can better predict GA in cases in which there are variations of the fetal head shape such as dolichocephaly and brachycephaly or even when the fetus is in a direct occipito-posterior position.[8]

Several studies have shown the TCD to be a good predictor of GA when compared to other clinical and fetal biometric parameters.[9] The TCD/AC ratio is independent of GA and may be useful in assessing fetal growth in pregnancies of mothers with unknown LMP.[10,11] Transverse cerebellar diameter is now considered a reliable predictor of GA in the third trimester.[12,13]

The measurement of TCD can be done on most fetuses, irrespective of the fetal head shape. The TCD varies with ethnicity.[14] There are numerous publications on sonographic fetal TCD and cerebellar appearance for Caucasians and other population groups. In contrast, local fetal TCD data are still limited.[7,15-19]

The aim of this study was to investigate the relationship between fetal TCD and menstrual GA and to generate normative references to the fetal TCD in the local population.

Materials and Methods

This was a descriptive cross-sectional study carried out at the Department of Radiology, Ladoke Akintola University of Technology Teaching Hospital Osogbo, Osun state, Nigeria.

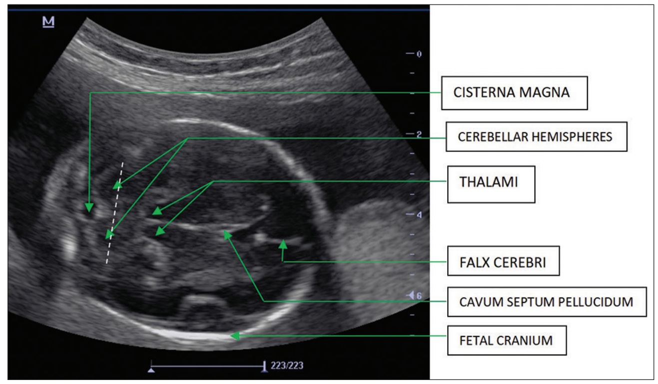

Figure 1: B-Mode transaxial sonographic appearance of Grade Ib cerebellum at 22 weeks GA showing rounded cerebellar hemispheres with poorly developed vermis giving the "eye-glass" appearance. GA: Gestational age

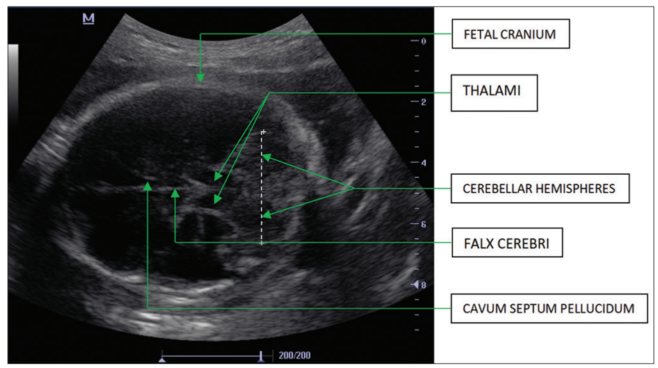

Figure 2: B-Mode transaxial sonographic appearance of Grade IIb cerebellum at 30 weeks GA showing an echogenic vermis connecting oval-shaped cerebellar hemispheres giving the "dumbbell" appearance. GA: Gestational age

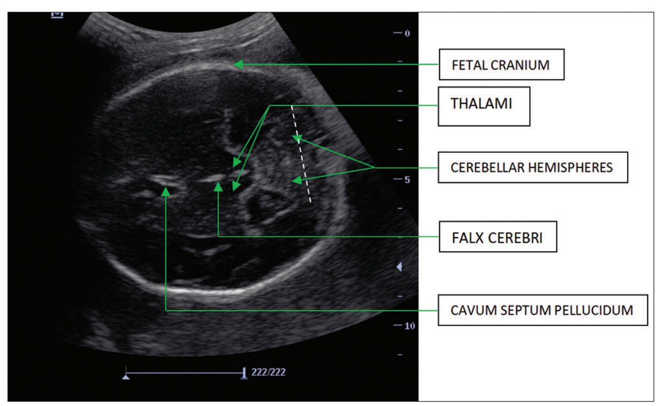

Figure 3: B-Mode transaxial sonographic appearance of Grade IIIb cerebellum at 35 weeks GA showing triangular or fan-shaped cerebellar hemispheres with the cerebellum now looking more solid than cystic. GA: Gestational age

The Ethical Review Committee of the hospital approved the study (LTH/EC/2015/11/240).

Four hundred pregnant women were enrolled consecutively after a written consent had been obtained. The inclusion criteria were normal singleton pregnancies at 14–38 weeks' gestation and being sure of the LMP. The fetal GA was calculated from the last normal LMP and validated with an early (<10 weeks) first-trimester ultrasound scan. Due to the cross-sectional study design, at least fifteen fetuses (15 different observations) were scanned for each week of pregnancy.[20-22] Each participant was scanned only once.[23] Pregnant women with abnormal amniotic fluid index, uncertain LMP, multiple pregnancies, chronic maternal illness (hypertension, diabetes mellitus, sickle cell disease, or renal disease), congenital fetal anomalies, and labor onset were excluded from the study.

The participants' demographic and relevant clinical information were collecting using a semi-structured interviewer-administered questionnaire. The participants' LMP, age, parity, and medical history were recorded. The parity was defined as the number of times the patient had given birth to a fetus after attaining the age of viability, whether the child was born alive or stillborn.

The subjects' weight (kg), height (m), body mass index (BMI; kg/m²), pulse rate, blood pressure (mmHg), and fasting plasma glucose were also determined using established standard methods. Overweight was defined as a BMI ≥25.0 kg/m^2 while obesity was defined as a BMI ≥30.0 kg/m^2. The normal pulse rate was taken as 60–100 beats per min. Diabetes mellitus was defined as a fasting blood glucose value >7.0 mmol/L (126 mg/dL) or subjects on medication for raised blood glucose. Hypertension was defined as blood pressure ≥140/90 mmHg or subjects on antihypertensive.

The eligible women were scanned in the supine position using MINDRAY D-6 ultrasound machine with the 3.5–5 MHz transducer. The transverse cerebellar diameter (TCD) and the other biometric parameters (BPD, HC, AC, and FL) were calculated electronically by the scanner based on previously published formulae.[22,24,25] After obtaining the thalamic plane used for BPD and HC, the transducer was then rotated about 30° below the thalamic plane to image the characteristic shape of the cerebellum. The transverse cerebellar diameter was measured in an "outer-to-outer" fashion [Figures 1-3]. Three measurements were taken on each parameter and the average was determined to minimize intra-observer error. All measurements were done by the first author.

The parenchyma of the fetal cerebellum was also evaluated and its appearance was classified into Grades I, II, or III. Grade I (a)–each cerebellar hemisphere is round, (b) the vermis is not welldeveloped and the cerebellum appears as "a pair of eyeglasses" at ultrasound, (c) the hemispheres are relatively anechoic and appears as two fluidcontaining cysts. Grade II: (a) The vermis is more prominent and appears as an echogenic rectangular tissue connecting the two hemispheres, giving the "dumbbell" appearance (b) Each hemisphere is oval, and the central portion is more echogenic than other background structures. Grade III (a) the cerebellum appears triangular or "fanshaped" (b) tissues in the central portion of the hemispheres show similar echogenicity to the margins and vermis, thus, the cerebellar appears more like a solid tissue than a cyst. The grading is a reflection of the cerebellum's ongoing increasing histological maturation and the differentiation of its Purkinje cells.[7,26]

The variables were analyzed using the Statistical Package for the Social Sciences (SPSS) version 17 for Windows (SPSS Inc., Chicago, Ill., USA). Descriptive statistics included mean ± standard deviation which was computed for TCD, BPD, HC, AC, and FL. Pearson's correlation coefficient was done to determine the correlation between the TCD and the other parameters $P \leq 0.05$ was considered statistically significant. Regression analysis was done to compare the TCD with the menstrual GA.

Results

The mean age ± standard deviation of the women was 30.2 ± 4.5 years (range = 16–45 years). The women in the 26–34 years of age group constituted the majority (288; 72%) of the patients. The 18–25 years and 36–45 years age groups had 56 (14%) women each. The mean parity of the women was 1.2 ± 1.0 (range = 0–4). Majority of the women (148; 37%) were para 1; para 0 = 118 (29.5%), para 2 = 82 (20.5%), para 3 = 42 (10.5%), and para 4 = 10 (2.5%).

The mean weight of the women was 71.0 ± 9.1 kg (range = 50–104 kg), the mean height was 1.64 ± 0.1 m (range = 1.53–1.80 m), while the mean BMI was 26.4 ± 3.4 kg/m^2 (range = 19.8–41.4 kg/m^2). Normal-weighted, overweight, and obese participants were 155 (38.8%), 184 (45.9%), and 61 (15.3%), respectively. The mean pulse rate was 83.5 ± 7.4 beats/min (range = 60–100 beats/min). The mean systolic blood pressure was 115.7 ± 9.0 mmHg (range = 90–140 mmHg), while the mean diastolic blood pressure was 71.8 ± 7.4 mmHg (range = 60–90 mmHg).

The mean BPD ranged from 27.4 ± 1.8 mm at 14 weeks to 92.0 ± 1.6 mm at 38 weeks. The mean HC ranged from 101.7 ± 7.0 mm at 14 weeks to 329.7 ± 7.5 mm at 38 weeks. The mean AC ranged from 85.6 ± 7.2 mm at 14 weeks to 342.5 ± 5.9 mm at 38 weeks. The mean FL ranged from 14.1 ± 1.1 mm at 14 weeks to 72.9 ± 1.6 mm at 38 weeks.

The mean TCD ranged from 13.3 ± 0.3 mm at 14 weeks to 52.3 ± 3.3 mm at 38 weeks. Figure 4 is a scatterplot of the 5^{th}, 50^{th}, and 95^{th} centiles for fetal TCD at any particular gestation. A strong linear relationship was observed between TCD and the menstrual GA. The mean TCD showed a progressive increase with advancing menstrual GA [Table 1].

A significant strong positive correlation ($P < 0.0001$) was noted between the menstrual age and BPD ($r = 0.975$), HC ($r = 0.973$), AC ($r = 0.981$), FL ($r = 0.977$), and TCD ($r = 0.972$) using Pearson's correlation [Table 2]. There was also a significant strong positive correlation ($P < 0.0001$) between the TCD and BPD ($r = 0.963$), HC ($r = 0.960$), AC ($r = 0.981$), and FL ($r = 0.961$). AC showed the strongest positive correlation with TCD [Table 2]. There was also a linear increase in TCD with menstrual GA (coefficient of determination, $R^2 = 0.945$;

Table 1: Relationship between transverse cerebellar diameter and menstrual gestational age

Menstrual GA (weeks)	Frequency (%)	TCD (mm), mean±SD	Minimum (mm)	Maximum (mm)
14	15 (3.75)	13.3±0.3	13.1	13.6
15	16 (4.0)	14.1±0.7	13.3	14.8
16	15 (3.75)	16.4±1.3	14.8	19.4
17	17 (4.25)	16.9±0.8	15.6	18.4
18	15 (3.75)	18.1±1.3	15.6	20.3
19	16 (4.0)	19.5±2.2	17.1	24.4
20	17 (4.25)	21.0±3.4	18.7	33.0
21	20 (5.0)	21.4±1.7	18.7	24.6
22	17 (4.25)	22.5±1.5	20.3	26.0
23	18 (4.5)	24.5±3.3	21.1	34.4
24	16 (4.0)	25.7±1.5	23.9	27.7
25	15 (3.75)	27.0±1.9	24.4	29.2
26	16 (4.0)	29.5±2.1	26.3	34.4
27	15 (3.75)	30.9±2.4	28.2	33.8
28	16 (4.0)	33.2±1.3	30.9	35.5
29	15 (3.75)	35.9±2.8	32.2	40.8
30	16 (4.0)	37.1±0.5	36.5	37.8
31	15 (3.75)	39.4±1.1	38.4	40.4
32	16 (4.0)	41.5±0.6	40.9	42.2
33	17 (4.25)	41.8±3.9	35.6	50.4
34	16 (4.0)	45.4±5.4	34.9	55.0
35	16 (4.0)	46.1±2.6	41.9	50.6
36	15 (3.75)	49.7±1.2	47.4	51.5
37	15 (3.75)	51.3±1.0	50.4	53.0
38	15 (3.75)	52.3±3.3	48.5	57.7
Total	400 (100)			

GA=Gestational age, TCD=Transverse cerebellar diameter, SD=Standard deviation

Table 2: Correlation of transverse cerebellar diameter and menstrual gestational age with fetal biometric parameters

Parameters	*r*	*P*
TCD versus BPD	0.963	0.0001
TCD versus HC	0.960	0.0001
TCD versus AC	0.970	0.0001
TCD versus FL	0.961	0.0001
GA versus BPD	0.975	0.0001
GA versus HC	0.973	0.0001
GA versus AC	0.981	0.0001
GA versus FL	0.977	0.0001
GA versus TCD	0.972	0.0001

AC=Abdominal circumference, BPD=Biparietal diameter, FL=Femur length, GA=Gestational age, HC=Head circumference, TCD=Transverse cerebellar diameter

$P = 0.001$) indicating that 94.5% of the TCD variance could be explained by menstrual GA. The Pearson's correlation coefficient (r) between menstrual GA and TCD was positively strong at 0.972 ($P < 0.0001$).

Linear regression established that TCD (mm) could significantly predict GA with the following regression

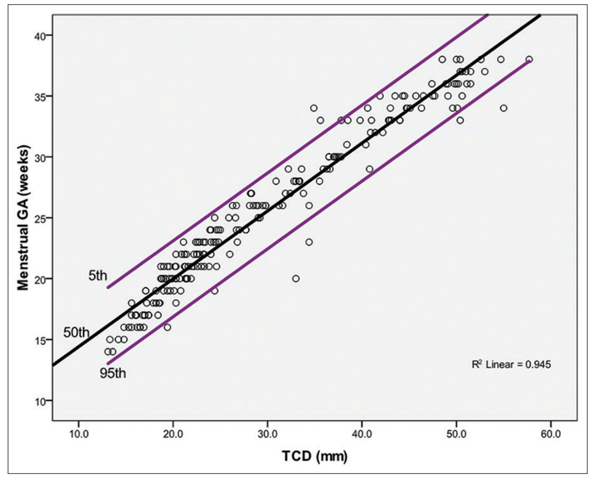

Figure 4: Scatterplot of fetal transverse cerebellar diameter (TCD) versus menstrual gestational age. The upper, middle, and lower lines represent the 5th, 50th and 95th centiles, respectively

equation: Predicted GA = 0.557 × TCD (mm) +8.840 [Table 3]. The coefficient indicates that for every additional millimeter increase in TCD, it could be expected that GA would increase by an average of 0.557 weeks. The model is significantly good enough in predicting the GA ($P < 0.001$). Table 4 juxtaposes our regression equation with those obtained in some previous studies. The predicted GAs based on the regression equation are shown in Table 5, which revealed that the predicted GA correlated more with the menstrual GA in the third trimester.

Of the 400 fetuses, majority (57.5%) were assigned Grade I with median menstrual GA and TCD of 21 weeks and 21.2 mm, respectively. The frequency of each cerebellar grade with respect to the menstrual GA showed a gradual and continuous shift from Grade I to Grade III [Table 6].

Discussion

The purpose of this study was to evaluate the relationship between fetal TCD and menstrual GA and to generate normative references to the fetal TCD in our locality. Pregnant women at 14–38 weeks GA were studied. The lower limit of 14 weeks was chosen because this was the earliest GA at which the resolution of the ultrasound machine used would demonstrate the fetal cerebellum clearly enough for measurements. The upper limit of 38 weeks was also chosen because of decreasing number of term pregnant women and increased likelihood of labor beyond this GA.

In similar studies in Benin city Nigeria,[7] Thailand[32], India,[6] Brazil,[33] and Hawaii USA,[34] the fetal cerebellum was demonstrated as from 13 weeks GA. Other previous studies have variously demonstrated fetal cerebellum on ultrasound at 10–12 weeks' gestation which was earlier than in this study.[6,8,12,35] This disparity is probably due to their use of more sophisticated ultrasound machines.

Table 3: Linear regression showing the relationship between gestational age and transverse cerebellar diameter

	Unstandardized coefficients (*B*)	SE	Standardized coefficients (*B*)	*t*	*P*	95% CI for *B*	
						LL	UL
Constant	8.840	0.219		40.441	<0.001	8.410	9.270
TCD (mm)	0.557	0.007	0.972	82.373	<0.001	0.544	0.570

Regression equation: Predicted GA=0.557 × TCD (mm)+8.840. CI=Confidence interval, SE=Standard error, LL=Lower limit, UL=Upper limit, TCD=Transverse cerebellar diameter, GA=Gestational age

Table 4: Transverse cerebellar diameter regression models of some previous studies

Authors	Regression equations for TCD	Regression coefficient	*P*
Gupta *et al*.[27]	TCD (mm)=6.119 × GA+11.201	0.946	<0.001
Mahmoud *et al*.[28]	GA=0.8683 × TCD (mm)+1.9098	0.940	<0.001
Mascarenhas[29]	GA=5.057 × TCD (cm)+11.82	0.810	<0.001
Satish Prasad and Likhitha[30]	GA=−0.007 TCD^2 (mm^2)+1.1032 TCD (mm)+0.2463	0.990	<0.001
Verburg *et al*.[31]	TCD (mm)=6.9519+0.03327 × GA^2	0.980	<0.001
This study	GA=0.557× TCD (mm)+8.840	0.972	<0.001

TCD=Transverse cerebellar diameter, GA=Gestational age

Table 5: Predicted gestational age from transverse cerebellar diameter based on the regression model

Mean TCD (mm)	Menstrual GA (weeks)	Predicted GA (weeks)
13.3	14	16.2
14.1	15	16.7
16.4	16	17.9
16.9	17	18.2
18.1	18	18.9
19.5	19	19.7
21.0	20	20.5
21.4	21	20.8
22.5	22	21.4
24.5	23	22.5
25.7	24	23.2
27.0	25	23.9
29.5	26	25.3
30.9	27	26.0
33.2	28	27.3
35.9	29	28.8
37.1	30	29.5
39.4	31	30.8
41.5	32	32.0
41.8	33	32.1
45.4	34	34.1
46.1	35	34.5
49.7	36	36.5
51.3	37	37.4
52.3	38	38.0

TCD=Transverse cerebellar diameter, GA=Gestational age

In this study, TCD (mm) was equivalent to the menstrual GA (weeks) in the second trimester, particularly between 16 and 22 weeks of gestation. After 22 weeks, the TCD exceeded the menstrual GA. These findings are similar to the study by Goel *et al*. which showed that the TCD was equivalent to the menstrual GA in the second trimester, particularly between 14 and 20 weeks of gestation.

The TCD increased in a linear fashion throughout the second and third trimesters. A similar observation was shown by Mahmoud *et al.*,[28] Gupta *et al.*,[27] Sharma and Ghode,[35] and Goel *et al*.[6] However, a curvilinear relationship was observed between TCD and menstrual GA in the studies by Satish Prasad and Likhitha[30] and Verburg *et al*.[31] This may be due to differences in the statistical methods used. Despite this, both the linear and curvilinear relationships showed positively strong correlations between TCD and GA, thereby stressing the reliability of TCD in estimating GA and monitoring fetal growth.

This study showed that the menstrual GA correlated more with BPD (r = 0.939) than with TCD (r = 0.902) in the third trimester. This finding is in contrast to a study by Naseem *et al*.[13] which showed that the menstrual GA correlated better with TCD (r = 0.957) than with BPD (r = 0.879). The difference may be due to the fact that their study focused on pregnant women particularly at 36 weeks of gestation while the index study reviewed a wider GA range (27–38 weeks) in the third trimester.

Fetal TCD showed a strong positive linear correlation with the commonly used fetal biometric parameters (BPD, HC, AC, and FL). A similar finding was observed by Haller *et al*.[36] and Reece *et al*.[8] Based on this finding of a close correlation between TCD and BPD/HC, TCD may be preferred to BPD in assessing the GA of fetuses in conditions where the fetal head is deformed such as in molding, dolichocephaly or brachycephaly.[32,37] In fact, the TCD continues to be a useful predictor of GA even in the presence of abnormal skull shapes, fetal growth restriction, multiple pregnancies, and large-for-date fetuses.[8,38-40]

The nomogram established from this study shows that the mean TCD values are accurate for predicting GA. In addition, the nomogram is useful in assessing the fetal GA when the LMP is not known. It is also useful in assessing deviation from normal growth pattern.

Table 6: Cerebellar grades with median gestational age and transverse cerebellar diameter

Cerebellar grade	Frequency (%)	Median GA (weeks)	Median TCD (mm)
I	230 (57.5)	21	21.2
II	74 (18.5)	29	35.5
III	96 (24.0)	35	48.1
Total	400 (100)		

TCD=Transverse cerebellar diameter, GA=Gestational age

The TCD linear regression equation derived showed that the predicted GA corresponds to the menstrual GA by ± 2 weeks throughout the second and third trimesters. Regression equations by Satish Prasad and Likhitha[30] and Verburg *et al.*[31] similarly predicted GA with 2 weeks variability throughout the second and third trimesters. Regression models by Gupta *et al.*[27] and Mahmoud *et al.*[28] predicted GA with ± 2 weeks accuracy in the second trimester only while both models demonstrate wide disparities between the menstrual GA and predicted GA in the third trimester.

There were gradual and steady sonographic changes in the dimension, echogenicity, and shape of the fetal cerebellum. The echogenicity of the cerebellum changed from hypoechoic/cystic appearance (Grade I) to isoechoic appearance (Grade II), and to hyperechoic/solid appearance (Grade III). The shape of the cerebellum also changed from "a pair of eyeglasses" (Grade I), to dumbbell-shaped (Grade II), and to fan-shaped (Grade III). This sonographic change in cerebellar appearance with advancing GA was similarly observed in studies by Adeyekun and Orji,[7] Malik *et al*.,[26] Sharma and Ghode[35] and Hashimoto *et al*.[41]

In this study, the median GA and TCD were 21 weeks and 21.2 mm for Grade I; 29 weeks and 35.5 mm for Grade II; while 35 weeks and 48.1 mm were recorded for Grade III. These findings are closely related to those of Adeyekun and Orji,[7] Malik *et al.,*[26] and Hashimoto *et al*.[41] According to Adeyekun and Orji,[7] the median GA and TCD were 21 weeks and 21.2 mm for Grade I; 28 weeks and 32.6 mm for Grade II; while 35 weeks and 47.1 mm were recorded for Grade III, respectively. Malik *et al*.[26] found the median GA and TCD to be 20 weeks and 21.0 mm for Grade I; 31 weeks and 36.0 mm for Grade II; and 36 weeks and 47.0 mm for Grade III, respectively. Hashimoto *et al.*[41] found the median GA and TCD to be 22 weeks and 22.0 mm for Grade I, 29 weeks and 35 mm for Grade II, and 36 weeks and 46 mm for Grade III, respectively. However, Sharma and Ghode[35] observed the changes in cerebellar appearance at earlier gestational ages when compared to this study. According to their study, the median GA and TCD were 18 weeks and 17 mm for Grade I, 27 weeks and 27 mm for Grade II, and 34 weeks and 42 mm for Grade III, respectively. The progressive change in cerebellar grade with advancing GA is reflected by progressive histological development, Purkinje cell differentiation in the cerebellum, and progressive decrease in cerebellar water content.[42,43] The cerebellar grading is important in chromosomal abnormalities such as trisomies 18 and 21 where there is a restriction of the development in cerebellar size and tissue maturation.[44]

The limitations of this study include the following: First, ultrasound is operator-dependent and liable to error obtained from the caliper system. This was minimized by taking measurements on magnified images. Each parameter was also measured three times and averaged to minimize intra-observer error. Second, the TCD measurements were only made by one sonologist rather than by multiple sonologists; therefore, inter-observer variability was not evaluated.

Conclusion

To sum up, the TCD increases linearly with advancing GA and other biometric parameters in the normally developing fetus. Therefore, TCD is a good marker for GA estimation and can be reliably used in cases when pregnant mothers are not sure of their LMP. There was a gradual and steady change in the ultrasonographic appearance of the fetal cerebellum with increasing GA. Such changes include those of shape (from "eye-glass" to fan shape) and echogenicity (from hypoechoic or hyperechoic). These changes are important in estimating the GA of the fetus.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Skinner C, Mount CA. Sonography Assessment of Gestational Age. Treasure Island, Florida, USA: StatPearls Publishing; 2022. Available from: https://www.ncbi.nlm.nih.gov/books/NBK570610/. [Last accessed on 2022 Oct 26].
2. Oboro VO, Bello TO, Oyeniran AO. First trimester sonographic dating formula for the Nigerian obstetric population. West Afr J Radiol 2012;19:1-4.
3. Abidoye IA, Ayoola OO, Idowu BM, Aderibigbe AS, Loto OM. Uterine artery Doppler velocimetry in hypertensive disorder of pregnancy in Nigeria. J Ultrason 2017;17:253-8.
4. Chawanpaiboon S, Kanokpongsakdi S, Vantanasiri C. Predicting fetal intrauterine growth retardation by using reference centile charts. Siriraj Med J 2017;60:316-9.
5. Azagidi AS, Ibitoye BO, Makinde ON, Idowu BM, Aderibigbe AS. Fetal gestational age determination using ultrasound placental thickness. J Med Ultrasound 2020;28:17-23.
6. Goel P, Singla M, Ghal R, Jain S, Budhiraja V, Babu CS. Transverse cerebellar diameter – A marker for estimation of gestational age. J Anat Soc India 2010;59:158-61.
7. Adeyekun AA, Orji MO. Relationship between ultrasound estimated fetal gestational age and cerebellar appearance in healthy pregnant Nigerian women. Ann Afr Med 2015;14:132-6.
8. Reece EA, Goldstein I, Pilu G, Hobbins JC. Fetal cerebellar growth unaffected by intrauterine growth retardation: A new parameter for prenatal diagnosis. Am J Obstet Gynecol 1987;157:632-8.
9. Montenegro NA, Leite LP. Fetal cerebellar measurements in second trimester ultrasonography–clinical value. J Perinat Med 1989;17:365-9.
10. Campbell WA, Nardi D, Vintzileos AM, Rodis JF, Turner GW, Egan JF. Transverse cerebellar diameter/abdominal circumference ratio

throughout pregnancy: A gestational age-independent method to assess fetal growth. Obstet Gynecol 1991;77:893-6.
11. Meyer WJ, Gauthier DW, Goldenberg B, Santolaya J, Sipos J, Cattledge F. The fetal transverse cerebellar diameter/abdominal circumference ratio: A gestational age-independent method of assessing fetal size. J Ultrasound Med 1993;12:379-82.
12. Chavez MR, Ananth CV, Smulian JC, Yeo L, Oyelese Y, Vintzileos AM. Fetal transcerebellar diameter measurement with particular emphasis in the third trimester: A reliable predictor of gestational age. Am J Obstet Gynecol 2004;191:979-84.
13. Naseem F, Fatima N, Yasmeen S, Saleem S. Comparison between transcerebellar diameter with biparietal diameter of ultrasound for gestational age measurement in third trimester of pregnancy. J Coll Physicians Surg Pak JCPSP 2013;23:322-5.
14. Jacquemyn Y, Sys SU, Verdonk P. Fetal transverse cerebellar diameter in different ethnic groups. J Perinat Med 2000;28:14-9.
15. Oloyede OA, Shorunmu TO, Adefuye PO, Abbey M. Foetal transcerebellar diameter (TCD) measurement between 18 and 23 weeks of pregnancy. Ann Health Res 2017;3:60-5.
16. Eze CU, Onu IU, Adeyomoye AA, Upeh ER. Estimation of gestational age using trans-cerebellar diameter: A sonographic study of a cohort of healthy pregnant women of Igbo ethnic origin in a suburb of Lagos, southwest Nigeria. J Ultrasound 2021;24:41-7.
17. Mohammed H, Joseph EC, Sidi M, Ya'u A, Mansur U, Dambele MY, *et al.* Sonogrphic reference values for fetal Tran-cerebellar diameter (TCD) in Kano metropolis. Dutse J Pure Appl Sci 2021;7:1-16.
18. Katuka A, Igashi J, Bello N, Mohammed H, Aliyu I. Transverse cerebellar diameter: Alternative parameter for gestational age assessment in Northern Nigeria. Alicante, Spain: Fetal Medicine Foundation; 2019. Available from: https://fetalmedicine.org/abstracts/2019/var/pdf/abstracts/2019/03245.pdf.
19. Eze CU, Onwuzu QE, Nwadike IU. Sonographic reference values for fetal transverse cerebellar diameter in the second and third trimesters in a Nigerian population. J Diagn Med Sonogr 2017;33:174-81.
20. Schmidt W, Kurjak A, editors. Normal fetomaternal Doppler indices in the second and third trimesters of pregnancy. In: Color Doppler Sonography in Gynecology and Obstetrics. Stuttgart New York: Thieme; 2004. p. 129-34.
21. Ayoola OO, Bulus P, Loto OM, Idowu BM. Normogram of umbilical artery Doppler indices in singleton pregnancies in South-Western Nigerian women. J Obstet Gynaecol Res 2016;42:1694-8.
22. Ishola A, Asaleye CM, Ayoola OO, Loto OM, Idowu BM. Reference ranges of fetal cerebral lateral ventricle parameters by ultrasonography. Rev Bras Ginecol Obstet 2016;38:428-35.
23. Hansmann M, Hackelöer BJ, Staudach A. Ultrasound Diagnosis in Obstetrics and Gynecology. Berlin, Heidelberg: Springer Berlin Heidelberg; 1986. p. 162.
24. Hadlock FP, Deter RL, Harrist RB, Park SK. Fetal biparietal diameter: Rational choice of plane of section for sonographic measurement. AJR Am J Roentgenol 1982;138:871-4.
25. Hadlock FP, Deter RL, Harrist RB, Park SK. Fetal head circumference: Relation to menstrual age. AJR Am J Roentgenol 1982;138:649-53.
26. Malik R, Pandya V, Shrivastava P. Gestational age estimation using transcerebellar diameter with grading of fetal cerebellum and evaluation of TCD/AC (Transcerebellar diameter/abdominal circumference) ratio as a gestational age independent parameter. Indian J Radiol Imaging 2003;13:95-7.
27. Gupta AD, Banerjee A, Rammurthy N, Revati P, Jose J, Karak P, *et al.* Gestational age estimation using transcerebellar diameter with grading of fetal cerebellar growth. Natl J Clin Anat 2012;1:115-20.
28. Mahmoud MZ, Mahmoud OA, Abdulla AA. Fetal transverse cerebellar diameter measurement for prediction of gestational age in pregnant Sudanese ladies. Int J Life Sci Med Res 2013;3:89-93.
29. Mascarenhas V. Cerebellar Dimensions in the Assessment of Gestational Age in Neonates [Doctor of Medicine Thesis 2012]. Bangalore, India: Rajiv Gandhi University of Health Sciences, Karnataka. Bangalore, Karnataka, India: Rajiv Gandhi University of Health Sciences; 2012. Available from: http://52.172.27.147:8080/jspui/handle/123456789/7162.
30. Satish Prasad B, Likhitha S. Cerebellar measurements with ultrasonography in the evaluation of fetal age. IOSR J Dent Med Sci 2014;13:49-56.
31. Verburg BO, Steegers EA, De Ridder M, Snijders RJ, Smith E, Hofman A, *et al.* New charts for ultrasound dating of pregnancy and assessment of fetal growth: Longitudinal data from a population-based cohort study. Ultrasound Obstet Gynecol 2008;31:388-96.
32. Singhakom N, Chawanpaiboon S, Titapant V. Reference centile charts for ratio of fetal transverse cerebellar diameter to abdominal circumference in a Thai population. J Med Assoc Thai 2004;87 Suppl 3:S54-8.
33. Holanda-Filho JA, Souza AI, Souza AS, Figueroa JN, Ferreira AL, Cabral-Filho JE. Fetal transverse cerebellar diameter measured by ultrasound does not differ between genders. Arch Gynecol Obstet 2011;284:299-302.
34. Sarno AP, Rose GS, Harrington RA. Coronal transcerebellar diameter: An alternate view. Ultrasound Obstet Gynecol 1992;2:158-61.
35. Sharma G, Ghode R. Fetal transcerebellar diameter and transcerebellar diameter – abdominal circumference ratio as a menstrual age independent parameter for gestational age estimation with grading of cerebellar. Int J Reprod Contracept Obstet Gynecol 2017;4:2036-40.
36. Haller H, Petrović O, Rukavina B. Fetal transverse cerebellar diameter/abdominal circumference ratio in assessing fetal size. Int J Gynaecol Obstet 1995;50:159-63.
37. Miković Z, Marković A, Dukić M, Pazin V. Growth of the fetal cerebellum in normal pregnancy. Jugosl Ginekol Perinatol 1989;29:157-60.
38. Goldstein I, Reece EA. Cerebellar growth in normal and growth-restricted fetuses of multiple gestations. Am J Obstet Gynecol 1995;173:1343-8.
39. Hill LM, Guzick D, Fries J, Hixson J, Rivello D. The transverse cerebellar diameter in estimating gestational age in the large for gestational age fetus. Obstet Gynecol 1990;75:981-5.
40. Shimizu T, Gaudette S, Nimrod C. Transverse cerebellar diameter in twin gestations. Am J Obstet Gynecol 1992;167:1004-8.
41. Hashimoto K, Shimizu T, Shimoya K, Kanzaki T, Clapp JF, Murata Y. Fetal cerebellum: US appearance with advancing gestational age. Radiology 2001;221:70-4.
42. Zecevic N, Rakic P. Differentiation of Purkinje cells and their relationship to other components of developing cerebellar cortex in man. J Comp Neurol 1976;167:27-47.
43. Selzer ME, Myers RE, Holstein SB. Maturational changes in brain water and electrolytes in rhesus monkey with some implications for electrogenesis. Brain Res 1972;45:193-204.
44. Hill LM, Marchese S, Peterson C, Fries J. The effect of trisomy 18 on transverse cerebellar diameter. Am J Obstet Gynecol 1991;165:72-5.