Accuracy of Ultrasound Estimation of Fetal Weight by Obstetrics and Gynaecology Residents and Maternal-fetal Medicine Subspecialists

PKS YAU MBChB, MRCOG (UK)
WK SIN MBBS, MRCOG (UK), FHKAM (O&G)
HC LEE MBBS, FRCOG (UK), FHKAM (O&G)
KC AU YEUNG MBBS, MRCOG (UK), FHKAM (O&G)
Department of Obstetrics and Gynaecology, Tuen Mun Hospital, Tuen Mun, Hong Kong

Objectives: This study was undertaken to assess the accuracy of sonographic estimations of fetal weight performed by maternal-fetal medicine subspecialists and obstetrics and gynaecology residents.
Methods: Retrospective data were retrieved between May and December 2011 for all women with singleton pregnancies of more than 24 weeks who had an ultrasound examination within 1 week of delivery. Sonographic parameters including the bi-parietal diameter, abdominal circumference, and femur length were measured according to the established criteria, and referred to the revised reference charts of fetal biometry. The estimated fetal weights were calculated using the Hadlock formula and compared with the infants' actual birth weights by using statistical analysis.
Results: The mean absolute errors ± standard deviation of ultrasound fetal weight estimations performed by maternal-fetal medicine subspecialists and obstetrics and gynaecology residents were 5.89% ± 5.10% and 7.77% ± 5.72%, respectively (p=0.03). The percentage of correctly estimated fetal weights (defined as <10% difference from the actual birth weight) was significantly different between the maternal-fetal medicine subspecialists and obstetrics and gynaecology residents at 79.3% and 65.4%, respectively (p=0.01).
Conclusion: The accuracy demonstrated by the obstetrics and gynaecology residents was comparable to some of the published studies. The maternal-fetal medicine subspecialists performed better in sonographic estimation of fetal weight than did the obstetrics and gynaecology residents. However, one in five of the estimates made by the maternal-fetal medicine subspecialists was more than 10% difference from the actual birth weight of the infant.
Hong Kong J Gynaecol Obstet Midwifery 2013; 13(1):27-32

Keywords: Biometry; Birth weight; Fetal weight; Pregnancy; Ultrasonography

Introduction

Estimates of fetal weight (EFWs) in late pregnancy or prior to delivery are often important variables in clinical decision-making in obstetrics. Clinical estimations based on symphysis–fundal height measurements and gestational age tend to be unreliable[1]. Ultrasound is often regarded as sufficient for making accurate EFWs, and is a widely available tool and a skill that all obstetrics and gynaecology (O&G) residents need to acquire. In some studies, ultrasound has been shown to determine the weight of the fetus to within 10% of the actual birth weight in as many as 75% of pregnancies and within 5% in as many as 40%[2].

Antenatal care has focused on the diagnosis of fetal growth restriction, which may be associated with iatrogenic premature delivery, intrauterine fetal compromise, or intrauterine demise. The delivery of macrosomic infants is equally important and is associated with higher rates of adverse outcomes for both mother and infant in comparison to the delivery of normal-weight infants. Risks to the large infant include shoulder dystocia, brachial plexus injury, perinatal asphyxia, and neonatal death[3-5]. Adverse maternal outcomes include prolonged labour, genital tract trauma, postpartum haemorrhage, and a higher risk of Caesarean section[4-6]. Accurate prediction of both small and large infants plays an important role in obstetric clinical practice.

Data on how the experience of the sonographer affects the accuracy of ultrasound EFWs are sparse. There are even fewer studies that assess the accuracy of ultrasound EFWs made by O&G residents alone[7-9]. The purpose of this study was to assess the performance of the sonographic EFWs within 1 week of delivery by maternal-fetal medicine (MFM) subspecialists and O&G residents.

Correspondence to: Dr PKS Yau
Email: syau071@hotmail.com

Methods

Retrospective data were retrieved manually by reviewing the records of all deliveries from May to December 2011 at Tuen Mun Hospital, Hong Kong. In this period, there were 4078 deliveries at the hospital. Only those women who had undergone an ultrasound examination within 1 week of delivery were selected for the study. Women with multiple pregnancies and stillbirths were excluded. The criterion of 1 week prior to delivery was chosen in an attempt to reflect the true birth weight and minimise the degree of error associated with a longer growth interval[10].

Two groups of sonographers were compared: MFM subspecialists (all were recognised MFM subspecialists and one completed his 3-year training in July 2012) and O&G residents who had passed the ultrasonography examination in their third year of training and had experience ranging from 2 to 36 months post-examination. All sonographic EFWs were performed by using a Phillips Ultrasound Scan Machine (Model HD11XE; Phillips Healthcare, Amsterdam, The Netherlands). During the scan, bi-parietal diameter (BPD), abdominal circumference (AC), and femur length (FL) were measured according to established criteria[11,12], and referred to the reference charts of fetal biometry revised by Tse in 1988 (communication, Dr WK Sin and Dr SF Wong). For all infants, the Hadlock equation[13] was used to calculate the EFW, as it is widely used at Tuen Mun Hospital:

$$\text{Log (EFW)} = -3.33108 + 0.99243 \times \log(\text{BPD}) + 1.55283 \times \log(\text{AC}) + 0.62047 \times \log(\text{FL})$$

There were nine cases where only the AC and the FL were available due to deep engagement of the fetal head or the position of the fetal head (e.g. direct occipitoposterior position). Four such cases occurred with MFM subspecialists and five cases occurred with O&G residents. In these situations, the following formula was used to calculate the EFW[14] (FFL = fetal FL; FAC = fetal AC):

$$\text{Log (EFW)} = -1.50430 + 0.15894 \times \text{FFL} + 0.03889 \times \text{FAC} - 2.41091 \times (\text{FFL})\wedge 2 \times (\text{FAC})/10000$$

Sonographic estimations of EFW and actual birth weights were collected. Other demographic data and variables were also collected for comparison. Statistical analyses were performed using Student's *t* test and Chi-square test with $p<0.05$ considered significant. Data were presented as mean ± standard deviation (SD). A primary analysis was performed to assess the accuracy of sonographic estimations of the fetal weight performed by MFM subspecialists and O&G residents across all birth weights. A secondary analysis was performed to assess the accuracy of sonographic EFWs performed by the two groups of sonographers for extreme birth weights (<2500 g and >4000 g). As the numbers involved in these extreme birth weights were small in each group, the data were calculated using Mann-Whitney test and the absolute errors (g) were presented as medians (interquartile range [IQR]). Typical ultrasound images taken by the MFM subspecialists and O&G residents are shown in the Figure.

Results

There were 297 scans assessing the fetal weight within 1 week of delivery. The O&G residents performed 162 scans and the MFM subspecialists performed 135 scans. Among the eight O&G residents who performed the scans, two had experience of 36 months after the ultrasound examination, three had 24 months of experience, and three had 2 months of experience; for the latter three O&G residents, their experience of independent practice increased to 10 months by the end of the study period. Before passing the ultrasonography examination, all of the O&G residents performed ultrasonography under supervision and had already gained at least 24 months of supervised experience. Among the MFM subspecialists, three were qualified MFM subspecialists and one completed the training in July 2012.

Table 1 shows the indications for ultrasonography. The baseline characteristics of the patients were similar between the two groups and there were no statistically significant differences (Table 2). The mean absolute percentage errors (± SD) of ultrasound EFWs performed by MFM subspecialists and O&G residents were 5.89% ± 5.10% and 7.77% ± 5.72%, respectively (p=0.003). The mean absolute errors of ultrasound EFWs performed by MFM subspecialists and O&G residents were 168 g ± 145 g and 230 g ± 172 g, respectively (p=0.001) [Table 3]. The percentage of correct EFWs (defined as <10% difference from the actual birth weight) was significantly different between the MFM subspecialists and the O&G residents at 79.3% and 65.4%, respectively (p=0.01) [Table 3].

A secondary analysis, including those with birth weights of <2500 g and >4000 g was performed. The baseline characteristics of the patients delivering babies of extreme birth weights were similar between the two groups and there were no statistically significant differences. The MFM subspecialists performed 32 ultrasonographies for deliveries with birth weights of <2500 g and 14 for deliveries with birth weights of >4000 g. The O&G residents performed 37 ultrasonographies for deliveries with birth weights of <2500 g and 13 for deliveries with birth weights of >4000 g.

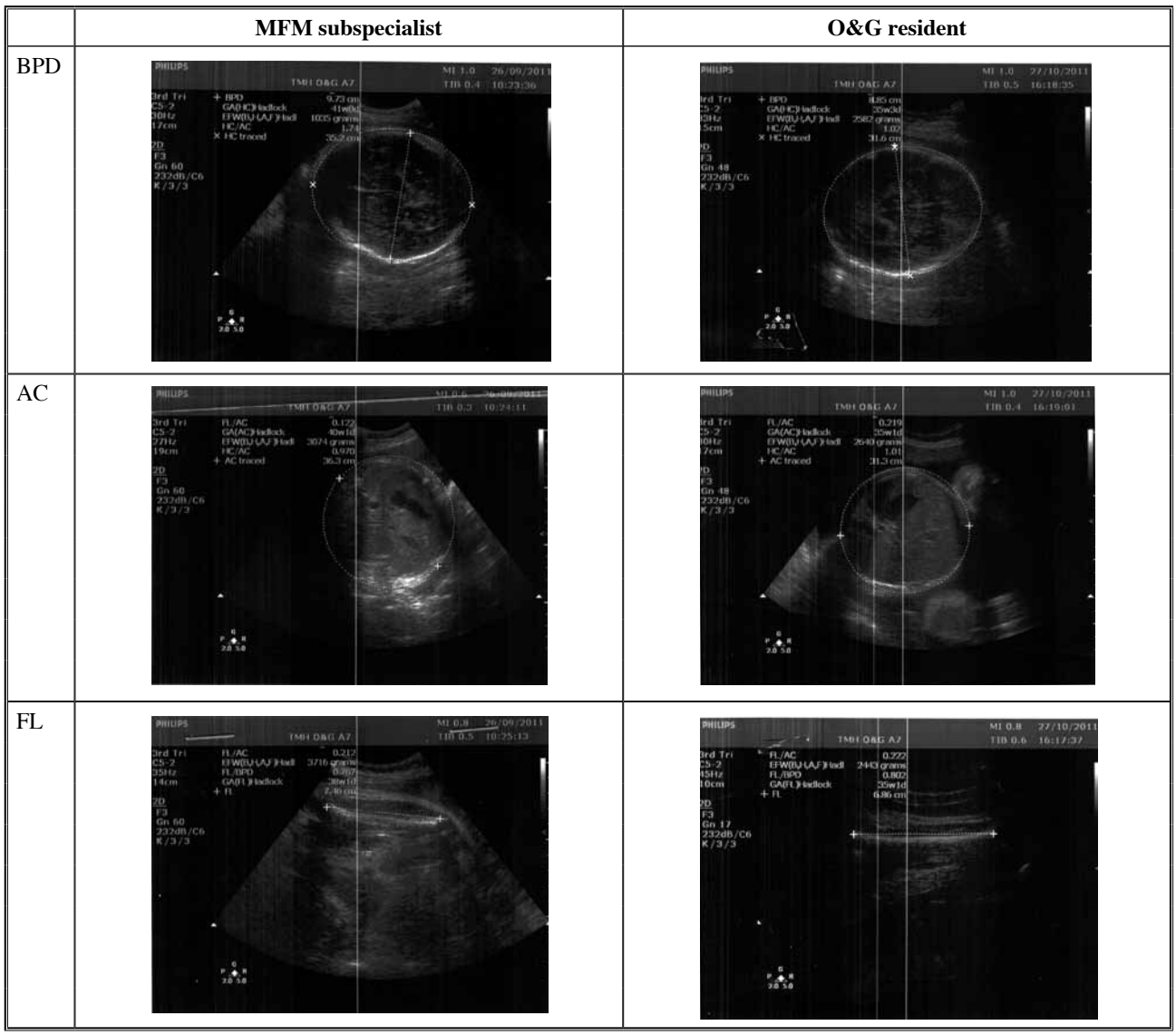

Figure. Bi-parietal diameter (BPD), abdominal circumference (AC), and femur length (FL) assessed by a maternal-fetal medicine (MFM) subspecialist and an obstetrics and gynaecology (O&G) resident

Table 1. Indications for ultrasonography

Indication for ultrasonography	Proportion of procedures (%)
Growth / fetal size	49.7
Liquor	15.9
Presentation	14.4
Antepartum haemorrhage	6.7
Reduced fetal movements	6.7
Abdominal pain / threatened preterm labour	3.8
Placenta praevia	2.8

In the group with birth weights of <2500 g, the median absolute error of the MFM subspecialists was 60 g (IQR, 30-140 g) with a median gestation of 35.8 weeks (IQR, 33.6-37.1 weeks). The median absolute error of the O&G residents was 140 g (IQR, 70-240 g) with a median gestation of 34.7 weeks (IQR, 32.9-37.5 weeks). The difference between the two groups was statistically significant (p=0.03) [Table 3].

In the group with birth weights of >4000 g, the median absolute error of the MFM subspecialists was 130 g (IQR, 60-340 g) and the median absolute error of the O&G residents was 400 g (IQR, 90-480 g) [p=0.10]. A total of five (18.5%) women in this group had gestational diabetes, but they were all treated by the MFM subspecialist group (Table 3). There was a general tendency for all sonographers to overestimate the birth weight for small fetuses (<2500 g) with a mean signed percentage error of +4.28% ± 9.30% and a mean signed error of +98 g ± 182 g. Large fetuses (>4000 g) tended to have their body weight underestimated with a mean signed percentage error of –4.26% ± 7.05% and a mean signed error of –183 g ± 296 g.

Table 2. Baseline characteristics of the study patients according to sonographer

Characteristic	% or mean ± standard deviation		p Value
	MFM subspecialists (n=135)	O&G residents (n=162)	
Patient age (years)	30.7 ± 5.2	30.4 ± 5.3	0.64
Gestational age (weeks)	37.7 ± 3.9	38.0 ± 2.5	0.40
Parity	0.6 ± 0.8	0.6 ± 1.0	0.97
Gravidity	2.2 ± 1.3	2.2 ± 1.3	0.97
Significant medical diseases	12.6	10.5	0.59
IGT / GDM	15.6	13.0	0.62
Fibroid	3.7	3.1	0.77
Abnormal liquor volume	21.5	21.0	1.00
Male fetus	53.3	50.6	0.73
Vaginal delivery	48.1	49.4	0.83
Vacuum extraction	3.0	7.4	0.91
Caesarean delivery	48.9	43.2	0.33
Time of scan to delivery (days)	1.9 ± 2.0	1.9 ± 2.0	0.80
Actual birth weight (g)	2950 ± 800	3010 ± 710	0.50

Abbreviations: MFM = maternal-fetal medicine; O&G = obstetrics and gynaecology; IGT = impaired glucose tolerance; GDM = gestational diabetes mellitus

Table 3. Comparison between MFM subspecialists and O&G residents

Birth weights	MFM subspecialists* (n=135)	O&G residents* (n=162)	p Value
Mean absolute error (%)	5.89 ± 5.10	7.77 ± 5.72	0.003
Mean absolute error (g)	168 ± 145	230 ± 172	0.001
Correct estimation % (<10% difference from actual birth weight)	79.3	65.4	0.01
Birth weights <2500 g	32 (46.4%)	37 (53.6%)	
Median absolute error (g)	60 (30-140)	140 (70-240)	0.03
Median gestation (weeks)	35.8 (33.6-37.1)	34.7 (32.9-37.5)	0.69
Birth weights >4000 g	14 (51.9%)	13 (48.1%)	
Median absolute error (g)	130 (60-340)	400 (90-480)	0.10
Median gestation (weeks)	35.3 (34.8-36.9)	35.9 (33.9 -37.1)	0.57
% with gestational diabetes	18.5	0	0.04

Abbreviations: MFM = maternal-fetal medicine; O&G = obstetrics and gynaecology

* Data are given as No. (%), mean ± standard deviation, or median (interquartile range)

Discussion

Only a few studies investigating the sonographic EFWs performed by O&G residents have been published[8,9]. Predanic et al[8] reported a significant improvement in EFWs with more training of residents. Ben-Aroya et al[9] reported that residents' fatigue affected the accuracy of clinical, but not sonographic EFWs. This study demonstrated that O&G residents and MFM subspecialists achieved accuracies of 65% and 79%, respectively, for EFWs to within 10% of the actual birth weight for all births.

The accuracy demonstrated by the residents in this study was comparable to those in other published studies. Predanic et al[8] reported that among the most experienced residents (≥24 months' training), 73.6% of their EFWs were within 10%. Residents who performed ultrasonography in this study had passed their ultrasound examination in their third year of training. Before this examination, the residents performed ultrasound under supervision. By then, they should have already gained at least 24 months of experience, and their post-examination experience ranged from 2 to 36 months.

Chauhan et al[15] showed that sonographic EFWs were predicted correctly for 58.3% within 10% of the actual birth weights. Five residents with previous training

in basic ultrasound and two MFM specialists were involved in predicting the fetal weights. Colman et al[10] demonstrated that the accuracy of predicting fetal weight correctly by ultrasound (defined as within 10% of actual birth weight) in large infants ranged from 69% among diabetic women to 74% for women without diabetes.

In all birth weights, the performance of MFM subspecialists in accurately predicting the actual birth weight (defined as within 10% of actual birth weight) was significantly better than that of the O&G residents (79.3% vs. 65.4%). Although the accuracy of the estimates performed by the MFM subspecialists was comparatively good, one (20.7%) of five EFWs was still >10% different from the actual birth weights. Ultrasound measurements give the impression of precision. However, the accuracy of ultrasound EFWs is limited by the fact that the fetus is an irregular, three-dimensional structure of varying density[16].

For birth weights of <2500 g, MFM subspecialists still performed significantly better than O&G residents in making accurate estimates of the actual birth weights (mean absolute error 60 g vs. 140 g). However, for birth weights of >4000 g, the median absolute errors of the MFM subspecialists and residents were 130 g and 400 g, respectively. The results in this group were not statistically significant, but they demonstrated a tendency towards more accurate estimates made by the MFM subspecialists. All patients with gestational diabetes were in the MFM subspecialist group and this represented a statistically significant confounding factor, making comparison between the two groups of sonographers difficult; no definite conclusions regarding their performances of EFW among the group of birth weights of >4000 g could be drawn. This phenomenon could be explained by the fact that the consultant responsible for the patients with gestational diabetes was an MFM subspecialist. Suggestions to even out the bias could be recruitment of MFM subspecialists to scan patients in the group with suspected birth weights of >4000 g, but with no gestational diabetes, or to extend the study period to include a larger number of patients in this group.

It is well known that accurate EFWs have an impact on the timing and route of delivery, especially for fetuses of extreme body weights. It was demonstrated in this study that participation in the ultrasound assessment by MFM subspecialists is important when evaluating the weights of fetuses who are suspected to be small (<2500 g). In fetuses suspected to be large (>4000 g), the tendency for MFM subspecialists to make more accurate estimates than the O&G residents was still present, although this was not statistically significant.

In this study there was an association between fetal size and direction of the weight estimation error. For one (34.6%) in three infants in the O&G residents group whose weight estimations were more than 10% different from the actual birth weight and one (20.7%) in five in the MFM subspecialist group, the error was generally in the direction of overestimation in small infants and underestimation in macrosomic infants (Table 3). This deficiency in accurately predicting the fetal weight could lead to underestimation of the clinical risks in regard to management of extreme birth weights. These trends have previously been noted in a systematic review of ultrasonic EFWs[17]. Dudley[17] analysed studies from 11 research groups that compared ultrasound EFWs with the actual birth weights to determine the accuracy of EFW. The fetal weights in the low-birth-weight populations were generally overestimated and, conversely, the fetal weights in the high-birth-weight populations were generally underestimated.

The tendency of ultrasound EFWs to err towards normal when the infant was subsequently found to be either <2500 g or >4000 g is important because accurate EFW is relevant to clinical decision-making, particularly for large or small fetuses. Suggestions for improving the accuracy of ultrasound estimation include averaging multiple measurements, continuous ultrasound training for O&G residents, improvements in image quality, and regular audit of measurement quality. Nonetheless, an important component in the error of EFWs is the inherent deficiency of the mathematical formula used. Despite numerous formulae available in the literature[17,18], there is no single formula for EFW that has achieved such accuracy as to be widely recommended[19].

This study was the first in Tuen Mun Hospital to investigate the accuracy of EFWs made by O&G residents and MFM subspecialists, and the accuracy demonstrated by the O&G residents was similar to some of the published studies[7-10]. However, the numbers involved at the extreme birth weights (<2500 g and >4000 g) were comparatively small, making comparison difficult. Another limitation of the study was that the measurements were not repeated by both groups of sonographers in each patient. However, this is not possible for a retrospective study because, in clinical practice, these two groups of sonographers have to perform ultrasound independently most of the time due to time constraints. In addition, the individual fetal biometric data and the situation (emergency or elective) in which the scan

was performed were not available.

In selecting only 297 women who had undergone ultrasound examination within 1 week of delivery, there could be a sampling bias. The duration of 2 weeks rather than 1 week could have been chosen to recruit a larger number of patients, but this could have increased the error in estimation and might not have reflected the actual birth weight. In addition, a more universal approach could have been employed and all patients scanned within a certain period of time. This would be possible in a prospective study. However, in a retrospective study such as this, the patients underwent ultrasonography if it was indicated clinically so some risk factors must have been identified to justify the ultrasound assessment.

An explanation for the significant difference in the estimation between MFM subspecialists and O&G residents is the difference in the ultrasound skills and experience that gained through training and practice. The implication for clinical practice is that MFM subspecialists should be encouraged to participate in ultrasound assessment, especially when evaluating fetuses who are suspected to be small (<2500 g). Whether this applies to those fetuses weighing >4000 g needs further study.

Addition of head circumference to the formula for EFW has been shown to improve the predictive accuracy in prospective studies of unselected fetuses[13,20]. However, it has been noted that no particular formula estimates birth weight significantly more accurately than any other[21]. Three-dimensional volumetry has also been used for fetal birth weight prediction. Schild et al[22] showed the superior role of 3-dimensional ultrasound in EFW close to delivery. These authors collected data, including several volumetric measurements as well as conventional 2-dimensional biometry, and found that the best-fit formula contained the parameters of upper arm, thigh, and abdominal volume as well as the BPD. The accuracy of the thigh volume in predicting the fetal weight has also been confirmed by other studies[23,24]. However, it is more time consuming than using standard 2-dimensional methods and is not widely available. Further search for more appropriate formulae and, perhaps, newer imaging modalities are needed to provide more accurate estimations of the actual birth weight.

References

1. Neilson JP. Symphysis-fundal height measurement in pregnancy. *Cochrane Database Syst Rev* 2000; CD000944.
2. Watson WJ, Soisson AP, Harlass FE. Estimated fetal weight of the term fetus. Accuracy of ultrasound vs. clinical examination. *J Reprod Med* 1988; 33:369-71.
3. Conway DL. Choosing route of delivery for the macrosomic infant of a diabetic mother: caesarean section versus vaginal delivery. *J Matern Fetal Neonatal Med* 2002; 12:442-8.
4. Boulet SL, Alexander GR, Salihu HM, et al. Macrosomic births in the United States: determinants, outcomes, and proposed grades of risk. *Am J Obstet Gynecol* 2003; 188:1372-8.
5. Stotland NE, Caughey AB, Breed EM, et al. Risk factors and obstetric complications associated with macrosomia. *Int J Gynaecol Obstet* 2004; 87:220-6.
6. Jolly MC, Sebire NJ, Harris JP, et al. Risk factors for macrosomia and its clinical consequences: a study of 350311 pregnancies. *Eur J Obstet Gynecol Reprod Biol* 2003; 111:9-14.
7. Noumi G, Collado-Khoury F, Bombard A, et al. Clinical and sonographic estimation of fetal weight performed during labor by residents. *Am J Obstet Gynecol* 2005; 192:1407-9.
8. Predanic M, Cho A, Ingrid F, et al. Ultrasonographic estimation of fetal weight: acquiring accuracy in residency. *J Ultrasound Med* 2002; 21:495-500.
9. Ben-Aroya Z, Segal D, Hadar A, et al. Effect of Ob/GYN residents' fatigue and training level on the accuracy of weight estimation. *Fetal Diagn Ther* 2002; 17:177-81.
10. Colman A, Maharaj D, Hutton J, et al. Reliability of ultrasound estimation of fetal weight in term singleton pregnancies. *N Z Med J* 2006; 119:U2146.
11. Horenstein J. Ultrasound assessment of fetal growth and fetal measurements. *Semin Perinatol* 1988; 12:23-30.
12. Moore TR, Cayle JE. The amniotic fluid index in normal human pregnancy. *Am J Obstet Gynecol* 1990; 162:1168-73.
13. Hadlock FP, Harrist RB, Sharman RS, et al. Estimation of fetal weight with the use of head, body and femur measurements—a prospective study. *Am J Obstet Gynecol* 1985; 151:333-7.
14. Hadlock FP, Harrist RB, Carpenter RJ, et al. Sono-graphic estimation of fetal weight. The value of femur length in add-ition to head and abdomen measurements. *Radiology* 1984; 150:535-40.
15. Chauhan SP, Hendrix NW, Magann EF, et al. Limitations of clinical and sonographic estimates of birth weight: experience with 1034 parturients. *Obstet Gynecol* 1998; 91:72-7.
16. Abramowicz JS, Ahn JT. Fetal macrosomia: diagnosis. *UpToDate Online* 2006. Available from: http://www.uptodate.com/contents/fetal-macrosomia?source=search_result&search=fetal+macrosomia&selectedTitle=1~150
17. Dudley NJ. A systematic review of the ultrasound estimation of fetal weight. *Ultrasound Obstet Gynecol* 2005; 25:80-9.
18. Nahum GG, Stanislaw H. Ultrasonographic prediction of term birth weight: how accurate is it? *Am J Obstet Gynecol* 2003; 188:566-74.
19. Australian Society for Ultrasound in Medicine. Statement on normal ultrasonic fetal measurements. *ASUM*; 2001. Available from: http://www.asum.com.au/newsite/Resources.php?p=Policy
20. Ott WJ, Doyle S, Flamm S, et al. Accurate ultrasonic estimation of fetal weight. *Am J Perinatol* 1986; 3:307-10.
21. Robson SC, Gallivan S, Walkinshaw SA, et al. Ultrasonic estimation of fetal right: use of targeted formulas in small for gestational age fetuses. *Obstet Gynecol* 1993; 82:359-64.
22. Schild RL, Fimmers R, Hansmann M. Fetal weight estimation by three-dimensional ultrasound. *Ultrasound Obstet Gynecol* 2000; 16:445-52.
23. Song TB, Moore TR, Lee JI, et al. Fetal weight prediction by thigh volume measurement with three-dimensional ultrasonography. *Obstet Gynecol* 2000; 96:157-61.
24. Lee W, Deter RL, McNie B, et al. Individualized growth assessment of fetal soft tissue using fractional thigh volume. *Ultrasound Obstet Gynecol* 2004; 24:766-74.