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Original Research

Normal Standard TCD/AC Ratio for the Evaluation of Intrauterine Growth Restriction in Singleton Fetuses

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Abstract

Background: Intrauterine growth restriction is associated with increased fetal mortality rate, and its early detection is important for determining delivery timing and planning neonatal care. This study aimed to examine the usefulness of the fetal transverse cerebellar diameter (TCD) to abdominal circumference (AC) ratio in fetal growth evaluation that can predict intrauterine growth restriction and propose a reference value for normal Korean fetuses. **Methods**: This study included a total of 1011 fetuses between 19 and 34 weeks of gestation from January 2021 to December 2022. A simple regression analysis was conducted to determine the relationship between TCD and AC and gestational age, and the normal mean values and percentiles of the TCD/AC ratio by gestational age were calculated. **Results**: TCD and AC correlated strongly with gestational age, increasing along with gestational age. The TCD/AC ratio in normal fetuses between 19 and 34 weeks of gestation was 13.26, with a 95th percentile of 14.39. **Conclusions**: The TCD/AC ratio can be utilized as a useful variable to predict intrauterine growth restriction when evaluating the growth of Korean fetuses. Furthermore, close observation is required when the TCD/AC ratio exceeds 14.39, allowing for early prediction and management of intrauterine growth restriction.

Keywords: fetal growth; intrauterine growth restriction; transverse cerebellar diameter; abdominal circumference

1. Introduction

Intrauterine growth restriction (IUGR) refers to the abnormal growth of the fetus during pregnancy, defined as cases wherein the size of the fetus is below the 10th percentile [1–3]. The causes of IUGR can vary, but most are associated with chromosomal abnormalities, malnutrition of the pregnant individuals, complications due to pregnancy, or a lack of adequate oxygen supply to the fetus. It affects 3–10% of all pregnancies, and regarding the perinatal mortality rate, fetuses with IUGR have a four to eight times higher risk rate than normal births. Even if the infant survives, the mortality rate reaches 50%. Thus, early detection of IUGR is crucial in determining the delivery timing and neonatal care after delivery [4].

When morphologically classifying IUGR, it can be clinically divided into symmetrical types, characterized by reduced fetus' head, femur length, abdominal circumference, and weight; and asymmetrical types, characterized by a normal head shape compared with the body. Symmetrical IUGR is caused by a relative decrease in cell proliferation from the early stage of pregnancy, resulting from genetic defects, congenital intrauterine infection, or chromosomal abnormalities; the size of the head and body becomes proportionally smaller, most commonly appearing before 28 weeks of pregnancy. Asymmetrical IUGR is almost always expressed in the third trimester and is caused by uteroplacental insufficiency, wherein oxygen and nutrients are not appropriately supplied, and brain size reduction rarely occurs [5,6]. Almost 70% of IUGR is asymmetric, and normal growth is possible if adequate nutrition is provided after birth. Therefore, an immediate response after delivery can be ensured via predicting IUGR by classifying it into one of the two types [7,8].

Fetal biometric parameters are mainly measured using ultrasound as a screening test for diagnosing IUGR, and accurately measuring gestational age plays a crucial role in determining the timing of labor induction and cesarean section. Gestational age is generally predicted by measuring the biparietal diameter, abdominal circumference (AC), and femur length [9–12]. Yet, these simple parameters are significantly affected when redistribution of cardiac output occurs along with the brain-sparing effect in fetuses with IUGR. Thus, presenting various markers is necessary to complement conventional fetal biometric parameter measurements [13,14].

According to previous studies, IUGR can increase diastolic blood flow in the fetal cerebral artery in the third trimester, cause a notch in the umbilical artery, and increase resistance in the uterine artery of the pregnant individual [15–19]. However, the cerebellum is not affected by the

growth restriction since there is no change in blood flow in the cerebellum; thus, the transverse cerebellar diameter (TCD) is the most reliable independent biometric parameter when evaluating actual gestational age, which is used to evaluate fetal growth. Fetal AC is a biometric parameter first affected by the decrease in hepatic glycogen and subcutaneous fat accumulation in IUGR, which can be used in combination with TCD for growth changes and IUGR evaluation in normal fetuses with unknown gestational age [15–19]. The ratio of fetal TCD to AC is a reliable predictor for evaluating fetal growth, with several countries having suggested ratios suitable for their demographic. Therefore, this study aimed to evaluate the relationship between fetal TCD and AC and compare it with previous reports in other countries to determine the normal TCD/AC ratio for Korean fetuses. Our objectives were to establish a reference value for the TCD/AC ratio for Korean fetuses and to assess its effectiveness in early detection and management of IUGR.

2. Materials and Methods

2.1 Sample

A total of 1011 data points were used for analysis. Pregnant women between 19–34 weeks of pregnancy and aged between 20–45 (mean: 33.2 ± 4.4) years who underwent ultrasonography as a regular examination at Ilsin Christian Hospital between January 2021 and December 2022 were included. The gestational age was determined based on the last menstrual period and confirmed by the crown-rump length of the embryo at approximately eight weeks of gestation. The final sample was selected based on these criteria to ensure accuracy and consistency in determining the gestational age. The exclusion criteria for the study were as follows: a congenital anomaly was identified; the last menstrual period and measured crown-rump length were discordant for >2 weeks; the participant had multiple gestations; and the participant had a condition that may affect the growth of the fetus, such as gestational diabetes. Ultrasonography was conducted with the pregnant participant's consent, and data measured by one examiner were used for analysis. The retrospective review of data for this study was approved by the Institutional Review Board (IRB) of the Catholic University of Pusan (CUPIRB-2022-01-003).

2.2 Measurement

To measure the TCD using ultrasonography, the longest length of both ends of the cerebellum was measured; for the AC, the circumference (including skin), was measured in a section showing the tree vertices of the left portal vein, stomach, and spine using an axial scan of the fetal liver [20,21]. The TCD/AC ratio (%) was obtained by quantifying all values in mm and multiplying them by 100 [22,23]. For the ultrasonic equipment, a 3.5 MHz curved Voluson E10 transducer from GE Healthcare (Chicago, IL, USA) was used.

2.3 Statistical Analysis

Data was analyzed using SPSS version 26.0 software (IBM Corp., Armonk, NY, USA). The minimum value, maximum value, mean and standard deviation (SD), and percentile of the TCD/AC ratio by gestational age were calculated. Percentiles were determined by first sorting the data in ascending order and then calculating the position of each desired percentile. For non-integer positions, interpolation was used between the closest ranks. The degree of correlation between variables and gestational age was expressed as a correlation coefficient (r). A simple regression was conducted to evaluate the explanatory power of the regression model. Statistical significance was defined as $p < 0.05$.

3. Results

A simple regression analysis was performed to understand the functional relationship between TCD and AC and gestational age and determine the effect of the two variables on gestational age. TCD showed a high correlation with gestational age (r = 0.982, $p < 0.001$), increasing as gestational age increased. The regression equation to predict gestational age was gestational age (GA) = 5.847 + 7.216 × TCD, indicating a correlation of determination of 0.965. AC also increased as gestational age increased (r = 0.965, $p < 0.001$), and the regression equation to predict gestational age was GA = 5.934 + 0.952 × AC, with a correlation of determination of 0.951. The correlation coefficient between TCD and AC was 0.961, showing a high correlation (Table 1).

Table 1. Correlation between GA, TCD, and AC in normal pregnancy cases (n = 1011).

Parameters compared	r	r^2	95% CI
GA and TCD	0.982	0.965	5.592–6.102
GA and AC	0.965	0.951	5.633–6.236
TCD and AC	0.961	0.924	0.545–1.313

GA, gestational age; TCD, transverse cerebellar diameter; AC, abdominal circumference; r, correlation coefficient; r^2, correlation of determination; 95% CI, 95% confidence interval.

The TCD/AC ratio exhibited a minimum value of 11.25, a maximum value of 14.97, and a total mean of 13.26. As shown in Table 2, the TCD/AC ratio was classified into the 5th, 10th, 50th, 90th, and 95th percentiles depending on gestational age. The TCD/AC ratio based on gestational age indicated a constant value, as shown in Fig. 1, and Table 3 (Ref. [23–31]) shows the normal standard values of the TCD/AC ratio for each country in previous studies.

Table 2. Fitted centiles of the normal Korean fetal TCD/AC ratio.

Gestational age (weeks)	N	Mean (SD)	Percentiles				
			5th	10th	50th	90th	95th
19∼20	71	13.30 (0.62)	12.29	12.53	13.29	14.23	14.28
21∼22	62	13.24 (0.69)	12.01	12.18	13.17	14.08	14.39
23∼24	209	13.21 (0.68)	12.26	12.33	13.23	14.09	14.31
25∼26	224	13.33 (0.69)	12.26	12.45	13.32	14.23	14.48
27∼28	110	13.03 (0.63)	12.09	12.17	13.01	13.89	14.18
29∼30	36	13.03 (1.66)	12.17	12.20	13.01	13.96	14.15
31∼32	135	13.34 (0.64)	12.33	12.57	13.31	14.10	14.38
33∼34	164	13.35 (0.62)	12.46	12.65	13.28	14.23	14.42
Total	1011	13.26 (0.66)	12.18	12.41	13.26	14.11	14.39

TCD, transverse cerebellar diameter; AC, abdominal circumference; N, values are presented as numbers; SD, standard deviation.

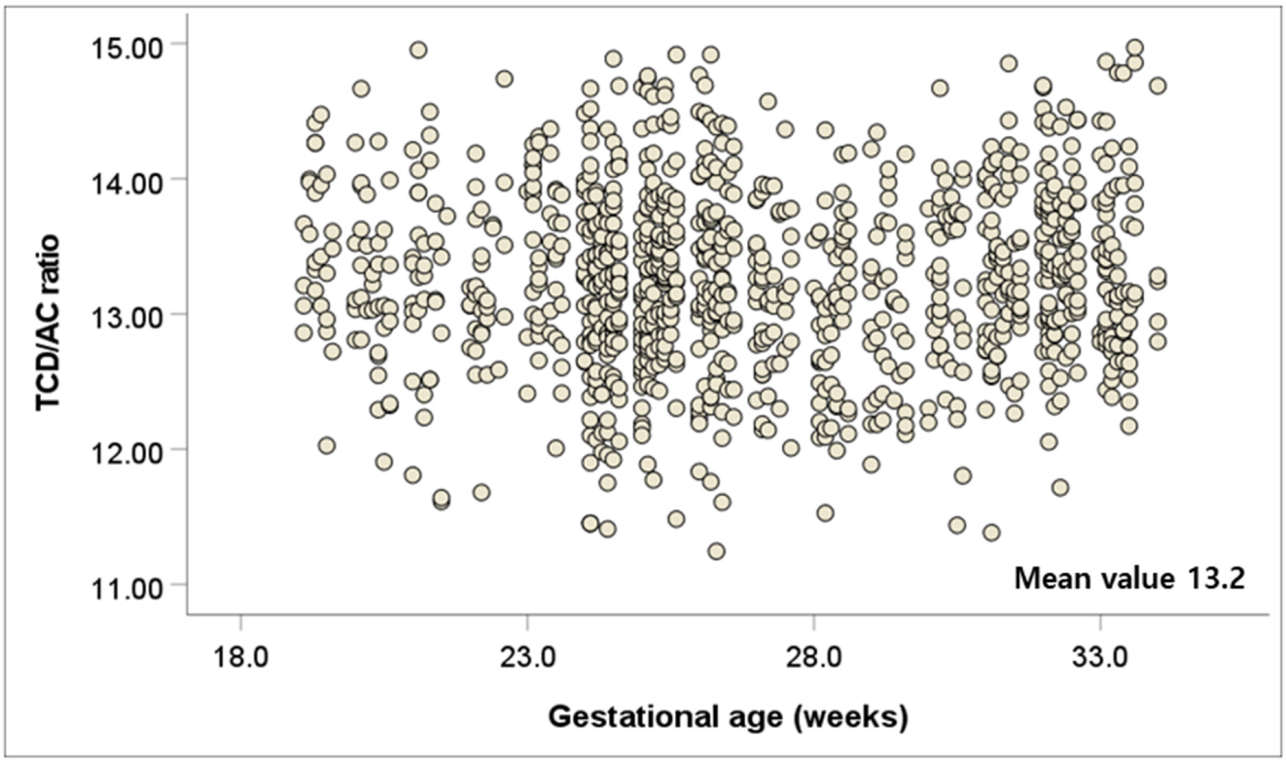

Fig. 1. Scatter diagram showing the relationship between TCD/AC ratio and gestational age in normal pregnancy cases. TCD, transverse cerebellar diameter; AC, abdominal circumference.

4. Discussion

IUGR is one of the causes of increased perinatal morbidity, including fetal asphyxia, meconium aspiration, emergency cesarean delivery, and mortality [32]. Fetuses with IUGR are at approximately twice the risk of stillbirth than those with normal growth, accounting for 1.5% of all fetuses, and the risk increases even more if growth restriction is severe. Since fetal size reflects pathophysiology, IUGR refers to poor growth, as well as all conditions related to fetal development, including fetal maturity and wellbeing [33]. Therefore, the main purpose of prenatal care is to identify the cause and determine the optimal delivery timing by monitoring fetal wellbeing when IUGR is suspected. When IUGR is defined as being below the 10th percentile of birth weight, the growth curve standard used in Korea uses data from abroad that does not consider racial and sociocultural characteristics. Hence, using it as a Korean standard is not appropriate. Although studies evaluating fetal growth according to gestational age have been steadily performed in Korea, most studies simply measured biometric parameters using ultrasound [34–37]. Additionally, these parameters may affect the accuracy of growth evaluation due to fetal growth and deformation caused by external pressure on the skull. However, TCD was found to be the most ac-

Table 3. Mean value of the TCD/AC ratio in other studies in normal pregnancy cases.

Study	Publication year	N	Mean ± SD
Present study		1011	13.26 ± 0.66
Jayaprakash *et al*. [23]	2018	148	14.59 ± 1.14
Hussain *et al*. [24]	2019	200	14.01 ± 0.74
Dhumale *et al*. [25]	2010	434	13.56 ± 1.21
Agrawal *et al*. [26]	2016	100	14.02 ± 1.20
Sharma and Ghode [27]	2015	100	13.75 ± 0.43
Ashfaq *et al*. [28]	2022	80	13.17 ± 2.21
Singh *et al*. [29]	2022	500	14.70 ± 0.01
Meyer *et al*. [30]	1993	700	13.69 ± 0.94
Dilmen *et al*. [31]	1996	330	14.36 ± 1.01

TCD/AC ratio, transverse cerebellar diameter (cm) and abdominal circumference (cm) ratio; N, values are presented as numbers; SD, standard deviation.

curate variable for predicting gestational age, even under extreme fetal growth restriction, in the TCD nomogram; this is because the TCD is not easily deformed owing to blood preservation in the cerebellum, even in the presence of IUGR [34–37].

Regarding IUGR, it has been reported that evaluating the TCD/AC ratio as a variable that may cause early deformation is a reliable and sensitive method for predicting IUGR [38]. Based on this previous study, the present study attempted to suggest a standard value for the independent TCD/AC ratio of Korean fetuses and explore its role as a marker for predicting IUGR. As a result, the mean TCD/AC ratio among 1011 normal fetuses was determined to be 13.26, indicating a constant value regardless of the change in gestational age. IUGR can be predicted at values above the 95th percentile, with the 95th percentile in this study determined to be 14.39. Thus, close observation is required to evaluate fetal growth when the TCD/AC ratio value exceeds 14.39. Exploring the study on the Western population in Table 2, the TCD/AC ratio in the normal control group showed a distribution of 13.17–14.79, which was higher than the results of our study in the Korean population. This finding is thought to reflect the difference in biological ratio between races. Most previous studies showed that the TCD/AC ratio cutoff value for IUGR was 15.40–16.00; this is 1.70–2.10 higher than that of the normal control group, indicating that the TCD/AC ratio is an ideal variable for predicting IUGR based on previous studies [23–31].

As this study was conducted retrospectively, a limitation arises from the inability to conduct a prospective comparison between the control group identified in previous studies and the IUGR experimental group, which may lead to biased results. Therefore, a prospective study on a larger scale is needed in the future. However, this study is significant as it is the first of its kind in Korea, where few studies have been attempted. Moreover, as the number of low-birth-weight infants due to advanced maternal age increases, it is expected that the results of this study will be used as an auxiliary means for predicting IUGR.

5. Conclusions

This study presented the mean percentile value of the TCD/AC ratio among 1011 Korean fetuses between 19–34 weeks of gestation. The TCD/AC ratio had a mean value of 13.26, regardless of gestational age, with a 95th percentile value of 14.39. Therefore, the suggested TCD/AC ratio can be used as a useful variable to evaluate normal fetal growth and predict IUGR.

Abbreviations

AC, abdominal circumference; IUGR, intrauterine growth restriction; TCD, transverse cerebellar diameter.

Availability of Data and Materials

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Author Contributions

SHY and DYL designed the research study. SHY performed the research. DYL analyzed the data. Both authors contributed to editorial changes in the manuscript. Both authors read and approved the final manuscript. Both authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

The retrospective review of data for this study was approved by the Institutional Review Board (IRB) of the Catholic University of Pusan (CUPIRB-2022-01-003). Ultrasonography was conducted with the pregnant participants' consent, and data measured by one examiner were used for analysis.

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Conflict of Interest

The authors declare no conflict of interest.

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