ACCURACY OF SONOGRAPHIC FETAL WEIGHT PREDICTION – EVALUATION OF SEX-SPECIFIC FORMULAS

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ABSTRACT

Traditional evaluation of fetal weight is performed by means of ultrasonography and mathematical formulas using combinations of biometric parameters, like abdominal circumference (AC), head circumference (HC), biparietal diameter (BPD), femur length (FL). It was recently shown that mentioned parameters and intrauterine growth patterns demonstrate gender-related differences. These reports were used to develop new formulas which take into account the influence of fetal sex. The aim of this paper was to determine the accuracy of ultrasound fetal weight estimations with use of many different formulas, test sex-specific formulas against established methods and to compare their precision in different weight groups. This retrospective study included 97 singleton fetuses with birth weight (BW) between 1040 g and 4740 g and ultrasound examination within 7 days before delivery. Estimated fetal weight (EFW) was calculated by Hadlock, Shepard, Campbell and Merz formulas and sex-specific models of Schild and Melamed. EFW was confronted with actual BW. Achieved results were compared in a few groups considering gender and BW. The accuracy of fetal weight estimations turned out to be higher for males regardless of the used formula. For the whole study population, the best accuracy was proved for Melamed formulas and the worst for models of Shepard and Merz. The highest precision of predictions was revealed in the group of newborns with BW 2500 – 3999 g. Estimated errors for low birth weight (LBW) infants and macrosomic fetuses were more significant. In most cases, new sex-specific formulas provide smaller mean errors than established methods.
BACKGROUND

Evaluation of fetal weight is a significant part of contemporary obstetrics. Knowledge of the expected birth weight allows to predict and decrease the risk of complications associated with fetal macrosomia (e.g. shoulder dystocia, prolonged second stage of labor, serious maternal trauma after delivery, increased postpartum hemorrhage) [1]. It helps to determine proper mode of delivery and plan the most suitable postnatal care. Moreover, estimated fetal weight (EFW) is an essential variable affecting perinatal morbidity and mortality in cases of IUGR. It provides detection of growth restrictions and gives opportunity for early implementation of intensive surveillance.

Commonly used method of fetal weight estimation is performed by means of ultrasonography and special mathematical formulas using combinations of obtained biometric parameters like abdominal (AC) and head circumference (HC), biparietal diameter (BPD) and femur length (FL).

The beginning of ultrasound evaluations dates back to the 70s of the last century, when correlation between AC and birth weight (BW) was noticed and a first, relatively simple, formula was created [2]. Over time, new formulas containing more parameters were developed and by the end of the 1980s formulas widely used today were established [2, 3, 4, 5]. Nowadays there are at least 30 published formulas and the most popular ones are included in ultrasound equipment packages.

Recent studies proved gender-related dissimilarities between intrauterine growth patterns [6, 7]. These reports were used to develop new models which, besides standard biometric parameters, consider also the influence of fetal sex [8, 9].

The aim of this study was to determine the accuracy of ultrasound fetal weight estimations with use of many different formulas, test sex-specific equations against established methods and compare their precision in different weight groups.

MATERIALS AND METHODS

This retrospective study was performed in a tertiary referral center in Wroclaw and included 97 liveborn, singleton fetuses delivered in 2016. Pregnancies complicated by fetal malformations and hydrops were omitted. Ultrasound examinations were performed within 7 days (median = 1; mean = 2.2; SD = 1.92) before delivery by means of GE Voluson E8. Measurements were performed by several physicians. EFW was calculated by unadjusted Hadlock, Shepard, Campbell and Merz formulas and sex-specific models of Schild and Melamed (Table 1).

Subsequently, EFW was confronted with actual BW and its accuracy was evaluated by calculating the absolute percentage error (APE = |EFW - BW|/BW x 100). Mean of absolute percentage error (MAPE) was indicated for: whole population, three weight groups (<2500 g; 2500 - 3999 g; >= 4000 g) and for each gender.

Statistical analysis was performed with the use of PQStat v1.6.4. Formulas were compared with the Student’s t-test and the differences were considered significant at P < 0.05.

RESULTS

BWs of included newborns ranged between 1040 g and 4740 g (mean = 2868 g; SD = 849.5). There were 45 (46%) females and 52 (54%) males. For the whole study population, the best precision was achieved for Melamed I and II formulas (both MAPE = 7.3%), which turned out to be significantly more accurate than all other equations mentioned in this paper (P < 0.03). The greatest value of MAPE was seen in Merz (11.4%) and Shepard formulas (11.5%) (Figure 1). The accuracy of fetal weight estimations was higher for males regardless of the used equation (Figure 2).

The most precise prediction was seen in eutrophic newborns (BW < 2500 g, n = 44). In this group, the lowest MAPE was achieved with sex-specific formulas of Schild (5.9%), Melamed I (6%), Melamed II (6%). Least accurate were the models of Shepard (MAPE = 10.5%) and Merz (MAPE = 8.8%) and they were significantly less precise than sex-specific equations (P < 0.002) (Figure 3).

Amongst low birth weight (LBW) infants (BW < 2500 g, n = 24), EFW was burdened with greater MAPE and formulas of Melamed were proved to be the most accurate (MAPE = 8.1%). In contrast, Merz formula showed the lowest level of accuracy (MAPE = 20.2%) in this weight range (Figure 4).

In opposition to all other groups, among macrosomic fetuses (BW >= 4000 g, n = 17) models of Merz and Shepard were associated with the lowest MAPE (7.8% and 8.9%, respectively) (Figure 5).

DISCUSSION

According to recent studies, there are some gender-related dissimilarities between intrauterine growth patterns. Fields et al. proved that full-term female newborns have more fat and less fat-free mass than males and these differences are statistically significant [8]. On average, boys are characterized by a greater BW than girls [9]. Sex-related discrepancies in fetal BPD, HC, AC but not FL were described by Schwärtzer et al. [9]. It was also shown that the accuracy of fetal weight estimations is significantly higher among males [10].

On the basis of these reports Schild and Melamed developed sex-specific formulas for EFW [6, 7]. There are only few studies verifying the precision of the new models but they gave very promising results for improving ultrasound predictions [7, 10, 11, 12]. On the other hand, the accuracy of mentioned formulas was assessed using a similar population to that from which they were generated, by the same authors or coworkers. This could potentially lead to overestimations so it was found important to investigate gender-specific models in an independent study in a Polish population.

The results presented in this paper remain consistent with works of Melamed et al. [7, 10] (n = 3416; n = 3672, respectively) and Siemer et al. [11] (n = 1941) which confirmed the predominance of new models in the whole
range of BW and especially in 2500 – 3999 g weight group.

Another fact revealed by the study was that for small fetuses (BW < 2500 g) Melamed formulas were associated with the best accuracy in contrast to Merz equation, which produced the greatest MAPE. The latter model does not appear to be useful for this subgroup. It is worth considering, because such differences may affect the obstetric management of LBW newborns, where complications are particularly suspected.

Accurate estimation of fetal weight is also a relevant parameter when macrosomia is expected and can determine the mode of delivery. In the current study, the Merz formula turned out to be the most suitable method for macrosomic fetuses.

Surprisingly, females demonstrated greater value of MAPE using all equations, even sex-specific ones. It may suggest that some intra-class differences of intrauterine growth pattern exist among females which complicates matching universal statistical method of assessment for this gender.

CONCLUSIONS

The accuracy of ultrasound fetal weight estimation is influenced by fetal sex, actual BW and used formula. The best precision of predictions is obtained in the group of male fetuses with BW between 2500 and 3999 g. Less accuracy of EFW among LBW infants and macrosomic newborns is probably caused by bigger diversity of intrauterine growth patterns compared to eutrophic fetuses. Gender-related equations provide smaller mean errors than established methods and improve the precision of estimates in all cases except fetal macrosomia.

Considering the above, it may be reasonable to develop formulas targeted for specific subgroups characterized by different growth models.

CITE THIS AS


ABBREVIATIONS

AC – abdominal circumference
APE – absolute percentage error
BPD – biparietal diameter
BW – birth weight
EFW – estimated fetal weight
FL – femur length
HC – head circumference
IUGR – intrauterine growth restriction
LBW – low birth weight
MAPE – mean of absolute percentage error

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Fig. 4. MAPE for each regression formula over the total weight range confronted to newborns with BW <2500 g.

Fig. 5. MAPE for each regression formula over the total weight range confronted to newborns with BW >= 4000 g.

**TAB. 1. CHARACTERISTICS OF FORMULAS INVESTIGATED IN PRESENT STUDY.**

<table>
<thead>
<tr>
<th>Formula</th>
<th>Year of publication</th>
<th>Parameters</th>
<th>Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Campbell, Wilkin [2]</td>
<td>1975</td>
<td>AC</td>
<td>$\log_e EFW = - 4.564 + 0.282(AC) - 0.00331(AC^2)$</td>
</tr>
<tr>
<td>Shepard [3]</td>
<td>1982</td>
<td>AC, BPD</td>
<td>$\log_{10} EFW = - 1.7492 + 0.166(BPD) + 0.046(AC) - 2.646(AC) \times (BPD)/1000$</td>
</tr>
<tr>
<td>Hadlock (I) [4]</td>
<td>1985</td>
<td>AC, BPD, FL</td>
<td>$\log_{10} EFW = 1.5662 - 0.0108(HC) + 0.0468(AC) + 0.171(FL) + 0.00034(HC^2) - 0.003685(AC) \times (FL)$</td>
</tr>
<tr>
<td>Schild (females) [6]</td>
<td>2004</td>
<td>AC, BPD, FL</td>
<td>$EFW = 43576.579 + 1913.853 \times \log_{10}(BPD) + 0.01323(HC^3) + 55.532(AC^2) - 13602.664(AC^{1/2}) - 0.721(AC^3) + 2.31(FL^3)$</td>
</tr>
<tr>
<td>Schild (males) [6]</td>
<td>2004</td>
<td>AC, BPD, FL, HC</td>
<td>$EFW = 43576.579 + 1913.853 \times \log_{10}(BPD) + 0.01323(HC^3) + 55.532(AC^2) - 13602.664(AC^{1/2}) - 0.721(AC^3) + 2.31(FL^3)$</td>
</tr>
<tr>
<td>Melamed (I) (females) [7]</td>
<td>2012</td>
<td>AC, BDP, FL, HC</td>
<td>$\ln EFW = 2.64735 - 0.01161(AC)(FL) + 0.01366(HC) + 0.11794(AC) + 0.47650(FL) + 0.00117(AC)(BPD)$</td>
</tr>
<tr>
<td>Melamed (I) (males) [7]</td>
<td>2012</td>
<td>AC, BDP, FL, HC</td>
<td>$\ln EFW = 2.33375 - 0.00483(AC)(FL) + 0.06371(HC) + 0.12748(AC) + 0.25083(FL) + 0.04006(BPD) - 0.00150(AC)(HC)$</td>
</tr>
<tr>
<td>Melamed (II) (females) [7]</td>
<td>2012</td>
<td>AC, BDP, FL, HC</td>
<td>$\ln EFW = 2.65191 + 0.10405(AC) - 0.00088(AC^2) + 0.53721(FL) + 0.01398(HC) - 0.03125(FL^2) + 0.00220(BPD^2)$</td>
</tr>
<tr>
<td>Melamed (II) (males) [7]</td>
<td>2012</td>
<td>AC, BDP, FL, HC</td>
<td>$\ln EFW = 2.21686 - 0.00824(AC)(FL) + 0.09304(HC) - 0.00122(HC^2) + 0.10260(AC) + 0.31613(FL) + 0.00566(FL)(BPD)$</td>
</tr>
</tbody>
</table>
FIG. 1. MAPE FOR EACH REGRESSION FORMULA OVER THE TOTAL WEIGHT RANGE.

FIG. 2. MAPE FOR EACH REGRESSION FORMULA IN MALES AND FEMALES.
FIG. 3. MAPE FOR EACH REGRESSION FORMULA OVER THE TOTAL WEIGHT RANGE CONFRONTED TO NEWBORNS WITH BW 2500-3999 G.

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