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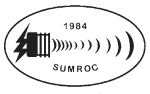

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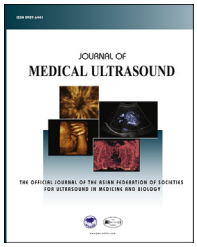

Original Article

A Systematic Evaluation of Ultrasound-based Fetal Weight Estimation Models on Indian Population

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Abstract *Background:* The purpose of this study was to systematically evaluate ultrasound-based fetal weight estimation models on Indian population to find out their performance across different weight bands and ability to correctly categorize low birth weight (LBW) and high birth weight (HBW) fetuses.
Methods: We used retrospectively collected data of 154 cases for the study. Inclusion criteria were a live singleton pregnancy, gestational age $\geq$34 weeks and ultrasound scan to delivery duration $\leq$7 days. Cases with fetal growth restriction or malformation were excluded. The cases were divided into standard weight bands of 500 g each based on newborns' actual birth weights (ABW). For each weight band, performance of 12 different models based on abdominal circumference (AC), biparietal diameter (BPD), head circumference (HC) and femur length (FL) was evaluated by mean percentage error (MPE) and its standard deviation (random error). Sensitivity and positive predict value (PPV) of models to categorize LBW (ABW $\leq$ 2500 g) and HBW (ABW $>$3500 g) neonates were also evaluated.
Results: We observed a significant variation in MPE of the 12 models with no single model being consistently superior across all the weight bands. For the cases with birth weight $\leq$3000 g, the Woo (AC-BPD) model was found to be more appropriate, whereas for the cases with birth weight $>$3000 g the Woo (AC-BPD-FL) model was found more appropriate. In general, models had a tendency to overestimate fetal weight in LBW neonates and underestimate it in HBW neonates. Overall, the models showed poor sensitivity and PPV to categorize LBW and HBW neonates. The highest sensitivity (57.1%) for LBW identification was observed with the Woo (AC-BPD) model; the highest PPV (50%) for HBW neonate identification was observed with the Hadlock (AC-HC), Warsof (AC-BPD) and Combs (AC-HC-FL) model.
Conclusion: We found that the existing fetal weight estimation models have high systematic and random errors on Indian population, with a general tendency of overestimation of fetal weight in the LBW category and underestimation in the HBW category. We also observed that

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these models have a limited ability to predict babies at a risk of either low or high birth weight. It is recommended that the clinicians should consider all these factors, while interpreting estimated weight given by the existing models.

Introduction

The ultrasound-based weight estimation is a well-established and routinely practiced method for intrauterine fetal well-being assessment. The ultrasound-based methods have evolved over a period of time with researchers proposing a number of models with different combinations of fetal biometry parameters. However, these models are shown to have high systematic and random errors associated with them; moreover, due to difference in population characteristics no single model has been shown to applicable for all populations [1,2]. Therefore, thorough validation studies are required before application of these models in routine practice [3].

For the existing ultrasound-based models, apart from Hebbar [4] and Hiwale et al. [2] not many validation studies have been carried on Indian population. These studies have observed that the existing models have high errors on Indian population. Both of these studies have evaluated performance of different models on an entire range of birth weights without any categorization in weight bands. However, it is known that the ultrasound-based models behave differently in different weight bands with high errors at the extreme ends of a birth weight range [1,5,6]. This behavior can introduce errors in fetal weight estimation leading to either missed or unnecessary interventions in low birth weight (LBW) or high birth weight (HBW) fetuses. Therefore, it is very important to have a reliable information on accuracy of existing models across standard weight bands in addition to information on the entire range of birth weights.

The high error associated with the existing models coupled with a lack of information on their accuracy across weight bands put Indian practitioners at a disadvantage. This study is an attempt to address this gap in the literature with in an objective to systematically evaluate performance of the existing models across the weight bands.

Material and methods

Study population

For the study, de-identified records of pregnant women were obtained from an archival (year 2013) of a tertiary care hospital in Bengaluru (Bangalore), India. These records were then scrutinized for inclusion and exclusion criteria. Inclusion criteria for the study were a live-birth singleton pregnancy, gestational age more than or equal to 34 weeks, and the last ultrasound scan to delivery duration less than equal to seven days. All the cases with pre-gestational or gestational diabetes, suspected fetal malformation or anomaly were excluded to avoid any bias in weight estimation. The cases with small for gestational age (SGA) newborns were also excluded due to sub-optimal performance of routine ultrasound-based models on theses fetuses [6]. All the cases with complications other than the exclusion criteria were included in the study.

For inclusion, gestational age was determined using the date of last menstrual period (LMP) or by the earliest ultrasound scan when LMP dates were not available. All ultrasound scans were performed by experienced radiologists using standard protocols. Weights of all newborn babies were measured immediately after birth. The SGA cases (birth weight $<$ 10th percentile for gestational age) were excluded using customized percentile charts by Mikolajczyk et al. for Indian population [7].

The retrospective data used for the study was obtained in accordance with local regulations after approval of an ethical committee in writing.

Selection of the models

For the study, we selected only those models, which on Indian population have shown systematic error within $\pm$10% in earlier studies. We selected 10% as a threshold because any model with more than $\pm$10% variation in estimated fetal weights is likely to be of a limited use in clinical practice [1]. To find out the relevant models a comprehensive literature search was conducted on the databases of Medline, Google scholar, general internet sources and reference lists of relevant papers. Selection was restricted to models based on combinations of four routinely used biometry parameters, such as abdominal circumference (AC), biparietal diameter (BPD), head circumference (HC) and femur length (FL).

All the selected 12 models (Table 1) were implemented in MATLAB® (MATLAB 9. 0.0.341360, The MathWorks Inc., Natick, MA, 2016). For each case, fetal weight was estimated by all the selected models using ultrasound parameters from the last week of pregnancy.

Categorization of cases in weight bands

To evaluate performance of the models across weight bands, all the cases were divided based on newborns' birth weights into standard weight bands of 500 g each. In each of these weight bands, performance of the different models was evaluated by comparing actual birth weights (ABW) with estimated fetal weights (EFW) given by the different models. Accuracy information provided by this approach is useful for comparative analysis of the models; therefore

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