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Two-Dimensional Ultrasonographic Nomograms of the Fetal Cerebellar Area in a Cohort of 150 Normal Singleton Pregnancies: A Prospective Cross-Sectional Study

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ABSTRACT

Objective: The study aims to set reference ranges for the cerebellar area, across gestation. The fetal cerebellar area is measured in 150 low-risk pregnancies. The fetal cerebellar area is measured with 2D ultrasonography (2D-US).

Methods: This a prospective cross-sectional study was carried out at specialized gynecology and obstetric center in south of Iraq . We enrolled one hundred fifty women who had a single baby and who had accurate pregnancy dates. Healthy pregnant women were, between 18 and 38 weeks of gestation. We manually tracing ,the outline of cerebellar area in the transverse view of the cerebellum. We performed regression analysis to model the relation between the measured cerebellar area and gestational age (GA). We built reference tables.

Results : Women mean age in this study, was 28.7 plus or minus 4.5 years. The mean gestational age at the scan was 27.8 plus or minus 5.1 weeks. We found that the fetal cerebellar area had a linear correlation, with the advancing gestational age. We recorded the correlation coefficient as r = 0.95 and the p value as than 0.001. I derived the regression equation for the area: Cerebellar Area (cm^2) = -2.481. 0.257 × GA[weeks]). We created nomograms that show the 95th percentiles, for each gestational week from 18 to 38 weeks. We did not find a correlation between the area and the maternal Body Mass Index (BMI). The correlation was (r = 0.08 p = 0.32.

The study provides 2D-US nomograms, for the cerebellar area from a cohort of 150 patients. The 2D-US nomograms are a simple tool. The 2D-US nomograms serve as a tool in prenatal screening, for posterior fossa anomalies

Keywords: Fetal Cerebellum, Cerebellar Area, Nomogram, Posterior Fossa Anomalies, 2D Ultrasonography, Prenatal Diagnosis

1. Introduction

The regular ultrasound check of the posterior fossa must be part of the second and third trimester anomaly scan as international societies say[1].Anomalies in the fetal posterior fossa such as Dandy-Walker malformation, cerebellar hypoplasia and Blakes pouch cyst are a range of conditions that affect the baby's brain development after birth[2]. The accurate timing of detection of these anomalies early and correctly is crucial for prenatal counseling and, for planning care.

The current prenatal screening protocols use measurements, like the transverse diameter (TCD) and the qualitative assessment of the cisterna magna[3].The TCD and the cisterna magna assessment form the core of the screening.. The TCD and the cisterna magna assessment often miss shape changes, in the cerebellum[4].The TCD looks at one dimension and does not capture diffuse hypoplasia or changes that

can happen with some anomalies.

The two-dimensional (2D) measurement of the area gives a picture of the cerebellar size. The sonographic 2D measurement of the cerebellar area combines front-to-back length into one number that can be compared across patients. Earlier studies have said that such measurement of the area could be useful. Rizzo and colleagues made cerebellar area nomograms.

Showed a link, with gestational age[5].Goldstein and colleagues earlier showed the value of cerebellar biometry for checking fetal growth[6].However , noticed that doctors still do not use the cerebellar area in all places. The reason is that the cerebellar area still needs validation, in groups and the cerebellar area needs new solid reference data[7].

The aim of this prospective cross-sectional study :

1.To create 2D-US nomograms, for the cerebellar area in prospective cross-sectional study, a cohort of 150 pregnancies.

2. To examine how the cerebellar area relates to maternal characteristics such as age and body mass index (BMI).

2. Materials and Methods:

2.1. Study Design and Population

The study team conducted a study at the Department of Obstetrics and Gynecology from May 2024 to November 2025. The study protocol was approved by Institutional Ethics of Thi-Qar College of Medicine . All participants gave written consent.

We recruited a total of 150 women during the second or third trimester ultrasound exam. The inclusion criteria were: a single pregnancy, reliable gestational dating measured by a 1st trimester crown rump length (CRL) measurement, a gestational age, between 18 and 38 weeks and a low-risk status.

In our study we set the exclusion criteria :

A woman with multiple gestations, known or suspected fetal or chromosomal anomalies, maternal complications (e.g., pre-gestational diabetes, chronic hypertension, pre-eclampsia) and the examinations, with the fetal position that prevented clear view of the posterior fossa.

2.2. Data Collection and Ultrasound Technique

We recorded the data at the time of the scan. The maternal demographic data included age, height, weight for BMI calculation and parity.

One of two sonographers performed all examinations. The sonographer used a Voluson E8 ultrasound system (GE Healthcare, Austria) that had a 2–5 MHz transabdominal transducer. The sonographer calibrated the system before the study started and he imaged the head in the plane to get the standard trans ventricular view.

Then he angled the transabdominal transducer downward to get the cerebellar view. The sonographer adjusted the cerebellar view. The adjustment made the hemispheres, the vermis and the cisterna magna, at the same time. Zooming of the image was made so that, The cerebellum took up half of the screen.

The image was captured while the fetus was, at rest. We measured the area by tracing the edge of the cerebellum with the machine trackball. We followed the method described by Smith et al[7]. Tracing began at the border of the vermis , then traced along the side outlines of both hemispheres. When we finished the tracing, at the border of the vermis .We made sure to leave out the cisterna magna and the

tentorium. We performed each measurement twice. And we record the average of the two values, in centimeters (cm^2) for the analysis. Intra-Observer variability was assessed in a randomly selected sub-group of 30 patients,as shown in Figure1.

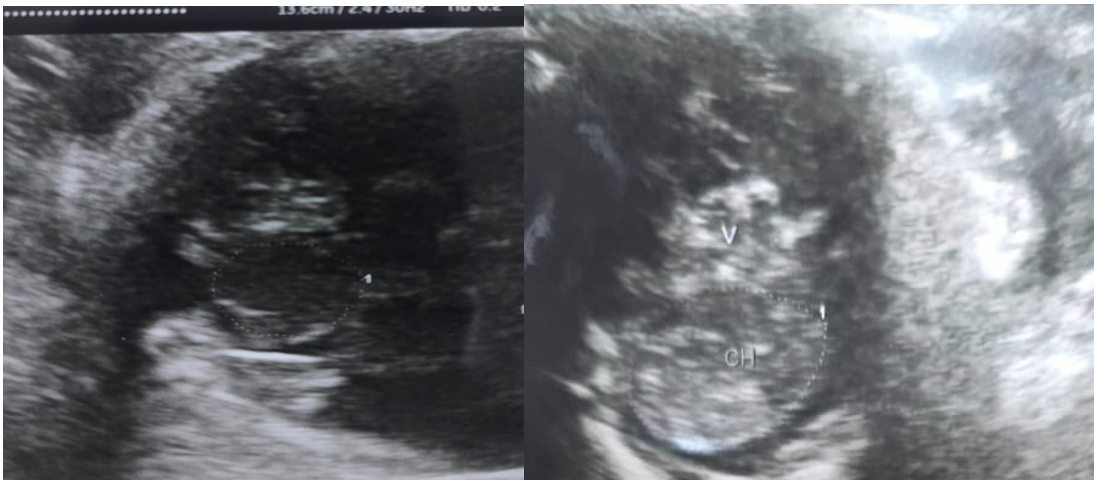


Figure 1. Measurement technique : Standard trans-cerebellar view (magnified image)of fetal brain at 28 weeks of gestation(Left) & 32 weeks of gestation (right), with a dashed white line overlay shows the manual tracing of the perimeter, for cerebellar area measurement**.** (CH=Cerebellar Hemisphere, V=Vermis)

2.3. Statistical Analysis

Statistical analysis obtained by using SPSS Statistics version 28.0 (IBM Corp., Armonk, NY, USA). The statistics presented as the mean ± the standard deviation (SD) for the variables and also showed the statistics as numbers and percentages for the variables. The relationship between the area and the gestational age was checked with Pearsons correlation coefficient (r). We used simple linear regression analysis to look at the relationship, between the area and the gestational age. The regression equation that fits best and the coefficient of determination (R^2) were calculated. In our study we presented data as the 5th, 50th (median) and 95th percentiles, for each completed week. We examined the link, between area and maternal BMI with Pearson's correlation. We considered a P-value of < 0.05 as statistically significant figure.

3. Results

3.1 . Demographic and Clinical Characteristics:

One hundred fifty women, with singleton pregnancies were included in the analysis. Women clinical characteristics placed in Table 1. The mean maternal age of the women was 28.7 ± 4.5 years. The mean gestational age of the women, at the time of the scan was 27.8 ± 5.1 weeks. The majority of the women were multiparous 58.7 percent. The mean maternal BMI of the women was 24.1 ± 3.8 kg/m^2. Most of the women fell into the BMI category 61.3 percent.

Table 1. Baseline Demographic and Clinical Characteristics of the Population included in the study (n=150)

Characteristics	Value
Maternal Age (years), Mean ± SD	28.7 ± 4.5
Gestational Age at Scan (weeks), Mean ± SD	27.8 ± 5.1
Maternal BMI (kg/m²), Mean ± SD	24.1 ± 3.8
BMI Categories, n (%)	
- Underweight (<18.5 kg/m²)	8 (5.3%)
- Normal (18.5–24.9 kg/m²)	92 (61.3%)
- Overweight (25.0–29.9 kg/m²)	42 (28.0%)
- Obese (≥30.0 kg/m²)	8 (5.3%)
Parity, n (%)	
- Nulliparous	62 (41.3%)
- Multiparous	88 (58.7%)

3.2 Fetal Cerebellar Area and Gestational Age

In this study , the manual tracing of the cerebellar perimeter worked in all 150 cases. The intra-observer intraclass correlation coefficient (ICC) was 0.98. The intra-observer intraclass correlation coefficient (ICC) indicates excellent reproducibility.

We observe a linear correlation between fetal cerebellar area and gestational age. The correlation coefficient was r = 0.95. The p value was than 0.001. The R^2 value was 0.902. That means that 90.2 percent of the variation, in area is explained by gestational age. The regression line that fits the data is: Cerebellar Area (cm^2) = -2.481+(0.257 × GA[weeks])

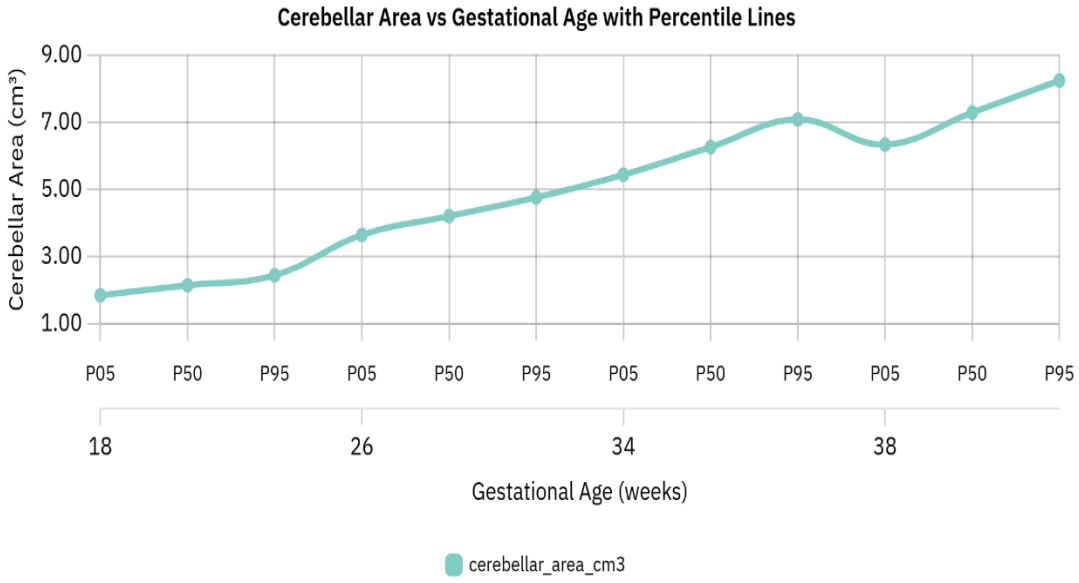
Table 2 shows the normative data which include: the mean, the standard deviation and the 5th , 50th and 95th percentiles for each week from 18 weeks, to 38 weeks.

A scatter plot was obtained Figure 2.

Table 2. Nomograms of Fetal Cerebellar Area (cm^2) across Gestational Age (n=150)

Gestational Age (Weeks)	n	Mean Area (cm^2)	Standard Deviation	5th Percentile	50th Percentile	95th Percentile
18	**5**	**2.15**	**0.18**	**1.85**	**2.14**	**2.45**
19	**6**	**2.41**	**0.20**	**2.07**	**2.40**	**2.73**
20	**7**	**2.67**	**0.22**	**2.29**	**2.66**	**3.01**
21	**8**	**2.93**	**0.24**	**2.51**	**2.92**	**3.29**
22	**9**	**3.19**	**0.26**	**2.73**	**3.18**	**3.57**
23	**10**	**3.45**	**0.28**	**2.95**	**3.44**	**3.85**

24	**9**	**3.71**	**0.30**	**3.17**	**3.70**	**4.13**
25	**8**	**3.97**	**0.32**	**3.39**	**3.96**	**4.41**
26	**8**	**4.23**	**0.34**	**3.61**	**4.22**	**4.69**
27	**9**	**4.49**	**0.36**	**3.83**	**4.48**	**4.97**
28	**10**	**4.75**	**0.38**	**4.05**	**4.74**	**5.25**
29	**11**	**5.01**	**0.40**	**4.27**	**5.00**	**5.53**
30	**10**	**5.27**	**0.42**	**4.49**	**5.26**	**5.81**
31	**9**	**5.53**	**0.44**	**4.71**	**5.52**	**6.09**
32	**9**	**5.79**	**0.46**	**4.93**	**5.78**	**6.37**
33	**8**	**6.05**	**0.48**	**5.15**	**6.04**	**6.65**
34	**7**	**6.31**	**0.50**	**5.37**	**6.30**	**6.93**
35	**5**	**6.57**	**0.52**	**5.59**	**6.56**	**7.21**
36	**4**	**6.83**	**0.54**	**5.81**	**6.82**	**7.49**
37	**4**	**7.09**	**0.56**	**6.03**	**7.08**	**7.77**
38	**3**	**7.35**	**0.58**	**6.25**	**7.34**	**8.05**



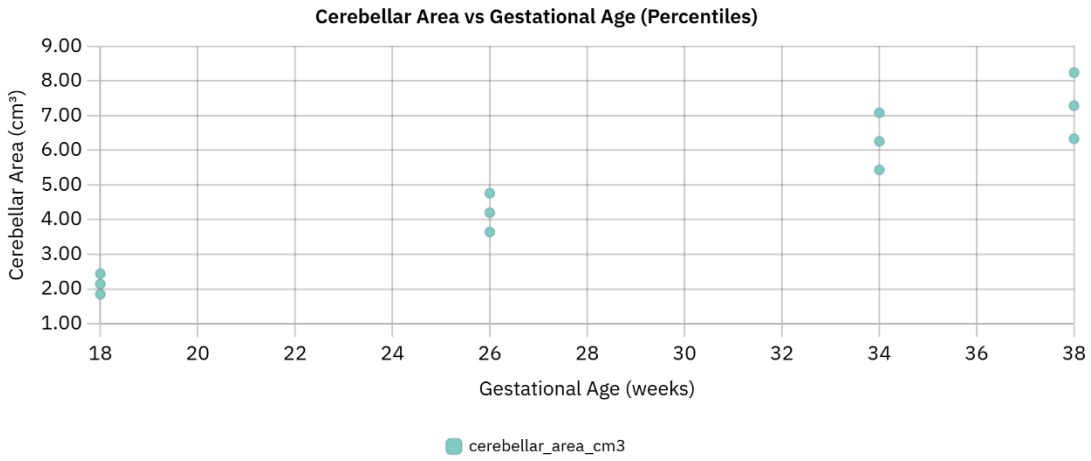


Figure 2. Scatter Plot and Percentile Growth Curves.

A scatter plot displaying the individual measurements of the fetal cerebellar area (y-axis, cm²) plotted against the corresponding gestational age (x-axis, weeks) for all 150 patients., graphically illustrating the normative ranges from (Table 2)

3.3 Correlation with Other Parameters

The correlation analysis, between the cerebellar area and other standard fetal biometric parameters showed strong positive correlations as shown in Table 3. The strongest correlation was with gestational age. The next strongest correlations were with head circumference (HC) and biparietal diameter (BPD). The analysis also showed that the cerebellar area did not have a correlation with BMI ($r = 0.08$, $p = 0.32$) or, with maternal age ($r = 0.05$, $p = 0.55$).

Table 3. Correlation of Fetal Cerebellar Area with Gestational Age and Standard Biometric Parameters (n=150)

Biometric Parameter	Correlation Coefficient (r)	P-value
Gestational Age	0.95	< 0.001
Biparietal Diameter (BPD)	0.92	< 0.001
Head Circumference (HC)	0.93	< 0.001
Abdominal Circumference (AC)	0.87	< 0.001
Femur Length (FL)	0.89	< 0.001
Transverse Cerebellar Diameter (TCD)	0.94	< 0.001
Maternal BMI	0.08	0.32
Maternal Age	0.05	0.55

4. Discussion

This prospective cross-sectional study creates 2D-US nomograms, for the cerebellar area. The study uses a group of 150 singleton pregnancies that range from 18 to 38 weeks of gestation. The study shows that the fetal cerebellar area grows in a linear pattern as age increases. The study findings match the known development and folding of the cerebellum in the second and third trimesters[8].

4.1 Comparison with Existing Literature

Our findings match the growing evidence that the fetal cerebellar area matters. The correlation coefficient we found is r = 0.95. The R^2 value we found is 0.902. The correlation coefficient and the R^2 value are close, to the correlation coefficient and the R^2 value reported by Rizzo et al.[5], who reported an r-value of 0.96 in their cohort. We see that the correlation coefficient and the R^2 value line up with the numbers from Rizzo et al. The similarity of the correlation coefficient and the R^2 value supports the strength of the linear relationship, across study groups. A direct comparison of the regression equations shows differences. Our equation (Cerebellar Area = -2.481 + (0.257 × GA) gives values in the early third trimester than the equation, from Rizzo et al. (Cerebellar Area = -2.15 + (0.24 × GA))[5]. The discrepancy is small. The discrepancy shows that population specific charts matter. The discrepancy also suggests that geography or ethnicity may affect growth. The earlier work of Chang et al. Supports this idea in an Asian population[9].

When we compare the measurement technique to studies the manual tracing method follows the principles described by Smith et al[7]. Gives a better approach, than the early work of Goldstein et al.[6],who mainly used TCD because the technology was limited time. The intra-observer reproducibility (ICC = 0.98) we achieved is higher than the inter-observer concordance correlation coefficient of 0.91 reported by Vulturar et al. In their study on volume[10]. The higher reproducibility shows that the standardized protocol, for 2D area measurement is reliable.

When we looked at the data we saw that the cerebellar area has a correlation, with the known measures TCD (r = 0.94) and HC (r = 0.93). We also saw that the cerebellar area matches the findings of Alpay et al. Alpay et al. Reported a coupling, between dimensions and overall cephalic growth. The clinical meaning is that the cerebellar area is not an isolated metric. The cerebellar area fits into the existing framework. The cerebellar area adds to the framework than replacing it[11].

4.2 .Clinical Utility and Future Directions

The clinical utility of this nomogram is substantial. We look at the cerebellar area measurement. When the cerebellar area measurement stays below the 5th percentile we think about conditions, like cerebellar hypoplasia. Global cerebellar hypoplasia can be linked to a variety of syndromes and can lead to poor brain development outcomes[12].When the cerebellar area measurement goes above the 95th percentile we think about conditions that cause expansion of the posterior fossa. Conditions such as a Dandy-Walker variant or a Blakes pouch cyst can cause expansion of the fossa[13].The cerebellar area measurement gives a two- dimensional quantitative approach . The cerebellar area measurement when combined with the look at cerebellar shape and the single-line TCD measurement, can make the screen, for anomalies more sensitive[14].

The lack of a significant correlation, between the area and maternal BMI is a noticeable sign. The lack of a correlation matches the results of a study by Hendler et al. On the impact of maternal obesity, on sonography[15]. The lack of a significant correlation indicates that the cerebellar area is a strong marker of fetal cerebellar growth. The lack of a correlation shows that the cerebellar area works on its own not depending on maternal body habitus, unlike visualization of other fetal structures which are might

impaired by increasing maternal weight .

Limitations: The main limitation of the study is that the study was done at a single center and used 150 participants. So that the study had data to show links but the study may give less accurate percentiles at the very early and very late weeks of pregnancy such, as 18 weeks and 38 weeks because the study had fewer participants at those ages. The study showed, intra-observer variability was low. The study did not assess inter-observer variability. We believe future research should involve collaborations to validate these nomograms in the more diverse populations. And also future research should check inter-observer agreement.

5. Conclusion

The study provides a set of 2D-US charts, for the cerebellar area. The charts come from a described group of 150 patients. The data show a linear growth through the second and third trimesters. The cerebellar area is a reliable measurement. We find that the cerebellar area can be added easily to screening. the use of the area may improve detection of back of brain problems. The use of the area can improve diagnosis counseling and perinatal care. We recommend studies. The new studies should validate the reference values in settings. The new studies should also evaluate the accuracy of the reference values, in populations, with confirmed fossa anomalies.

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Conflict of interest statement: The authors have no conflict of interest with respect to the publication of this article.

Ethical Consideration: The ethical committee approved the study at University of Thi-Qar 64001, Iraq.

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