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ORIGINAL ARTICLE

Accuracy of sonographic estimated fetal weight in suspected macrosomia: the likelihood of overestimating and underestimating the true birthweight

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ABSTRACT

Objective: Macrosomia has increased risk of serious adverse outcomes for both infants and their mothers. As such, many providers recommend induction of labor or cesarean delivery (CD) based on sonographic estimated fetal weight (sonoEFW) cutoffs. It is known that sonoEFW is a poor predictor of birthweight (BW), especially at the extremes of weight. It is not clear, however, whether sonoEFWs tend to underestimate or overestimate the true BW among fetuses with suspected macrosomia. The objective of this study was to compare rates of overestimation of BW among women with suspected macrosomia by sonoEFW.

Methods: This was a retrospective cohort study of women who presented to a single maternal–fetal medicine ultrasound unit within 2 weeks prior to delivery from January 2011 to November 2017. We identified women who received a sonoEFW ≥4000 g. The study sample was divided into four sonoEFW categories: 4000–4249, 4250–4499, 4500–4749, and ≥4750 g. Accuracy of sonoEFW was compared across groups, with the primary outcome being overestimation of BW.

Results: A total of 502 patients were included, of whom 301 (60.1%) had a sonoEFW 4000–4249 g, 135 (26.9%) had a sonoEFW 4250–4499 g, 45 (9.0%) had a sonoEFW 4500–4749 g, and 21 (4.2%) had a sonoEFW ≥4750 g. In each sonoEFW group, the risk of overestimating BW was greater than 50%, and the likelihood of overestimation of BW increased significantly across sonoEFW groups (69.4, 76.3, 80.0, 95.2%, $p < .001$). This held true after adjusting for differences in baseline characteristics, including diabetes and amniotic fluid index. BW ≥4500 g was not accurately predicted. Among women with sonoEFW 4500–4749 g, only 28.9% delivered a neonate with a BW >4500 g; for women with a sonoEFW ≥4750 g, only 47.6% had a BW >4500 g. One hundred sixty-one (32.1%) women underwent CD for suspected macrosomia. Of these CDs, 48 (29.8%) of neonates had a BW <4000 g and 134 (83.2%) had a BW <4500 g.

Conclusion: In patients undergoing sonoEFW within 2 weeks of delivery, sonoEFWs ≥4000 g are significantly more likely to overestimate than underestimate the true BW. Obstetricians should be cautious about intervening based on sonoEFW alone, given the high risk that this value is an overestimation of the true weight.

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Cesarean delivery; induction of labor; macrosomia; sonographic estimated fetal weight

Introduction

The prevalence of macrosomia, defined as a birthweight (BW) ≥ 4000 g or ≥4500 g regardless of gestational age (GA), has increased in the USA over the last two decades; today neonates with BW ≥4000 g account for 8% of all deliveries [1,2]. It is unclear, however, how accurately macrosomia is predicted prior to delivery. Identifying suspected macrosomia is important, as macrosomic neonates have increased risk of birth injuries, shoulder dystocia, and respiratory complications while mothers have increased risk of postpartum hemorrhage, higher order perineal lacerations, and cesarean delivery (CD) [3–5].

Fetal weight estimation is a routine part of prenatal care that allows providers to plan optimal modes of delivery and assess risk [6]. This can be done clinically or using ultrasound estimated fetal weight (sonoEFW). In the setting of a suspected large fetus, sonoEFW is currently the preferred method to make decisions regarding delivery [7]. SonoEFW uses 2-dimensional ultrasound imaging to record fetal biometric parameters, which are incorporated into a formula to estimate fetal weight. There are over 30 published formulas, however, most obstetricians in the USA use the Hadlock formula [8]. This formula incorporates abdominal circumference (AC), head circumference (HC), femur length (FL), and biparietal diameter (BPD).

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In cases of suspected macrosomia, obstetricians can potentially intervene to prevent complications. The American College of Obstetricians & Gynecologists (ACOG) recommends offering CD for women with a sonoEFW >5000 g or >4500 g for diabetic mothers [1]. ACOG does not currently recommend offering induction or labor for suspected macrosomia. A recent randomized controlled trial of women with sonoEFW >95th percentile, however, showed decreased risk of shoulder dystocia and an increased likelihood of vaginal delivery after induction between 37–38 6/7 week' GA compared to expectant management [9]. There is little consensus on the benefit of elective CD with sonoEFW <5000 g or induction after 39 weeks, so decisions about mode of delivery are often left to the obstetrician's clinical judgement.

Obstetricians rely on the accuracy of the sonoEFW to make critical decisions when macrosomia is suspected. It has been previously established that sonoEFW is a poor predictor of BW especially at the extremes of weight [10–12]. The margin of error has been reported to be between 10 and 15% [8,10]. Many of these studies, however, assume that there is an equal probability that the sonoEFW is an underestimate and overestimate of the true BW [13,14]. While the margin of error of sonoEFW may be statistically meaningful, this does not have much utility in clinical practice. For obstetricians, knowing whether the margin of error tends to skew in one direction and if the sonoEFW is more likely to overpredict or underpredict the true BW is much more useful for making decisions concerning management of delivery.

In this study, we sought to compare the rates of overestimation of BW among women with a term, singleton pregnancy with suspected macrosomia by sonoEFW.

Materials and methods

This was a retrospective cohort study of all women who presented to a single maternal-fetal medicine ultrasound unit from January 2011 to November 2017. We included women who were delivered at Mount Sinai Hospital, a large tertiary academic medical center in New York City. We included women who had a sonoEFW ≥4000 g in a singleton pregnancy within 2 weeks of delivery.

There is no universal definition for macrosomia, as the risks associated with macrosomia increase linearly with BW [1]. For our analysis, we used two different definitions of macrosomia that are commonly used, BW ≥4000 g and BW ≥4500 g.

Over the course of the study period, our ultrasound unit routinely used the Hadlock formula for sonoEFW. All ultrasounds were performed by RDMS-certified sonographers, and all ultrasounds were reviewed by maternal-fetal medicine specialists. The decision to perform sonoEFWs prior to delivery was made according to contemporary best practices.

We excluded women with multifetal gestations, major fetal anomalies discovered before or after birth, and women whose last sonoEFW was greater than 2 weeks from delivery.

For each patient, we reviewed the computerized medical record, hospital inpatient records, operative reports, and discharge summaries. We recorded maternal baseline characteristics, ultrasound data, delivery information, and neonatal hospital course. Gestational age was determined by last menstrual period and confirmed by ultrasound in all patients. The pregnancy was redated if there was a more than 5-day discrepancy up to 9 weeks or a more than 7-day discrepancy after 9 weeks. If the pregnancy was the result of *in vitro* fertilization (IVF), gestational age was determined from IVF dating.

The study sample was divided into four sonoEFW categories: 4000–4249, 4250–4499, 4500–4749, and 4750 g or greater. We compared BW to sonoEFW across the four groups. Our primary outcome was overestimation of BW, defined as a sonoEFW > BW. Secondary outcomes included positive predictive value of macrosomia (defined as cases when BW >4000 g and BW >4500 g), absolute error (BW-sonoEFW), percent error ([BW-sonoEFW]/BW*100), median error, range between sonoEFW and BW, overestimation of BW by >500 g, and overestimation by 10, 15, and 20%. We compared baseline characteristics and outcomes across sonoEFW groups using chi-square for trend and one-way ANOVA as appropriate (IBM SPSS for Windows 22.0, IBM Corp). A *p*-value of <.05 was considered significant. Multiple regression analysis was performed to control for baseline differences in maternal characteristics and covariates thought to be associated with sonoEFW accuracy. Adjusted odds ratios were reported for binary outcomes and adjusted correlation coefficients were reported for continuous outcomes, as well as adjusted *p*-values.

Previous studies have assumed a 50% rate of overestimation for sonoEFWs [13,14]. Assuming an alpha error of 5%, in order to have 80% power to demonstrate increase in overestimation of BW from 50% in the 4000–4249 g sonoEFW group to 75% in the 4750 g or greater sonoEFW group, a total of 116 patients would be needed in these two groups.

Table 1. Baseline characteristics of women with sonographic estimated fetal weight ≥4000 g.

Baseline characteristics	sonoEFW 4000–4249 g ($n = 301$)	sonoEFW 4250–4499 g ($n = 135$)	sonoEFW 4500–4749 g ($n = 45$)	sonoEFW ≥4750 g ($n = 21$)	p-value
Maternal age (years)	34.0	33.8	34.3	34.7	.91
White race	257 (85.4%)	113 (83.7%)	40 (88.9%)	17 (81.0%)	.88
BMI at sono	30.7	30.8	30.1	32.7	.77
Diabetes (any)	23 (7.6%)	18 (13.3%)	1 (2.2%)	4 (19.0%)	.29
GDM	19 (6.3%)	12 (8.9%)	1 (2.2%)	1 (4.8%)	.67
Pre-GDM	4 (1.3%)	6 (4.4%)	0 (0.0%)	3 (14.3%)	.01
Polyhydramnios	32 (10.6%)	23 (17.2%)	9 (20.5%)	6 (28.6%)	.003
GA at sono (w)	39.3	39.3	39.3	38.9	.31
Time between sonoEFW and delivery (days)	6	5	4	4	.004
Breech	6 (2.0%)	1 (0.7%)	2 (4.4%)	1 (4.8%)	.38
Neonatal sex					.01
Male	165 (54.8%)	84 (62.2%)	32 (71.1%)	15 (71.4%)	
Female	136 (45.2%)	51 (37.8%)	13 (28.9%)	6 (28.6%)	

GA: gestational age; GDM: gestational diabetes; pre-GDM: pregestational diabetes; sonoEFW: sonographic estimated fetal weight; Sono: sonogram.

This project was approved by the Biomedical Research Alliance of New York Institutional Review Board.

Results

Five hundred two patients met inclusion criteria, of whom 301 (60.1%) had a sonoEFW 4000–4249 g, 135 (26.9%) had a sonoEFW 4250–4499 g, 45 (9.0%) had a sonoEFW 4500–4749 g, and 21 (4.2%) had a sonoEFW ≥4750 g. Baseline characteristics of sonoEFW groups are shown in Table 1. There were no significant differences between the groups for all characteristics except pregestational diabetes, polyhydramnios, and time between sonoEFW and delivery. Rates of pregestational diabetes and polyhydramnios increased significantly across sonoEFW groups.

Overall, 281 (56.1%) of neonates had a BW ≥4000 g and 54 (10.8%) had a BW ≥4500 g. Accuracy of sonoEFW in predicting BW is shown in Table 2. As expected, mean BW significantly increased across sonoEFW groups ($p < .001$). Mean BW was less than the predicted sonoEFW for all groups, with a mean BW of 4481 g when sonoEFW ≥4750 g. Positive predictive value for macrosomia increased significantly across groups ($p < .001$). BW was correctly predicted to be ≥4000 g in 43.5, 68.1, 84.4, and 95.2% for each sonoEFW group, respectively. BW ≥4500 g was not accurately predicted. Among women with sonoEFW 4500–4749 g, only 28.9% delivered a neonate with a BW >4500 g; for women with a sonoEFW 4750 g or greater, only 47.6% delivered a neonate with a BW >4500 g. This trend is shown in Figure 1.

In each sonoEFW group, the risk of overestimating BW was greater than 50%, and the likelihood of overestimation of BW increased significantly across sonoEFW groups (69.4, 76.3, 80.0, and 95.2%, respectively, $p < .001$), as shown in Table 2 and Figure 2. Overestimation of BW by >500 g occurred in 33 (11.0%), 22 (16.3%), 11 (24.4%), and 14 (66.7%) of cases for each sonoEFW group, respectively. Absolute, percent, and median error between sonoEFW and BW significantly increased across groups reaching an absolute and median error >500 g for sonoEFW ≥4750 g ($p < .001$).

We performed a regression analysis to estimate the association between sonoEFW and overestimation of BW (Table 3). We adjusted for differences in baseline characteristics and prespecified covariates, including maternal BMI, pregestational diabetes, polyhydramnios, time between delivery and sonoEFW, breech position, and neonatal sex. As in the univariate analysis, increasing sonoEFW was associated with an increased risk of overestimating BW (aOR = 1.47, 95% CI 1.09, 1.96). This analysis was repeated for the other measures of sonoEFW accuracy; all relationships remained significant after adjustment.

Finally, we compared mode of delivery across sonoEFW groups. Overall, 161 (32.1%) of women underwent CD for the primary indication of suspected macrosomia. Of those women who underwent CD for macrosomia, 48 (29.8%) of neonates had a BW <4000 g and 134 (83.2%) had a BW <4500 g.

Discussion

Our data suggest that among women with a term, singleton pregnancy who had a sonoEFW within 2 weeks of delivery, sonoEFW ≥4000 g systematically overestimates true BW. The risk of overestimating BW increases with increasing sonoEFW, reaching 95% likelihood of overestimating the BW when sonoEFW is ≥4750 g. Similarly, the absolute error, percent error, median error, and overestimation of BW by >500 g increase significantly as sonoEFW increases. This held

Table 2. Accuracy of sonographic estimated fetal weight for EFW ≥4000 g.

	sonoEFW 4000–4249 g ($n = 301$)	sonoEFW 4250–4499 g ($n = 135$)	sonoEFW 4500–4749 g ($n = 45$)	sonoEFW ≥4750 g ($n = 21$)	*p*-value
Mean birthweight (g)	3970	4167	4314	4472	<.001
Birthweight >4000 g	131 (43.5%)	92 (68.1%)	38 (84.4%)	20 (95.2%)	<.001
Birthweight >4500 g	13 (4.3%)	18 (13.3%)	13 (28.9%)	10 (47.6%)	<.001
Absolute error (g)	260	293	343	566	<.001
% error	6.3%	6.7%	7.4%	11.2%	<.001
Median error (g)	+158	+205	+353	+558	<.001
Range (EFW-BW) (g)	−785, +899	−781, +760	−635, +1015	−199, +1344	
Overestimation of BW	209 (69.4%)	103 (76.3%)	36 (80.0%)	20 (95.2%)	.003
Overestimation >500 g	33 (11.0%)	22 (16.3%)	11 (24.4%)	14 (66.7%)	<.001
Overestimation by >10%	65 (21.6%)	36 (26.7%)	15 (33.3%)	14 (66.7%)	<.001
Overestimation by >15%	24 (8.0%)	8 (5.9%)	6 (13.3%)	7 (33.3%)	<.001
Overestimation by >20%	7 (2.3%)	3 (2.2%)	3 (6.7%)	3 (14.3%)	.01

BW: birthweight; EFW: estimated fetal weight; sonoEFW: sonographic estimated fetal weight.

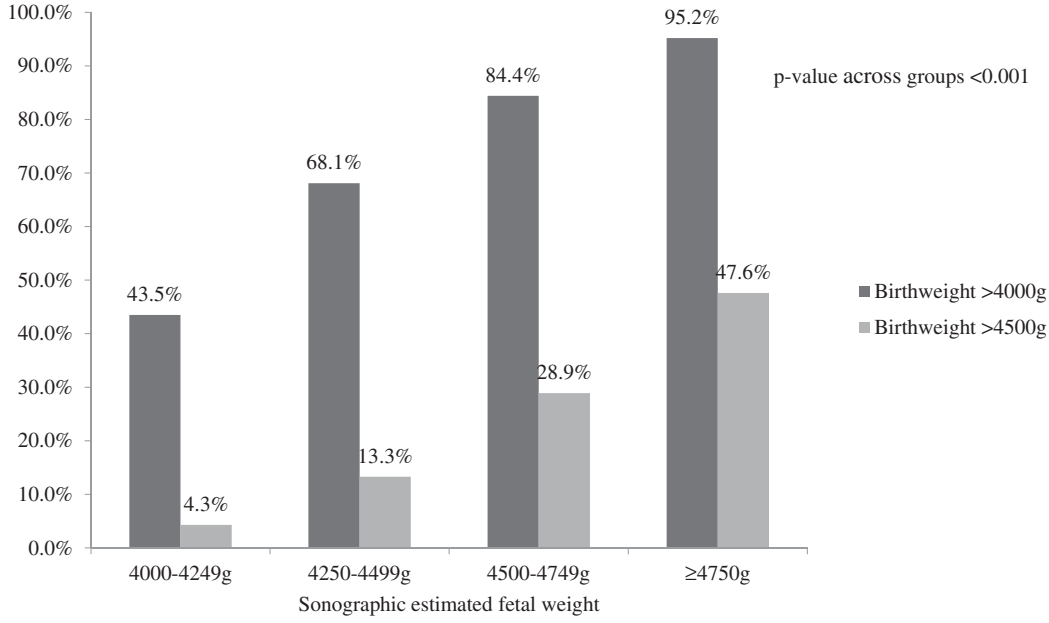

Figure 1. Likelihood of macrosomia across sonoEFW groups. Description: likelihood of macrosomia increases significantly across sonoEFW groups. Birthweight (BW) ≥ 4500 g was not accurately predicted; when sonoEFW was 4750 g or greater, only 47.6% of neonates had a BW >4500 g.

true even after adjusting for differences in baseline characteristics and potential confounders. Of those women who underwent CD for suspected macrosomia, 134 (83.2%) of neonates had a BW <4500 g, representing potentially unnecessary interventions. This has important clinical implications. When caring for women with suspected macrosomia, providers should counsel patients that although ultrasound has a margin of error, at higher estimated fetal weights, the error is significantly skewed towards overestimating the BW. Decisions regarding timing and mode of delivery should be taken this into consideration.

Previous studies on the accuracy of sonoEFW in large fetuses have demonstrated varying results. One study examining the accuracy of the Hadlock formula among diabetic and nondiabetic women within 3 days of delivery found a mean absolute percent error of 13% for infants with sonoEFW >4500 g compared to 8% for nonmacrosomic neonates [15]. Our data is largely consistent with the results of this study. Though we found a lower absolute percent error between sonoEFW and BW, with the highest error of 11.0% when sonoEFW ≥4750 g, we found that absolute error increased with increasing sonoEFW. A recent study examining the accuracy of 20 different formulas in predicting macrosomia found, in contrast to our data, that the majority of formulas tended to underestimate macrosomia [16]. In this study, however, the authors began with the BW and went backwards to determine the sonoEFW. Clinically, the more important question for providers that we sought to answer is how to interpret a sonoEFW when it demonstrates suspected macrosomia. This may account for the differences in our findings.

Previous studies have also shown that the accuracy of sonoEFW may be limited by external variables such

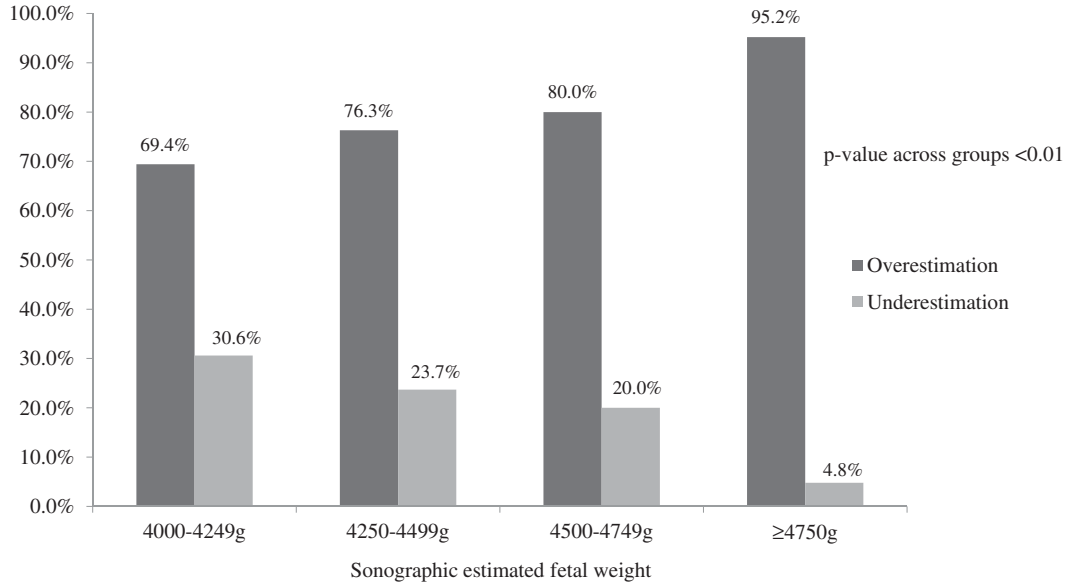

Figure 2. Likelihood of overestimating and underestimating birthweight across sonoEFW groups. Description: There is a greater likelihood that the sonoEFW overestimates rather than underestimates the birthweight for all groups. Likelihood of overestimation increases significantly across groups, reaching 95.2% when sonoEFW is 4750 g or greater.

Table 3. Accuracy of sonographic estimated fetal weight by sonoEFW group.[a]

	Unadjusted OR/correlation coefficient	Adjusted OR/correlation coefficient[b]	Adjusted *p*-value
Mean birthweight (g)	174.2 (141.6–206.8)	173.6 (141.1–206.1)	<.001
Birthweight >4000 g	2.76 (2.06–3.70)	2.96 (2.27–4.05)	<.001
Birthweight >4500 g	2.79 (2.06–3.76)	3.13 (2.20–4.45)	<.001
Absolute error (g)	67.4 (45.4–89.4)	65.2 (42.5–87.9)	<.001
% Error	1.02 (0.51–1.52)	0.97 (0.45–1.50)	<.001
Overestimation of BW	1.51 (1.14–2.00)	1.47 (1.09–1.96)	.010
Overestimation >500 g	2.10 (1.62–2.72)	2.16 (1.63–2.85)	<.001

BW: birthweight; sonoEFW: sonographic estimated fetal weight.
[a]Reference group is 4000–4249 g.
[b]Adjusted for maternal BMI, pregestational diabetes, polyhydramnios, time between delivery and sonoEFW, breech position, and neonatal sex.

as maternal obesity, amniotic fluid index, and neonatal sex [1,17,18]. Our data shows increasing rates of polyhydramnios and pregestational diabetes across sonoEFW groups. The results of our regression analysis, however, suggest that these variables alone do not account for the overestimation of BW. Finally, a more recent study of sonoEFWs among term, nulliparous women undergoing induction of labor found that 9.5% of sonoEFWs overestimated the true BW by >15% [7]. This study, however, only included 8 (3.3%) women with sonoEFW >4000 g. Our data suggests that the rate of overestimation is much higher in women with a sonoEFW >4000 g; we found that that sonoEFW overestimated the true BW by >500 g in 24.4% of cases when sonoEFW 4500–4749 g and 66.7% of cases when sonoEFW ≥4750 g. Given that providers are more likely to recommend interventions when sonoEFW exceeds 4000 g, our results showing high rates of overestimation of BW are important for providers to consider when making decisions about mode of delivery.

Our study is limited by its retrospective design. Though our overall sample size is large, our study is limited by the small number of subjects in the highest sonoEFW groups. Data from the National Center for Health Statistics suggests that only 1.1% of live-born neonates in the US weigh >4500 g [2]. Thus, the small sample of neonates with sonoEFW 4500–4749 ($n = 45$) and sonoEFW ≥4750 g ($n = 21$) in our cohort is not surprising. Repeating this analysis in a larger cohort is possible, however, this would require multiple sites and introduce bias related to differences in ultrasound equipment and interoperator reliability. Additionally, our study may be limited by the homogeneous population. Previous studies have suggested that maternal race and ethnicity may influence the accuracy of sonoEFW [12]. Though using data from one practice limits the number of patients in this analysis and reduces the heterogeneity of the population, we believe it increases the reliability of the data. Finally, our analysis excluded women who had multiple gestations, so we cannot comment on the overestimation

of BW in these women. As multiple gestations are far less likely to be macrosomic than singleton pregnancies, this question is likely less clinically significant.

As the CD rate in the USA remains high, identifying strategies to reduce unnecessary CDs is critical. A recent study found that among women who delivered macrosomic infants (BW >4000 g), the risk of CD was significantly higher among women who underwent sonoEFW within a month of delivery compared to women who did not have a sonoEFW within a month of delivery [19]. This suggests that sonoEFW itself may be a risk factor for CD. Our findings in this current study suggest that the tendency of sonoEFWs to overestimate BW may further increase the rate of CD. Our analysis revealed that of 164 women who underwent CD for suspected macrosomia, 134 women (83.2%) delivered a neonate with BW <4500 g. These CDs may have been avoidable if the sonoEFW had not overestimated the BW. Future studies should aim to determine if a correction factor or alternative formula may better predict BW for larger fetuses.

In conclusion, in patients undergoing sonoEFW for a term, singleton pregnancy within 2 weeks of delivery, sonoEFWs ≥4000 g are significantly more likely to overestimate than underestimate the true BW. Obstetricians should be cautious about intervening based on sonoEFW alone, given the high risk that this value is an overestimation of the true weight.

Disclosure statement

No potential conflict of interest was reported by the authors.

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