

Three-dimensional sonographic description of the fetal frontal bones and metopic suture

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ABSTRACT

Objective To describe the morphology of the frontal bones and metopic suture at 9–34 weeks of gestation using three-dimensional (3D) ultrasonography.

Methods This was a cross-sectional study of the frontal bones and metopic suture in 16 fetuses at 9–34 weeks of gestation. 3D ultrasonography was used to obtain volumes of the whole fetal skull in the mid-sagittal plane. The volumes were analyzed using the rendering mode and transparent maximum mode in order to achieve a clear view of the frontal bones and the metopic suture.

Results At 9 weeks, a small ossification center was visible in the middle of each supraorbital part of the frontal bones and by 11 weeks the frontal bones appeared as 'thick eyebrows'. In the second trimester there was progressive radial bone expansion and delineation of the metopic suture and in the third trimester there was closure of the metopic suture, starting from the glabella and moving upwards towards the anterior fontanelle.

Conclusions This study provides 3D ultrasound images that illustrate the process of ossification of the frontal bones and the subsequent development of the metopic suture during prenatal life. Copyright © 2005 ISUOG. Published by John Wiley & Sons, Ltd.

INTRODUCTION

Abnormal development of the fetal metopic suture is found in association with many genetic syndromes. Prenatal sonographic diagnosis of craniosynostosis, which is either syndromal or isolated, is based on the combination of identifying the premature closure of the sutures and the associated deformation of the

skull^{1–3}. There is some evidence that since cranial sutures represent the junction between curvilinear bones, their assessment is made more accurately by three-dimensional (3D) rather than conventional two-dimensional (2D) ultrasonography^{4–6}. In this descriptive study we report on the 3D appearance of the frontal bones and metopic suture between 9 and 34 weeks of gestation.

METHODS

This was a cross-sectional study of the frontal bones and metopic suture in 16 fetuses at 9–34 weeks of gestation, based on the last menstrual period and confirmed by the measurement of crown–rump length (CRL) in early pregnancy. The 3D volumes were obtained with the fetuses in the mid-sagittal plane, the transducer being parallel to the direction of the nose. The 3D examinations were carried out transabdominally or transvaginally (RAB 4-8L probe or RIC 5-9H, 4D Transvaginal probe, Voluson 730 Expert, GE Medical Systems, Milwaukee, WI, USA), by sonographers with extensive experience in 3D ultrasonography. The sweep angle was selected to include the whole fetal skull. For postprocessing the 3D volumes were analyzed using the surface rendering mode and transparent maximum mode with the three orthogonal planes (Voluson 730 Expert Operation Manual, GE Medical Systems, Milwaukee, WI, USA). Having selected plane A showing the fetal profile, fine rotational adjustments were done to show the frontal bones lined horizontally with the *x*-axis. The rendering box was then narrowed to include only the fetal face. The size of the rendering box varied according to the gestational age, and the image was displayed with a combination of transparent maximum and surface texture modes in order to achieve a clear view of the frontal bones and the metopic suture.

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RESULTS

The frontal bones and metopic sutures at 9–34 weeks are illustrated in Figure 1. At 9 weeks, a small ossification center is visible in the middle of each supraorbital part of the frontal bones. Subsequently, ossification spreads medially and laterally, so that by 11 weeks the frontal bones appear as 'thick eyebrows'. Between 11 and 20 weeks ossification spreads upwards in a radial fashion. Furthermore, in the advancing zone of ossification, the

new bone appears irregular and trabeculated and grows in an endocranial to ectocranial direction (Figure 2)⁷.

At 11 weeks' gestation, the frontal bones reach the midline at the nasal area and subsequently extend superiorly towards the future anterior fontanelle. Similarly, the gap between the two frontal bones in the midline starts closing from the nasal region at around 16 weeks' gestation and moves superiorly towards the anterior fontanelle by 28 weeks. At 32 weeks' gestation there is apparent closure of the metopic suture at the supranasal region and



Figure 1 Fetal face in coronal view rendered with a combination of transparent maximum and surface texture modes of display of 16 normal fetuses from 9 to 34 weeks of gestation. In each case the crown–rump length (CRL) or biparietal diameter (BPD) is given.

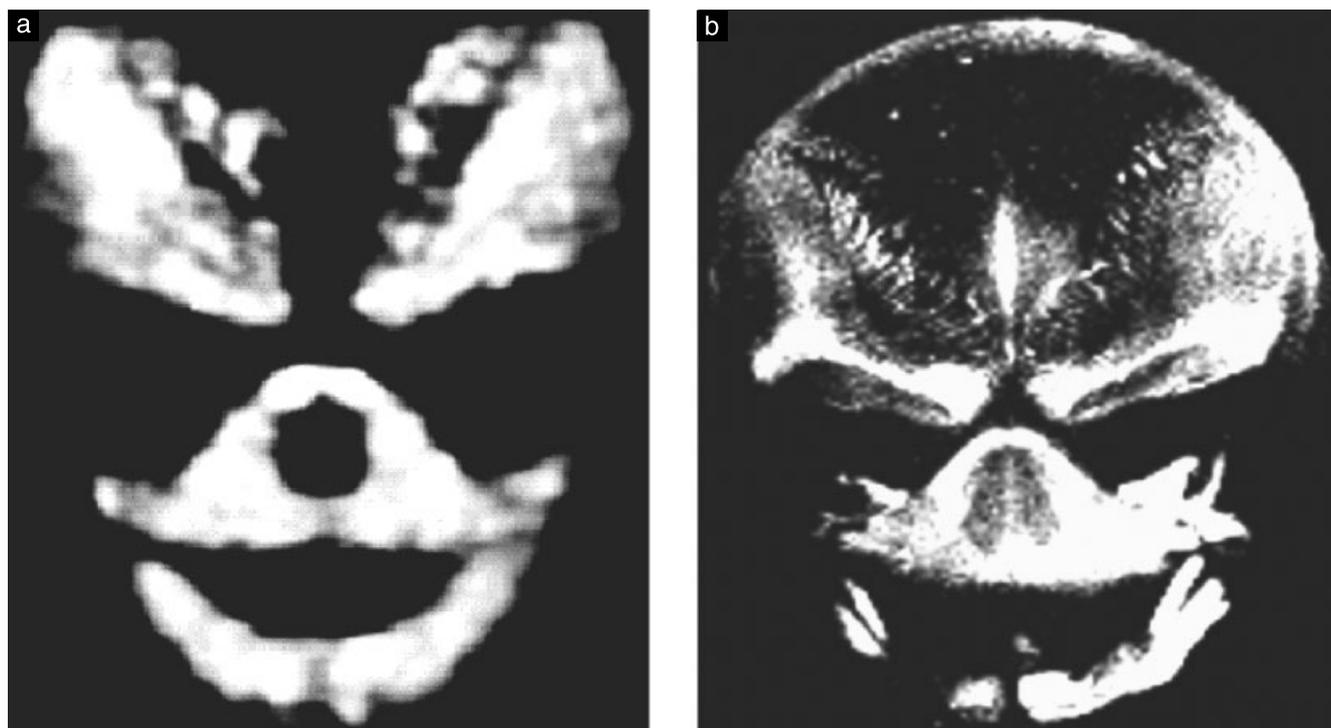


Figure 2 Face in coronal view of 12-week fetuses, showing ossification in the supraorbital region of the frontal bones and new bone formation at the upper edges which is irregular, trabeculated and in an endocranial to ectocranial direction. (a) A three-dimensional image from a live fetus; (b) photograph of a fetus taken in 1937 after treatment with alcohol and formalin solution⁷ (reproduced with the permission of Blackwell Publishing).

subsequently the closure moves superiorly towards the anterior fontanelle.

DISCUSSION

In this study we were able to examine the development of the frontal bones by 3D ultrasonography and the use of, firstly, the surface rendering mode, which allows visualization of the whole of the frontal bones despite the curvature of the skull and, secondly, the transparent maximum mode, which accentuates the signals from bony structures and suppresses those from the surrounding soft tissues. We demonstrated that ossification of the frontal bones starts in the first trimester in the middle of each supraorbital region and then spreads horizontally; in the second trimester there is progressive radial bone expansion and delineation of the metopic suture; and in the third trimester there is closure of the metopic suture, starting from the glabella and moving upwards towards the anterior fontanelle.

The 3D sonographic findings of this study are compatible with the results of extensive postmortem anatomical studies. The frontal bones are ossified in membrane from two primary centers in the supraorbital region, which first appear when the fetal CRL is 26–35 mm, corresponding to 9 + 2 to 10 + 1 weeks of gestation^{7–10}. Subsequently, waves of osteodifferentiation spread along the superciliary arch and then radially upwards⁷. In our study, at 9 weeks' gestation there was evident ossification in the middle of each supraorbital

part of the frontal bones, at 11 weeks the frontal bones appeared as 'thick eyebrows', and in the subsequent weeks ossification spread upwards in a radial fashion. The bones reached the midline at the nasal area and then extended superiorly towards the future anterior fontanelle.

In membranous ossification, a number of flat bones characterized by the presence of needle-like bone spicules are formed and these spicules progressively radiate from the primary ossification centers towards the periphery¹¹. With further growth during fetal and postnatal life, the membranous bones enlarge by apposition of new layers on the outer surface and by simultaneous osteoclastic resorption from the inside. This radiating, irregular, trabecular growth, in an endocranial to ectocranial direction, within the advancing zone of ossification is well illustrated in the 3D ultrasound picture in Figure 2, which is remarkably similar to the photograph of the fetal skull published in 1937 by Inman and Saunders⁷.

In a previous 3D ultrasound study of fetuses at 11 to 13 + 6 weeks' gestation we reported that the gap between the two frontal bones in the midline does not decrease significantly with gestation¹². As shown in Figure 1, it appears that the gap starts closing at around 16 weeks in the supranasal region, and with advancing gestation the two frontal bones enlarge and converge in the midline as if being zipped together.

During the third trimester there is absence of a visible gap between the two frontal bones, starting in the supranasal region and then moving upwards towards

the anterior fontanelle. Traditionally, it was thought that physiological closure of the metopic suture is completed at between 1 and 2 years of life¹³. However, a study using reconstructed 3D computed tomography (CT) scans in 159 infants at 1–27 months of age, demonstrated that in 33% of cases at 3 months, in 60% at 5 months and in all cases by 9 months there was complete ossification of the metopic suture with no visible patency of the suture line between the glabella and anterior fontanelle and no evidence of frontal notching of the anterior fontanelle¹⁴. Our findings suggest that the onset of fusion of the frontal bones, starting from the glabella, is evident from the 32nd week of intrauterine life.

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