

Fetal trunk and head volume measured by three-dimensional ultrasound at 11 + 0 to 13 + 6 weeks of gestation in chromosomally normal pregnancies

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ABSTRACT

Objective To establish the relationship between fetal trunk and head volume measured by three-dimensional (3D) ultrasound and gestational age at 11 + 0 to 13 + 6 weeks of gestation.

Methods The fetal trunk and head volume were measured using 3D ultrasound in 417 chromosomally normal fetuses from singleton pregnancies at 11 + 0 to 13 + 6 (median, 12 + 0) weeks of gestation. Regression analysis was used to determine the significance of the association between fetal volume and gestational age. The Bland–Altman analysis was used to compare the measurement agreement and bias for a single examiner and between different examiners.

Results The fetal trunk and head volume increased linearly with gestation from a mean of 5.8 mL at 11 + 0 weeks to 33.3 mL at 13 + 6 weeks and 1 SD was 4.4 mL. There was also a significant linear association between fetal volume and crown–rump length (CRL), from a mean of 5.1 mL at a CRL of 45 mm to 37.5 mL at a CRL of 84 mm and 1 SD was 2.7 mL. However, within this gestational range, a doubling in CRL, from a mean of 48 mm at 11 + 0 weeks to 79 mm at 13 + 6 weeks, was associated with a 5–6-fold increase in fetal volume. The mean difference in fetal volume between paired measurements by the same sonographer was –0.87 mL (95% limits of agreement, –2.31 to 4.05 mL) and the mean difference between paired measurements by two sonographers was –1.09 mL (–5.49 to 3.32 mL).

Conclusions 3D ultrasound can provide a reproducible measurement of the fetal trunk and head volume in early pregnancy. At between 11 + 0 and 13 + 6 weeks there is a 5–6-fold increase in fetal volume but only a doubling

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INTRODUCTION

In the first trimester of pregnancy, assessment of gestational age and fetal growth, as well as the diagnosis of early-onset fetal growth restriction in association with fetal abnormalities, are essentially based on two-dimensional (2D) sonographic measurement of the fetal crown–rump length (CRL)^{1–7}. The introduction of three-dimensional (3D) ultrasound has now made it possible to measure fetal volume, and two studies (on a combined total of 106 fetuses) have reported on the relation between this measurement and gestational age at 6–12 weeks^{8,9}. Measurement of fetal nuchal translucency (NT), as an effective method of early screening for chromosomal defects, has led to the widespread introduction of routine ultrasound scanning at 11 + 0 to 13 + 6 weeks of gestation^{10,11}. The aim of the present study was to establish a reference range of fetal trunk and head volume at 11 + 0 to 13 + 6 weeks that could form the basis for a new approach to the early diagnosis of impaired fetal growth.

METHODS

A 3D volume of the fetus was acquired by transabdominal sonography (RAB 4–8L probe, Voluson 730 Expert, GE Medical Systems, Milwaukee, WI, USA) in singleton pregnancies before fetal karyotyping at 11 + 0 to 13 + 6 weeks of gestation. All scans were performed by sonographers with extensive experience in 3D ultrasound and the study was carried out in our center during

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a 10-month period (between December 2003 and September 2004). In all cases there was prior screening for chromosomal defects by a combination of maternal age and fetal NT¹¹, and the patients included in the study were those that opted for chorionic villus sampling after counseling. The inclusion criteria for this study were singleton pregnancy, live fetus with CRL between 45 and 84 mm, and normal fetal karyotype. The same 3D volumes were previously used to measure placental volume and gestational sac volume^{12,13}.

The VOCALTM (Virtual Organ Computer-aided AnaLysis) technique was used to obtain a sequence of six longitudinal sections of the fetus around a fixed axis, each after a 30° rotation from the previous one (Voluson 730 Expert Operation Manual, GE Medical Systems). The contour of the fetus (excluding the limbs and the NT) was drawn manually in each of the six different planes to obtain the 3D volume measurement (Figure 1). Every measurement was done offline after the scan by the same operator and before knowing the result of the karyotype.

In 40 randomly selected cases, the fetal trunk and head volume was measured by the same sonographer twice and also by a second sonographer once in order to compare

the measurements and calculate intra- and interobserver agreement.

Statistical analysis

Regression analysis was used to determine the significance of the association between fetal trunk and head volume in mL and gestational age in days and CRL in millimeters. The Bland–Altman analysis was used to compare the measurement agreement and bias for a single examiner and between different examiners¹⁴. The data were analyzed using the statistical software SPSS v.11.5 (SPSS Inc., Chicago, IL, USA), and a *P*-value of less than 0.05 was considered statistically significant.

RESULTS

The fetal trunk and head volume were successfully measured in all 417 pregnancies that fulfilled the entry criteria. The median maternal age was 37 (range, 19–47) years, the median fetal CRL was 66.5 (range, 45–84) mm and the median gestation was 12 + 0 (11 + 0 to 13 + 6) weeks. The fetal trunk and head volume increased significantly with gestation, from a mean of 5.8 mL at

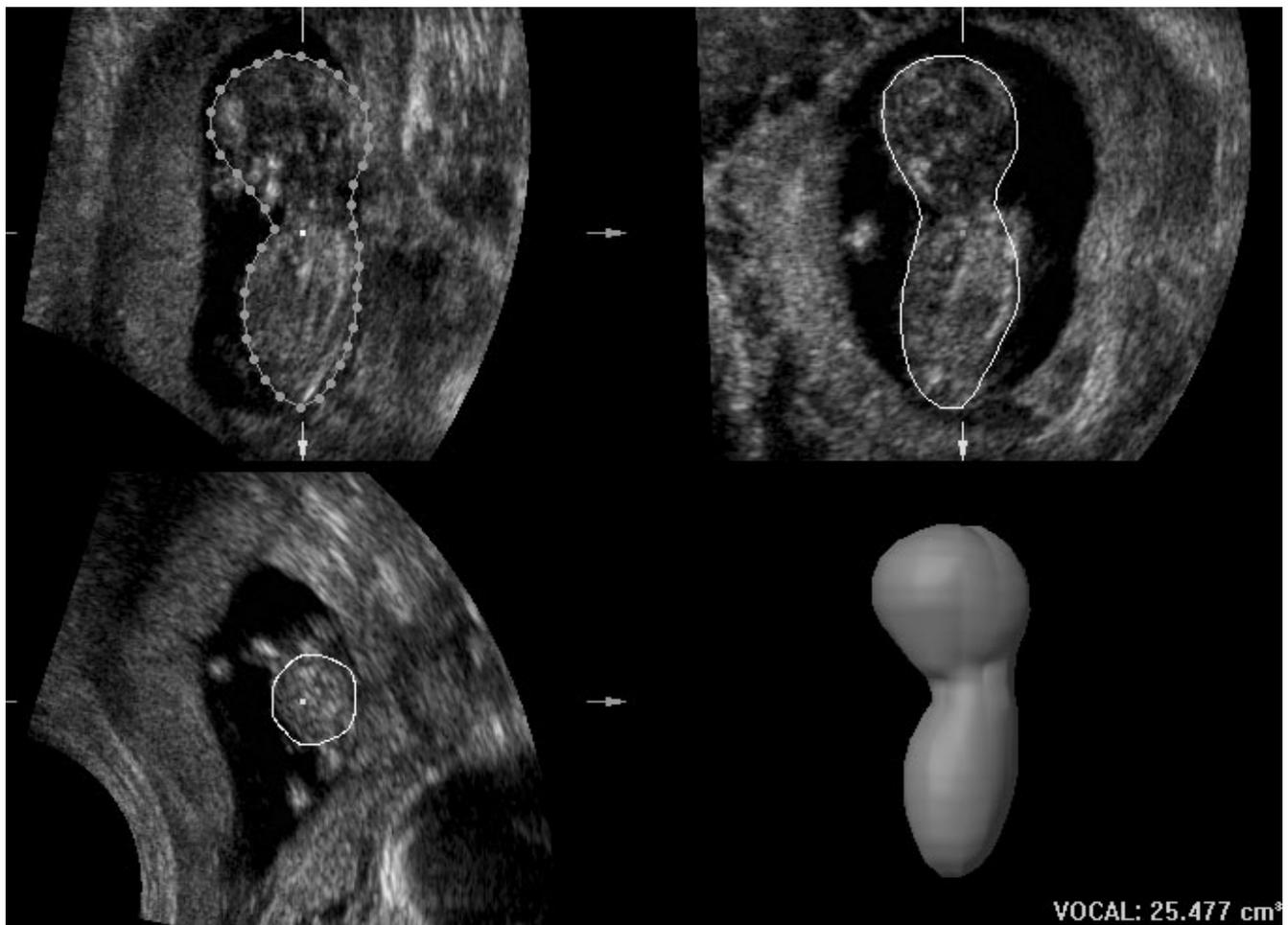


Figure 1 Three-dimensional trunk and head volume of the fetus obtained using the Virtual Organ Computer-aided AnaLysis (VOCALTM) technique.

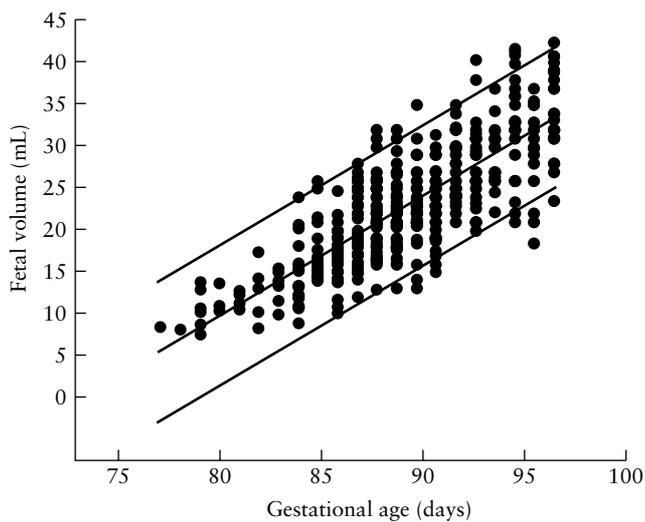


Figure 2 Reference range (mean, 95th and 5th centiles) for fetal trunk and head volume with gestation in chromosomally normal pregnancies at 11 + 0 to 13 + 6 weeks of gestation.

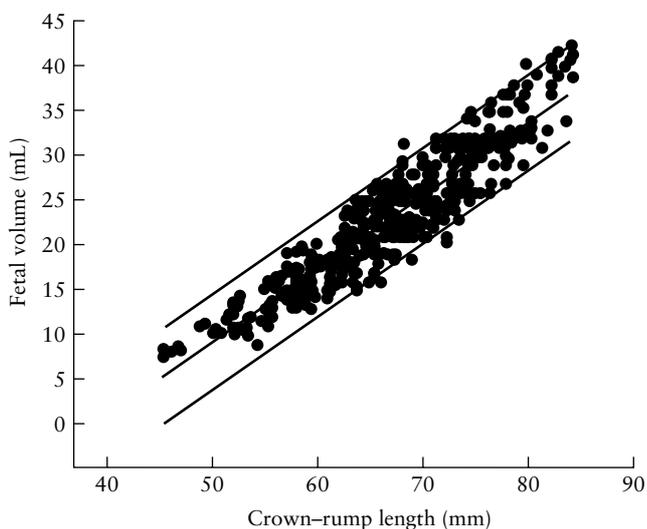


Figure 3 Reference range (mean, 95th and 5th centiles) for fetal trunk and head volume with crown-rump length in chromosomally normal pregnancies at 11 + 0 to 13 + 6 weeks of gestation.

11 + 0 weeks to 33.3 mL at 13 + 6 weeks (fetal volume in mL = $1.376 \times \text{gestation in days} - 100.2$, SD = 4.4 mL, $r = 0.799$, $P < 0.0001$; Figure 2) and with CRL, from a mean of 5.1 mL at a CRL of 45 mm to 37.5 mL at a CRL of 84 mm (fetal volume in mL = $0.831 \times \text{CRL} - 32.3$, SD = 2.7 mL, $r = 0.928$, $P < 0.0001$; Figure 3). The CRL increased with gestation, from a mean of 48 mm at 11 + 0 weeks to 79 mm at 13 + 6 weeks (CRL in mm = $1.480 \times \text{gestation in days} - 65.9$, SD = 4.5 mm, $r = 0.766$, $P < 0.001$).

In the Bland-Altman plot, the mean difference between paired measurements by the same sonographer was -0.87 mL and the 95% limits of agreement were -2.31 mL (95% CI, -3.18 to -1.44) to 4.05 mL (95% CI, 3.18 to 4.92). The mean difference between paired measurements by two sonographers was -1.09 mL and

the 95% limits of agreement were -5.49 mL (95% CI, -6.70 to 4.29) to 3.32 mL (95% CI, 2.12 to 4.53).

DISCUSSION

This study has demonstrated that 3D ultrasound can provide a reproducible measurement of the fetal trunk and head volume, which increases linearly with gestation between 11 + 0 and 13 + 6 weeks.

Two previous studies of fetal volume by 3D ultrasound examined 34 patients at 7–10 weeks and 72 fetuses at 6–12 weeks of gestation, respectively^{8,9}. In both of these studies the scans were carried out transvaginally and volumes, which included the limbs, were calculated using the VOCAL technique in the first and the multiplanar method in the second study, respectively. In our center there is more experience with transabdominal than transvaginal scanning, and in all cases we were able to obtain sufficiently good images to calculate the fetal volumes. We decided to exclude the limbs from the volume measurements because at 11 + 0 to 13 + 6 weeks the legs are usually crossed over each other and the hands are often in contact with the face, which would make volume calculation too complex and probably less reproducible. In the calculation of fetal trunk and head volumes we used the VOCAL technique. It has been previously demonstrated that the VOCAL and multiplanar techniques are equally accurate and reliable for *in-vitro* measurements of objects greater than 20 mL¹⁵. Although there are no studies demonstrating the accuracy of these methods for smaller objects, our results show that in 95% of cases the differences between measurements performed by the same and by different observers were less than 4 mL, which is actually much less than most fetal volumes calculated from 11 + 0 to 13 + 6 weeks.

The findings of the present study and previous 3D studies, which are summarized in Figure 4, provide *in-vivo* evidence of a biphasic pattern of fetal growth in early pregnancy. Several 2D sonographic studies have reported the S-shaped pattern of fetal growth with gestation, with the linear component at 10 and 30 weeks^{1–3,16}. This has also been reported in postmortem pathological studies, which demonstrated a biphasic pattern in fetal growth with a mean embryonic/fetal weight of approximately 1, 8 and 45 g at the respective gestations of 8, 11 and 14 weeks¹⁷. Thus the first 10 weeks of gestation, which is the embryonic period, are primarily devoted to embryogenesis with establishment of all major organ systems¹⁸. Subsequently, with the onset of the fetal period, there is a shift in emphasis towards growth and maturation.

In the fetuses in the present study there was a doubling in CRL between 11 + 0 and 13 + 6 weeks but a simultaneous 5–6-fold increase in fetal trunk and head volume. The extent to which this additional information provided by 3D ultrasound can potentially allow a better understanding of the patterns of fetal growth

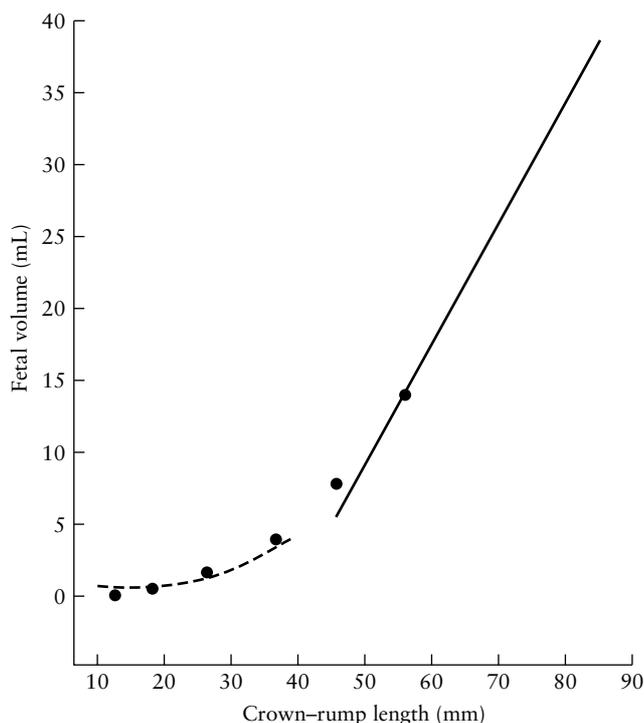


Figure 4 Mean values of fetal trunk and head volume for crown-rump length in the present study (—) and in those in the studies by Blaas *et al.*⁸ (---) and Aviram *et al.*⁹ (●●●).

in normal and pathological pregnancies remains to be determined.

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