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Finding the most accurate method to measure head circumference for fetal weight estimation

Ulrike Schmidt [a], Dunja Temerinac [a,b], Katharina Bildstein [b], Benjamin Tuschy [a], Jade Mayer [a], Marc Sütterlin [a,b], Jörn Siemer [c], Sven Kehl [a,d,*]

[a] Department of Obstetrics and Gynecology, University Medical Centre Mannheim, Heidelberg University, Mannheim, Germany
[b] Department of Obstetrics and Gynecology, Stadtklinik Frankenthal, Frankenthal, Germany
[c] Department of Obstetrics and Gynecology, Klinikum Pforzheim, Pforzheim, Germany
[d] Department of Obstetrics and Gynecology, Erlangen University Hospital, Erlangen, Germany

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ABSTRACT

Objective: Accurate measurement of fetal head biometry is important for fetal weight estimation (FWE) and is therefore an important prognostic parameter for neonatal morbidity and mortality and a valuable tool for determining the further obstetric management. Measurement of the head circumference (HC) in particular is employed in many commonly used weight equations. The aim of the present study was to find the most accurate method to measure head circumference for fetal weight estimation.
Study design: This prospective study included 481 term pregnancies. Inclusion criteria were a singleton pregnancy and ultrasound examination with complete fetal biometric parameters within 3 days of delivery, and an absence of structural or chromosomal malformations. Different methods were used for ultrasound measurement of the HC (ellipse-traced, ellipse-calculated, and circle-calculated). As a reference method, HC was also determined using a measuring tape immediately after birth. FWE was carried out with Hadlock formulas, including either HC or biparietal diameter (BPD), and differences were compared using percentage error (PE), absolute percentage error (APE), limits of agreement (LOA), and cumulative distribution.
Results: The ellipse-traced method showed the best results for FWE among all of the ultrasound methods assessed. It had the lowest median APE and the narrowest LOA. With regard to the cumulative distribution, it included the largest number of cases at a discrepancy level of ±10%. The accuracy of BPD was similar to that of the ellipse-traced method when it was used instead of HC for weight estimation.
Conclusion: Differences between the three techniques for calculating HC were small but significant. For clinical use, the ellipse-traced method should be recommended. However, when BPD is used instead of HC for FWE, the accuracy is similar to that of the ellipse-traced method. The BPD might therefore be a good alternative to head measurements in estimating fetal weight.

Introduction

Accurate fetal weight estimation (FWE) is an important prognostic parameter for neonatal morbidity and mortality and is a valuable tool for determining the further obstetric management [1]. Fetal biometry using ultrasound has therefore become part of routine practice in obstetrics. Standard fetal biometry measurements – such as abdominal circumference (AC), femur length (FL), biparietal diameter (BPD), and head circumference (HC) – are used in many formulas. However, the accuracy of these formulas appears to be generally poor [2], and accurate head measurement of the fetus is essential [3]. There is general agreement on the sonographic plane at which HC and BPD should be measured: it is the transverse section at the level at which the continuous midline echo is broken by the cavity of the septum pellucidum in the anterior third [4]. However, ways of calculating the HC have not been standardized, and it can be done with different methods. The aims of the present study were to compare different methods of calculating head circumference and to determine the most accurate one for FWE.

* Corresponding author at: Department of Obstetrics and Gynecology, University Medical Centre Mannheim, Heidelberg University, Theodor-Kutzer-Ufer 1-3, 68167 Mannheim, Germany. Tel.: +49 621 383 3447/+49 17660025334; fax: +49 621 383 5074.
E-mail address: sven.kehl@gmail.com (S. Kehl).

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Material and methods

A prospective multicenter study was conducted between March and December 2011 at the Perinatal Center at the University Medical Centre Mannheim, Mannheim, Germany, the Department of Obstetrics and Gynecology, Stadtklinik Frankenthal, Frankenthal, Germany, and the Department of Obstetrics and Gynecology, Ludmillenstift Hospital, Meppen, Germany.

Pregnant women with singleton pregnancies and a fetus in cephalic presentation at term (≥259 days of gestation) were recruited consecutively by the physicians in the labour. Oral informed consent was obtained. The ultrasound examination with complete biometric parameters – BPD, occipitofrontal diameter (OFD), HC, AC and FL – was carried by a total of seven different examiners. When onset of labour was excluded, the women left the hospital and measurement was repeated during the next admission, if the last assessment of fetal biometry was not undertaken within the last three days. Each fetus was included only once. Pregnancies with structural or chromosomal malformations, as well as intrauterine fetal deaths, were excluded. The gestational age was defined by the measurement of crown-rump length in the first trimester [5,6]. For all measurements, a Samsung Medison SonoAce R7 (Sonoace Ltd., Marl, Germany) was used with standard techniques [3,7].

Three different methods were used to calculate the sonographic HC. First (in the ellipse-calculated method), the BPD is measured at the largest distance from the outer edges of the skull at the level of the cavity of the septum pellucidum [8]. Measurements of the OFD are done in the same plane, between the outer edge of the frontal bone and the outer edge of the occiput. The following formula is used to estimate the HC from the measurements of the OFD and BPD: $HC = \pi \times \sqrt{[(BPD^2 + OFD^2)/2]}$. Kurmanavicius et al. have described this method (the ellipse-calculated method) in detail previously [3].

The second method (the ellipse-traced method) involves measuring the HC by placing an ellipse around the outer edge of the fetal skull. The ultrasound machine automatically determines the longest (DL) and shortest diameter (DS). The distances measured are then inserted into the above-mentioned formula for the ellipse-calculated method.

In the third method (the circle-calculated method), the same BPD and OFD measurements from the ellipse-calculated method are used in a different equation for calculating the HC: $\pi \times [(ATD + APAD)/2]$ [7].

As a reference value for the sonographic measurements, together with the birth weight, HC was also measured in the neonates within 1 hour after delivery. The measuring tape was placed along the maximum horizontal plane, along the occipital prominence at the back, above the ears, and directly above the eyebrows at the front. The postnatal HC measurement is very reliable, with extremely high correlation coefficients for both intraobserver (0.999) and interobserver (0.979) measurements [9,10].

Fetal weight estimation with the four different methods of HC calculation (ellipse-traced, ellipse-calculated, circle-calculated, and postpartal) was done using the Hadlock formula (HC, AC, FL) [11]. In previous studies, our group and others have shown that the Hadlock formulas are among the most accurate weight equations for term fetuses, and they have therefore been adopted as the clinical standards in our institutions [2,12–14]. In addition to HC, FWE was also determined with another Hadlock formula, using the BPD instead (BPD, AC, FL) [11]. In contrast to our BPD and HC measurements, the measuring track was set between the outer and the inner edge of the skull bone in the original publication of Hadlock.

The accuracy of the estimated fetal weight (EFW) was assessed by calculating the percentage error (PE; $(EFW - BW)/BW \times 100$) and the absolute percentage error (APE; $|EFW - BW|/BW \times 100$). The mean PEs for all the equations were compared with zero using the *t*-test at a significance level of 5% in order to assess whether any significant systematic bias had occurred. A variance test for the PE values was performed using the Pitman method [15,16]. At a significance level of 5% and with a sample size of more than 400, *R* values greater than 0.098 were significant. For APE values, differences between the various techniques were compared using Wilcoxon's test at a significance level of 5%.

The limits of agreement (LOA) method described by Bland and Altmann [17] was also used. The overall mean difference between the derived fetal weight and BW refers to the extent of systematic error, whereas the LOA refers to random error. The 95% LOA indicates what difference between the real BW and the EFW can be expected, and what tendency (to underestimate or to overestimate) is commonly found.

Percentages of fetal weight estimations falling within discrepancy levels of ±10% of the actual BW were also calculated for each technique. Differences between the postpartal measurements and the sonographic equations were compared using McNemar's test. *P* values ≤0.05 were considered to be significant.

The Statistical Package for the Social Sciences (SPSS), version 15.0.1 (2006; SPSS, Inc., Chicago, Illinois, USA) was used for statistical evaluation.

Results

A total of 458 women was included in this study. The median maternal age was 30, ranging from 18 to 46 years. The gestational age ranged from 37 weeks to 42 weeks, with a median gestational age of 39 weeks 5 days. The median gravidity was 2 (range from 1 to 8) and the parity including the delivery in this study 1 [1–7]. The period between ultrasound measurement and delivery was 1 day, ranging from 0 to 3. The median birth weight was 3380 g (2160–4785). The postpartal HC measurements ranged from 312 mm to 402 mm, with a median of 350 mm. There were 13 newborns with a birth weight below 2500 g and 28 with 4000 g or more.

The results of the different ultrasound measurements for HC and BPD are shown in Table 1. When the Hadlock formulas were used to estimate fetal weight, all of the methods for the HC significantly underestimated fetal weight. It was only when the BPD was used that no systematic error was found in the PE (Table 2). As an indicator of random error, the SD of the reference method (postpartal HC) was compared with all of the other methods; the variance test only showed a significant difference with the BPD formula in this case (Table 2).

The APEs are shown as median values and ranges in Table 2. The lowest median APE was found for the ellipse-traced method. In comparison with the reference method, only the circle-calculated measurements were significantly larger.

Table 3 illustrates the limits of agreement between the fetal weight estimates and true birth weight. FWE calculated with the postpartal HC measurements demonstrated the narrowest LOA. The BPD method showed the smallest tendency to either overestimate or underestimate fetal weight.

Table 1
Head circumferences, either calculated using the three different ultrasound methods or measured after birth, and sonographic biparietal diameter of the head (BPD) (in mm).

	Median (range)
BPD	95.1 (81.5 to 113.1)
Ellipse-traced	338.0 (288.7 to 394.4)
Ellipse-calculated	329.9 (290.9 to 386.5)
Circle-calculated	328.5 (290.6 to 384.1)
Postpartal	350.0 (312.0 to 402.0)

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