Original Article

Estimation of Gestational Age by Ultrasound Measurement of Fetal Transcerebellar Diameter

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Abstract

Background: Accurate determination of gestational age is essential in obstetric practice, particularly in pregnancies complicated by fetal growth restriction or skeletal abnormalities where conventional fetal biometric measurements may be unreliable. The transcerebellar diameter, due to its stable developmental trajectory, has been proposed as an alternative parameter for gestational age estimation. This study assessed the accuracy of transcerebellar diameter for gestational age estimation compared to biparietal diameter, head circumference, abdominal circumference and femur length and evaluated its performance in fetal growth restriction and skeletal dysplasia. **Material and Methods:** A cross-sectional observational study was conducted on 270 pregnant women between 14 and 40 weeks of gestation. Standard fetal biometry and transcerebellar diameter were measured by ultrasonography. Correlations between transcerebellar diameter and gestational age determined by first trimester dating scans were analyzed for both normal and fetal growth restriction pregnancies. **Results:** In normal pregnancies, transcerebellar diameter correlated strongly with gestational age (r = 0.961; 96.1% accuracy), comparable to biparietal diameter (r = 0.973; 97.3%), head circumference (r = 0.967; 96.7%), femur length (r = 0.970; 97.0%) and abdominal circumference (r = 0.966; 96.6%). In fetal growth restriction, transcerebellar diameter remained more accurate (r = 0.921; 92.1%) than biparietal diameter (r = 0.894; 89.4%), head circumference (r = 0.929; 92.9%), femur length (r = 0.867; 86.7%) and abdominal circumference (r = 0.825; 82.5%). **Conclusion:** Transcerebellar diameter is a stable and accurate parameter for gestational age estimation across both normal and abnormal fetal growth patterns. Its inclusion in routine biometry may improve accuracy where conventional parameters fail.

Keywords: Transcerebellar Diameter, Gestational Age, Fetal Growth Restriction, Biometric Paradox.

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Introduction

Accurate gestational age (GA) determination remains critically challenging in low-resource settings, where estimation errors contribute to 38% of iatrogenic preterm deliveries and 22% of post-term complications due to reliance on less precise methods like last menstrual period (LMP) and fundal height (FH).[1,2] Studies demonstrate that LMP-based dating can overestimate GA by ±14–25 days compared to ultrasound, increasing preterm misclassification rates by 100% and post-term inductions by 12.1% to 3.4% when ultrasound is unavailable.[3-5]

While traditional biometric parameters biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC) and femur length (FL) have revolutionized prenatal care since Hadlock's 1984 equations, their limitations persist in cases of fetal growth restriction (FGR) and skeletal dysplasias.[6-8] BPD and HC are susceptible to cranial molding, while FL becomes unreliable in skeletal abnormalities, reducing the precision of GA estimation in such situations.[9]

The cerebellum offers a promising alternative due to its unique developmental trajectory. Enclosed within the ossified posterior fossa by 14 weeks it follows an intrinsically programmed growth pattern largely resistant to external compressive forces.[10,11] The transcerebellar diameter (TCD) which measures the maximum transverse width of the fetal cerebellum, thus remains relatively unaffected by extrinsic growth disturbances. Studies confirm TCD's reliability in intrauterine growth restriction (IUGR), where up to 80% of IUGR fetuses demonstrate normal TCD values despite abnormalities in BPD or FL highlighting its biological stability.[7,12] Also TCD shows less than 10% variability even in severe FGR while AC measurements can deviate by 15–22% under similar conditions.[13,14]

Recent advances in neurosonography have renewed interest in cerebellar biometry. In an Indian cohort study TCD demonstrated superior GA correlation in FGR pregnancies outperforming AC

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consistent with findings in South Asian populations.[15] Three-dimensional volumetric analyses further confirmed TCD's resistance to late gestation growth plateaus that typically affect femur length.[13] But clinical adoption is still limited by the lack of well-established reference curves for specific populations especially South Asians. Existing TCD nomograms are primarily derived from Caucasian, African and East Asian cohorts, leaving South Asian populations underrepresented.

By validating TCD in both normal and abnormal growth, this study provides a tool to overcome the biometric paradox. In asymmetric or abnormal growth, where conventional biometry loses accuracy, TCD remains stable. This improves gestational age estimation, especially in skeletal dysplasia and fetal growth restriction.

Materials and Methods

This study was a hospital-based, time-bound and cross-sectional observational study done in the Department of Radiodiagnosis of a Medical College and Hospital. A total of 270 patients referred to our department for antenatal scan fulfilling the inclusion criteria, between 14-40 weeks were included in the study. Inclusion criteria were as follows: 1. Pregnancy having 12-40 weeks of gestation 2. Pregnant women having single live fetus. 3. Given informed consent 4. Having documented first trimester dating scan. Exclusion criteria: 1. High risk pregnancy 2. Not having documented first trimester dating scan. 3. Not giving consent 4. Fetuses with cranial anomalies, skull anatomical anomalies. 5. Multifetal pregnancies.

Informed consent was taken after a complete description of study and handing over patient information sheet. After completing the PC-PNDT Act formalities, obstetric ultrasound was performed. All patients were examined in supine position using a low frequency transducer (3-5 MHz). Fetus was observed for viability and gross congenital defect. Each patient was subjected to ultrasound once for fetal biometry and TCD measurement. The TCD, BPD (Biparietal diameter), HC (Head circumference), AC (Abdominal circumference) and femoral length (FL) was collected, Hadlock formula was used to assess the Gestational age (GA). To measure the TCD, the landmarks of the thalami, cavum septum pellucidum and third ventricle were identified. The transducer was slightly rotated caudally to bring the characteristic "butterfly" appearance of the cerebellum into view. TCD was measured as the widest diameter across both hemispheres in an outer-to-outer fashion.

Statistical analysis: Data was tabulated in Microsoft Excel sheet for analysis. Further depiction of data was done in the form of tables and charts. SPSS was used to analyze the data. The correlation and relationship of the TCD with GA obtained from dating scan, LMP, FL, BPD, HC and AC parameters were established using a Pearson correlation and regression analyses. We established a significance level of $p = 0.05$ to determine the statistical significance of a value. Any value less than or equal to 0.05 was deemed statistically significant.

The study was conducted in accordance with declaration of Helsinki. Institutional Scientific And Ethics committee clearance was obtained. All patients were included in this study after signing a written informed consent.

Results

A total of 270 pregnant women between 14 and 40 weeks of gestation were included. The mean transcerebellar diameter (TCD) showed a progressive increase with advancing gestational age. At 14 weeks the mean TCD was 14.83 mm. It increased steadily across gestation, reaching 24.47 ± 2.30 mm by 24 weeks and 43.17 ± 4.06 mm by 35 weeks. The maximum mean TCD recorded was 48.99 ± 4.44 mm at 38 weeks, with a slight reduction observed at 39 and 40 weeks (46.50 ± 2.74 mm and 47.74 ± 2.07 mm, respectively).

The highest number of participants were distributed between 21 to 25 weeks of gestation, with 43 cases at 22 weeks (15.93%) and 34 cases each at 23 and 24 weeks (12.59%). The distribution of cases was lower at both early and late gestations with only 1–3 cases observed in the 14–20 weeks and 29–30 weeks groups. The standard deviation increased slightly with gestational age indicating mild variability in TCD measurements in the third trimester.

Figure 1: Reference curve for TCD (mm) across gestational age 14-40 weeks

Table 1: Distribution of Mean ± SD Transcerebellar Diameter (TCD) Measurements with Frequency and Percentage Across Gestational Age (in Weeks)

Week	TCD (Mean ± SD)	Frequency	Percentage
14	14.83	1	0.37%
15	15.1	1	0.37%
16	17.09 ± 1.03	3	1.11%
17	17.13 ± 1.65	2	0.74%
18	17.32 ± 1.32	3	1.11%
19	20.08 ± 0.93	5	1.85%
20	19.85 ± 0.99	8	2.96%
21	20.87 ± 1.16	19	7.04%

22	21.64 ± 2.17	43	15.93%
23	22.59 ± 1.71	34	12.59%
24	24.47 ± 2.30	34	12.59%
25	23.72 ± 1.45	5	1.85%
26	23.00 ± 2.83	2	0.74%
27	28.66 ± 3.12	5	1.85%
28	30.41 ± 5.39	5	1.85%
29	31.51	1	0.37%
30	30.87 ± 1.09	3	1.11%
31	35.65 ± 3.44	4	1.48%
32	34.75 ± 7.99	8	2.96%
33	39.87 ± 3.49	12	4.44%
34	37.25 ± 3.81	16	5.93%
35	43.17 ± 4.06	13	4.81%
36	44.98 ± 2.01	13	4.81%
37	48.30 ± 3.35	8	2.96%
38	48.99 ± 4.44	5	1.85%
39	46.50 ± 2.74	9	3.33%
40	47.74 ± 2.07	7	1.48%

Table 2: Correlation between TCD and routine fetal biometric parameters.

Parameters	Correlation coefficient(r-value)	p-value
Correlation of TCD with BPD	0.963	< 0.001
Correlation of TCD with HC	0.971	< 0.001
Correlation of TCD with FL	0.958	< 0.001
Correlation of TCD with AC	0.974	< 0.001

The transcerebellar diameter (TCD) demonstrated strong and statistically significant positive correlations with all conventional fetal biometric parameters. The correlation was highest with abdominal circumference (AC) ($r = 0.974$, $p < 0.001$) followed by head circumference (HC) ($r = 0.971$, $p < 0.001$). Biparietal diameter (BPD) also showed a strong correlation ($r = 0.963$, $p < 0.001$), as did femur length (FL) ($r = 0.958$, $p < 0.001$). All correlations were statistically significant at $p < 0.001$, indicating a very low probability of these associations occurring by chance.

Table 3: Accuracy (%) of TCD in estimating Gestational Age(weeks) compared to other parameters.

Biometric Parameter	Correlation with GA (weeks)(Normal Pregnancy)	Accuracy (Normal)	Correlation with GA (weeks) (FGR Pregnancy)	Accuracy (FGR)
TCD	0.961	96.10%	0.921	92.10%
BPD	0.973	97.30%	0.894	89.40%
HC	0.967	96.70%	0.929	92.90%
FL	0.97	97.00%	0.867	86.70%
AC	0.966	96.60%	0.825	82.50%

Cases

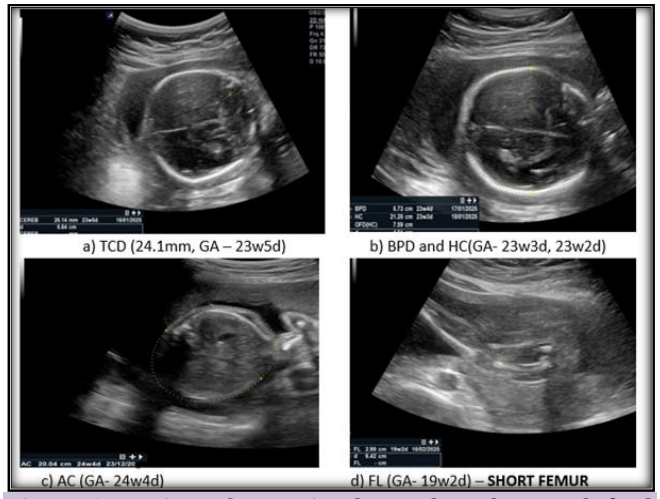

Figure 2: Estimated gestational age by Ultrasound fetal parameters (Hadlock formula) in a primigravida with fetal skeletal dysplasia.
a) TCD measures approx. 24.1mm and corresponds to 23 weeks 05 days GA
b) BPD corresponds to 23 weeks 3 days GA and HC corresponds to 23 weeks 2 days GA
c) AC corresponds to 24 weeks 4 days GA
d) FL corresponds to 19 weeks 2 days GA, since the femurs are short in length and bowed due to skeletal dysplasia.

Mean GA by routine Fetal parameters: 22 weeks 3days.
TCD corresponds to GA measured by Dating scan, while mean of routine fetal parameters is affected by short femur leading to underestimated GA.

In normal pregnancies, TCD demonstrated a strong correlation with gestational age ($r = 0.961$) and an accuracy of 96.1%. This was comparable to conventional parameters such as biparietal diameter (BPD; $r = 0.973$, accuracy 97.3%) femur length (FL; $r = 0.970$, accuracy 97.0%), head circumference (HC; $r = 0.967$, accuracy 96.7%) and abdominal circumference (AC; $r = 0.966$, accuracy 96.6%). In pregnancies complicated by fetal growth restriction (FGR), TCD continued to show strong correlation ($r = 0.921$) with an accuracy of 92.1%. In comparison, conventional parameters showed reduced correlations and accuracies: BPD ($r = 0.894$, 89.4%), HC ($r = 0.929$, 92.9%), FL ($r = 0.867$, 86.7%) and AC ($r = 0.825$, 82.5%).

Figure 3. Estimated gestational age by Ultrasound fetal parameters (Hadlock formula)
a) TCD measures approx. 28.4mm and corresponds to 25 weeks 01 day GA
b) BPD corresponds to 24 weeks 6 days GA and HC corresponds to 24 weeks 5 days GA
c) AC corresponds to 24 weeks 4 days GA
d) FL corresponds to 24 weeks 6 days GA

Mean GA by routine Fetal parameters: 24 weeks 6 days.
TCD corresponds to GA by dating scan as well as mean of routine fetal parameters.

Discussion

In this study TCD demonstrated a consistent and progressive increase across gestation [Table 1 &Figure 1] with strong positive correlations observed between TCD and established fetal biometric parameters [Table 2]. TCD showed comparable accuracy to conventional measurements such as BPD, HC, AC and FL in normal pregnancies [Table 3] while maintaining superior reliability in cases of fetal growth restriction (FGR), where conventional parameters demonstrated reduced accuracy. TCD has been shown in previous studies to remain a stable parameter even when long bone measurements are compromised; however, skeletal dysplasia cases were not assessed in the present study.

Precise gestational age determination influences critical decisions regarding corticosteroid administration, delivery timing and neonatal care planning. Our study addresses this crucial gap by establishing population specific TCD nomograms for Central Indian pregnancies while validating TCD's diagnostic performance in growth-restricted fetuses.

Our results demonstrate TCD's superior accuracy in gestational age estimation across normal and FGR pregnancies. In normal pregnancies, TCD achieved 96.1% accuracy with strong correlation (r=0.97, Table2) against first-trimester dating scans, comparable to recent international studies including the Saudi Arabian cohort (r=0.976, n=384) and Pakistani(91% third-trimester accuracy, n=500).[16-19] Crucially TCD maintained robust performance in FGR cases (92.1% accuracy, r=0.921) significantly outperforming abdominal circumference (82.5%) and femur length (86.7%). A TCD/AC ratio >15 demonstrated 83% sensitivity and 96.1% specificity for detecting FGR suggesting its potential as a diagnostic threshold in Central Indian populations aligning with the 2024 Korean study's 95th percentile threshold of 14.39 (n=1,011). These findings establish TCD as the most resilient biometric parameter in growth-compromised pregnancies.[20]

TCD's diagnostic superiority stems from the cerebellum's unique anatomical and physiological characteristics. Encased within the ossified posterior fossa by 14 weeks gestation, the cerebellum resists external deformation from oligohydramnios, cranial molding or uterine compression that commonly affects biparietal diameter and head circumference measurements.[21,22] More importantly, the "brain-sparing effect" a well-documented adaptive mechanism in FGR preferentially maintains cerebellar blood flow through vasodilation of middle cerebral arteries while constricting peripheral circulation.[23,24] This neuroprotective response ensures continued cerebellar growth despite systemic hypoxia, explaining why TCD deviates by <10% in severe FGR compared to 15–22% reductions in abdominal circumference.[24]

A recent review highlights the critical role of the brainstem in cardiovascular and respiratory control and discusses how chronic hypoxia in FGR alters its development and function. The brainstem's maintenance of activity under hypoxic stress supports the evolutionary prioritization hypothesis, as it regulates vital survival mechanisms such as heart rate and breathing. This adaptation is part of the broader "brain-sparing effect" where blood flow is redirected to protect essential neural structures during placental insufficiency.[25-29]

Studies demonstrate that as FGR progresses, cerebral blood flow is redistributed, with the brainstem and cerebellum maintaining higher perfusion relative to the cerebral cortex. This hemodynamic adjustment prioritizes oxygen and nutrient delivery to regions critical for survival, such as the brainstem (cardiovascular/respiratory control) and cerebellum (motor coordination), while cortical regions experience reduced flow.[26-31]

Comparative Analysis with International Studies

Our TCD-gestational age correlation (r=0.97) aligns closely with recent global studies: Saudi Arabia (r=0.976), India (r=0.979) and Egypt (r=0.984), confirming TCD's universal reliability across diverse populations.[17,19,27] In the present study, the maximum transverse cerebellar diameter (TCD) observed at 40 weeks was 47.74 mm. This aligns closely with Indian studies, such as Nighat Ara et al. (48.4 mm).[17,19,27,30] The 2024 Korean study's TCD/AC ratio (13.26±2.1) provides Asian-specific reference values, with our FGR threshold of >15 aligning with their 95th percentile approach.[20] Third-trimester accuracy studies consistently favor TCD over conventional biometry, our 92.1% FGR accuracy exceeds the 2024 Egyptian study's composite biometry performance (87.3%) and matches the 2024 Pakistani third-trimester validation (91.43%).[19,32]

These findings advocate for TCD's integration into standard fetal biometry protocols, particularly in resource-limited settings where FGR prevalence is high. TCD measurement requires minimal additional scanning time (30-45 seconds) and demonstrates excellent inter-observer reliability (ICC=0.94), making it feasible for routine implementation.[33] TCD's

potential to reduce unnecessary interventions by improving gestational age estimation may contribute to lowering iatrogenic preterm deliveries though formal cost-effectiveness analysis was not conducted in this study.[3-5] The characteristic cerebellar "butterfly" sign provides easily identifiable anatomical landmarks for TCD measurement, making it operator-friendly.[17,29] While TCD/AC ratio has shown promise in identifying FGR, further studies are needed to validate specific cutoff thresholds for different populations.[17,20] Integration of TCD with Doppler indices such as middle cerebral artery pulsatility, may provide additional insights into brain-sparing physiology and warrants future investigation.[34]

Several limitations warrant acknowledgment. Our single-center design may limit generalizability, though consistency with multi-center international studies suggests broader applicability. The FGR subgroup (n=34, 12.6%) reflects regional prevalence but requires validation in larger cohorts for robust TCD/AC threshold determination. Third-trimester measurements occasionally faced technical challenges from fetal positioning and acoustic shadowing (<2% of cases), highlighting the need for operator training. Ethnic homogeneity (Central Indian population) limits extrapolation to other South Asian subgroups, necessitating region-specific validation studies. Long-term neurodevelopmental outcomes were not assessed, though existing literature suggests preserved cerebellar growth correlates with favorable cognitive development.[21] Finally our study examined singleton pregnancies exclusively TCD performance in multiple gestations requires separate investigation.

Several research priorities emerge from our findings. Multi-center validation across diverse South Asian populations should establish comprehensive regional nomograms, while prospective studies should evaluate TCD's impact on clinical decision-making and perinatal outcomes. Integration of artificial intelligence algorithms could enhance TCD measurement automation and reduce inter-observer variability. Three-dimensional ultrasonography may provide volumetric cerebellar assessments potentially improving diagnostic accuracy beyond linear TCD measurements. Investigation of TCD's predictive value for neurodevelopmental outcomes in FGR survivors could strengthen its clinical utility. Finally cost-effectiveness analyses should quantify healthcare savings from improved gestational age accuracy, supporting policy decisions regarding TCD implementation in resource-limited settings. Development of portable ultrasound protocols for TCD measurement could democratize access to accurate fetal dating in rural areas where specialist care is limited.

Conclusion

This study explored the use of ultrasound measurement of Transcerebellar Diameter (TCD) for gestational age estimation, highlighting its potential as an accurate, non-invasive tool for assessing fetal gestational age estimation. Our findings demonstrated a strong correlation between TCD and gestational age, suggesting that TCD can be reliably used in both normal pregnancies and those with fetal growth restriction (FGR). This reinforces its utility in providing early and precise gestational age assessments, which can lead to better clinical decision-making and improved pregnancy outcomes. While the study's sample size and potential biases should be acknowledged as limitations, these factors open avenues for future research. Larger, more diverse studies could further solidify TCD's role in fetal dating and its potential to enhance prenatal care.

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Conflicts of interest

There are no conflicts of interest.

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