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● *Original Contribution*

COMPARISON OF 2-D AND 3-D ESTIMATES OF PLACENTAL VOLUME IN EARLY PREGNANCY

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Abstract—Ultrasound estimation of placental volume (PlaV) between 11 and 13 wk has been proposed as part of a screening test for small-for-gestational-age babies. A semi-automated 3-D technique, validated against the gold standard of manual delineation, has been found at this stage of gestation to predict small-for-gestational-age at term. Recently, when used in the third trimester, an estimate obtained using a 2-D technique was found to correlate with placental weight at delivery. Given its greater simplicity, the 2-D technique might be more useful as part of an early screening test. We investigated if the two techniques produced similar results when used in the first trimester. The correlation between PlaV values calculated by the two different techniques was assessed in 139 first-trimester placentas. The agreement on PlaV and derived "standardized placental volume," a dimensionless index correcting for gestational age, was explored with the Mann–Whitney test and Bland–Altman plots. Placentas were categorized into five different shape subtypes, and a subgroup analysis was performed. Agreement was poor for both PlaV and standardized PlaV ($p < 0.001$ and $p < 0.001$), with the 2-D technique yielding larger estimates for both indices compared with the 3-D method. The mean difference in standardized PlaV values between the two methods was 0.007 (95% confidence interval: 0.006–0.009). The best agreement was found for regular rectangle-shaped placentas ($p = 0.438$ and $p = 0.408$). The poor correlation between the 2-D and 3-D techniques may result from the heterogeneity of placental morphology at this stage of gestation. In early gestation, the simpler 2-D estimates of PlaV do not correlate strongly with those obtained with the validated 3-D technique. (E-mail: christina.aye@obs-gyn.ox.ac.uk)

Key Words: **Placental volume estimation, Ultrasound, 2-D, 3-D, Screening, Small for gestational age.**

INTRODUCTION

Small for gestational age (SGA) status, or weight below the 10th centile, increases the risk of adverse perinatal outcomes, including stillbirth (Doctor et al. 2001; Figueras et al. 2008; Flenady et al. 2011; Froen et al. 2004; McCowan et al. 2000; Severi et al. 2002). In the United Kingdom, screening for SGA infants currently relies on maternal history and risk factors identified at the booking visit. This technique has poor sensitivity and specificity, and as a result, many normal pregnancies are over-medicalized while SGA babies are often missed. Effective screening in early pregnancy of women at risk for delivering SGA babies would allow improved monitoring of pregnancies at risk for SGA and potentially facilitate delivery in a timely fashion.

The relationship between placental weight at birth and birth weight is well established (Eskild and Vatten 2010; Sinclair 1948), as is the pathologic significance of a small placenta at delivery (Little 1960). Placental volume (PlaV) has been proposed as part of a screening test for the prediction of growth-restricted babies.

Recently, a semi-automated ultrasound image segmentation technique using the random walker algorithm (Grady 2006) was developed and validated against the gold standard of manual delineation to estimate 3-D PlaV (Stevenson et al. 2010). The speed, ease and consistency of this process would make it potentially useful as part of a screening test. Gestational age-corrected PlaVs estimated using this technique have been found to be lower at 11–13 wk in babies eventually born SGA at

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term, with a sensitivity of 70% for a false-positive rate of 20% and an area under the curve of 0.82 (0.69–0.94) in a low-risk population (Collins et al. 2013).

A method using 2-D sonography has also recently been proposed to provide an immediate estimate of PlaV. This estimate, obtained by using linear measurements of placental width, height and thickness to calculate the convex–concave shell volume of the placenta, has been reported to be significantly correlated with actual placental weight when used in the third trimester (Azpurua et al. 2010).

We sought to investigate whether PlaV estimates obtained with this 2-D method are comparable to those generated using the semi-automated 3-D technique. If the two methods are comparable, the 3-D PlaV estimation could be replaced by the 2-D method, making any resulting screening tool simpler. In addition, expensive 3-D ultrasound equipment would not be required, making the method applicable in all health care settings.

METHODS

Patient selection

The study was conducted in a UK teaching hospital with the ethical approval (REC Ref. No. 08/H0604/163) of the National Health Service Research and Ethics Committees. Written consent was obtained before enrollment. Women with singleton pregnancies undergoing first-trimester scans between December 2008 and December 2010 were invited to participate. Those <16 y of age, having a body mass index >35 or having significant maternal chronic illnesses, such as diabetes, ischemic heart disease and autoimmune conditions, for example, systemic lupus erythematosus, were not invited to participate in the study.

Data acquisition

Scans were undertaken between 11 + 0and 13 + 6wk of gestation by a single operator (S.C.) with the participant in a semirecumbent position. Gestational age was calculated from the crown–rump length (CRL) during this visit. Three-dimensional volumetric scans of the placenta were acquired using a GE Voluson E8 (GE Healthcare, Milwaukee, WI, USA) and a RAB4-8-D 3-D/4 D curved array abdominal transducer (4–8.5 MHz) (GE Healthcare). After confirmation of viability and identification of placental position, the optimal probe placement for 3-D acquisition of the whole placenta was identified. This was usually a cross-sectional plane close to the center of the placenta. A static, gray-scale volume was captured using pre-determined machine settings (Table 1). The volume was then checked to ensure that the whole placenta had been included. If not, the angle was increased or the probe repositioned, and the process was repeated. Once a complete placental volume was captured, it was saved and analyzed off-line.

Table 1. Ultrasound machine B-mode settings

Speckle reduction imaging	3
Angle	60
Dynamic contrast	6
Focal zones	1
Harmonic frequency	High
Gain	5
Gray map	7
Tint	Clear
Line filter	Off
Persistence	3
Enhance	3
Line density	Normal
Reject	15

Each captured 3-D volume was analyzed in two different ways. The 3-D placental volume was estimated using the previously validated rapid, semi-automated image analysis tool (Stevenson et al. 2010) by a single investigator (S.C.). The 2-D estimate was calculated by examining all the slices from the captured volume until the investigator (C.A.) perceived that she had selected the cross section where the width of the placenta was at its maximum. The 2-D estimated PlaV was then derived from manual measurements of the width, height and thickness of the placenta taken from that slice using the technique of Azpurua et al. (2010). The PlaVs from these two methods were then adjusted for gestational age by calculating the sPlaV, a novel dimensionless index, using the formula PlaV$^{1/3}$/CRL (Collins et al. 2013).

Placentas were then subjectively divided by one investigator (C.A.) into five different broad categories on the basis of their shape (Figs. 1, 2). The categories were based on the appearance of the placenta at the cross section where the width was at its maximum, that is, at the same cross section used to calculate the volume estimate with the 2-D technique. This was done to investigate whether there was increased agreement between the two techniques if the placentas were a discoid, curvilinear shape, as the 2-D calculation assumes such a placental shape.

Statistical analysis

Statistical analysis was performed using SPSS (Version 20.0, IBM, NY, USA) and Excel (Microsoft, Redmond, WA, USA). Normality was assessed by visual assessment of *Q*–*Q* plots and histograms in addition to the Kolmogorov–Smirnov and Shapiro–Wilk tests and *z*-values for skewness and kurtosis. The 2-D and 3-D estimates of PlaV and sPlaV were compared using a two-sided, dependent-sample Student *t*-test for normally distributed data and a Mann–Whitney *U*-test for non-normal data. Bland–Altman plots were also created to compare values using the two different methods (Bland