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From 2D to 5D the evolution of fetal neurosonography

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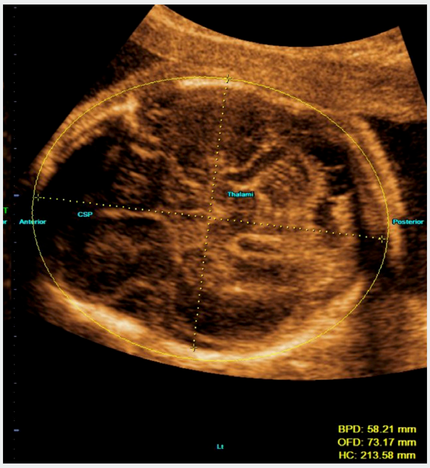

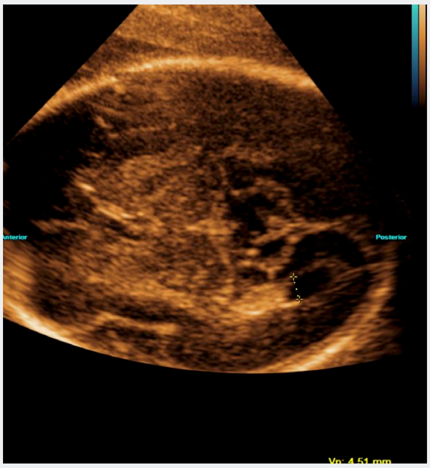

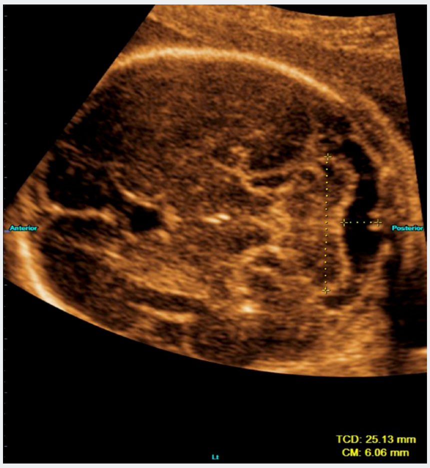

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Introduction

Central nervous system (CNS) malformations are the most common defects in the human fetus and affect approximately 0.3-1% of live births[1-2]. Prenatal detection and accurate definition of CNS malformations are important since these anomalies frequently have a severe prognosis and are often associated with genetic syndromes[2].

Despite the high incidence of CNS anomalies and the clinical importance of their prenatal diagnosis, the efficacy of the screening program is still far from producing satisfactory results, especially when the study of the fetal head is limited to the axial brain planes[3]. An extended study of fetal CNS anatomy, including the addition of sagittal and coronal planes of the fetal brain, may help to improve the diagnostic efficacy[4]. Despite such evidence, the international guidelines for CNS anomalies screening suggest to limit the study to the three axial brain planes that allow to visualize falx, cavum septi pellucidum, thalami, lateral ventricles with the choroid plexus, cerebellum, and cisterna magna but do not permit the study of the corpus callosum, the cerebellar vermis, or other midline brain structures[3]. However, the identification of anomalies involving these structures is crucial since these anomalies are the most frequently associated with other malformations and chromosomal or genetic abnormalities[2].

The addition of sagittal and coronal planes in the screening evaluation of fetal CNS anatomy may help to improve the diagnostic effectiveness but unfortunately these scanning planes require either a transvaginal approach, which is possible depending on fetal position or a transabdominal approach by a transfrontal view through the metopic suture[3,4]. In both approaches, the chances of obtaining good quality images highly depend on the sonographer's skill and are usually time consuming. As a consequence, an operator's experience has a significant impact on the quality of CNS images and on the subsequent prenatal detection rates of major CNS defects[4].

Three dimensional (3D) ultrasonography has been suggested as a method to overcome the limitation of operator's dependency[5,6]. Namely, this technique allows the acquisition of volumes starting from a standard view of the fetal head and then the off-line navigation of the brain using multiplanar reconstruction which requires to obtain all the diagnostic planes. Thus, 3D ultrasonography has the potential of increasing the detection rate of CNS anomalies by assessing all the CNS diagnostic planes.

The evaluation of fetal CNS system with 3D ultrasound consists of two essential steps: volume acquisition and post-processing of the volume. However, before its clinical application, it is necessary to further evaluate the quality of the images obtained by 3D analysis, the diagnostic efficacy in case of CNS anomalies and the possibility to automate volume evaluation (5D).

Acquisition

Brain volumes were usually acquired starting with a transverse view of the fetal head at the level of the trans-cerebellar axial plane by keeping the angle between the incident ultrasound beam and the cerebral midline at approximately 45° to minimize the acoustic shadow of the skull base on the brain structures of reconstructed planes (Fig.1). The sweep acquisition angle is set between 40° and 60° according to gestational age in order to include the entire fetal brain within the volume.

Volumes are acquired during fetal rest and maternal apnea in an "extreme" quality mode. The main advantage of this approach is that the starting plane is one of the axial planes routinely used in basic examinations of the fetal brain, thus, not requiring advanced capacity of a sonographer. Our group recently demonstrated that after a proper training, sonographers of peripheral centers performing routine fetal examination, but lacking specific experience in fetal neurosonogram volumes succeed in acquiring high quality CNS volumes in 98% of the pregnancies studied. From these volumes expert reviewers were able to off-line reconstruct the axial, sagittal and coronal diagnostic planes[7].

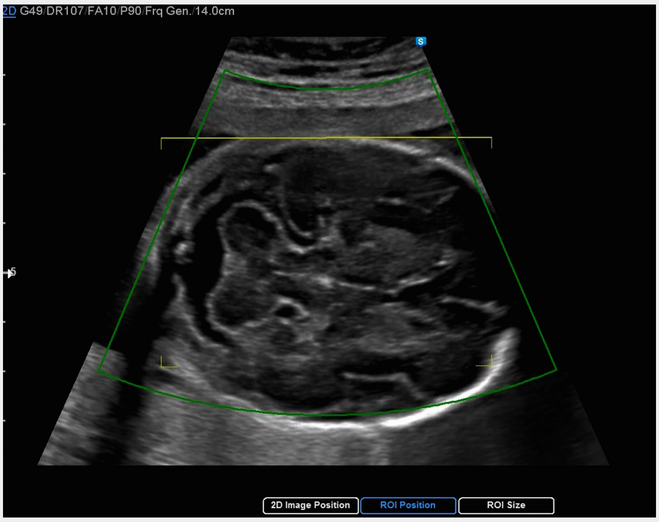

Figure 1. Transcerebellar view of the fetal head. This section is used to acquire the CNS volume. The midline is oblique in order to minimize the acoustic shadow of the skull. The region of interest (ROI) box (green lines) is superimposed.

Post-processing

Post-processing of volume is usually performed with a multiplanar approach by placing the reference point in the middle of cavum septi pellucidum and the skull is then rotated around the z axis until the midline of reference image A becomes horizontal. If necessary, adjustments of the B plane around the x axis are performed to obtain the same axial alignment. In this way, the mid sagittal view of the brain is obtained in C reference plane. High Definition Volume Imaging (HDVI) is used to optimize the visualization (Fig. 2).

Manually navigating with the reference point in the volume allows to reconstruct all the diagnostic planes. Application of the Oblique View eXtended (OVIX) allows a marked improvement in contrast and resolution resulting in an easier and more detailed assessment of brain structures (Fig. 3).

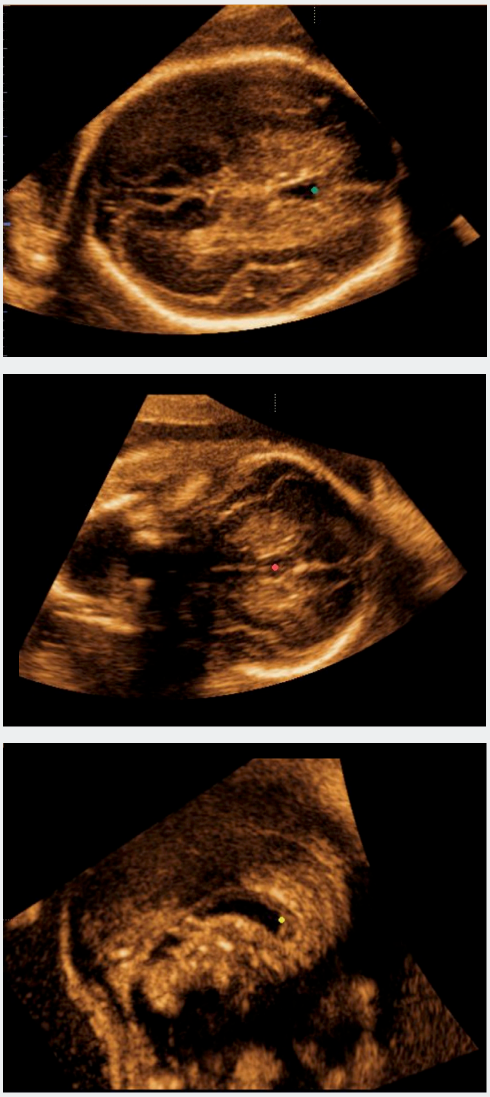

Figure 2. Multiplanar reconstruction of axial, coronal and sagtital planes. The cursor point is placed in the cavum septi pellucidum. In the lower panel (C), the midsaggital view of the fetal brain is visualizaed showing the corpus callosum and the cerebellar vermis.

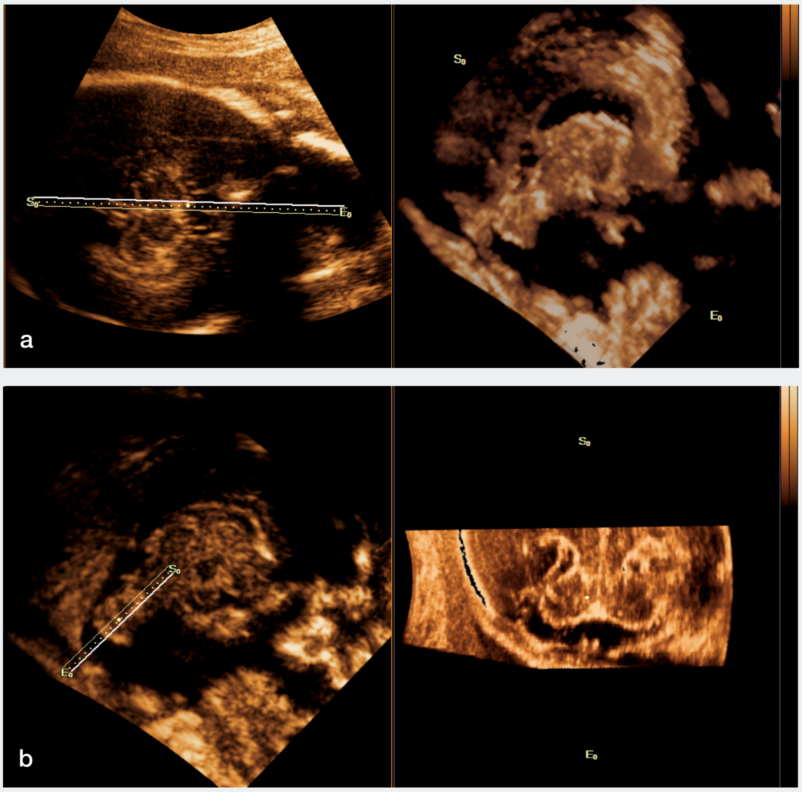

Figure 3. Application of the OVIX function allows an improved visualization of the midsagittal view (a) and of the cerebellum (b)

Quality of 3D fetal brain images

Caution is necessary in the interpretation of reconstructed 3D images, since imaging artifacts cannot be always excluded. In order to test the quality of reconstructed planes, we performed comparative studies designed to analyze in the same fetuses 2D and 3D images of corpum callosum (CC) and cerebellar vermis (CV) (Fig 4, 5). We demonstrated that measurements such as the length and circumference of CC and CV obtained by 3D correlated well with those obtained with 2D (Fig. 6)[8,9].

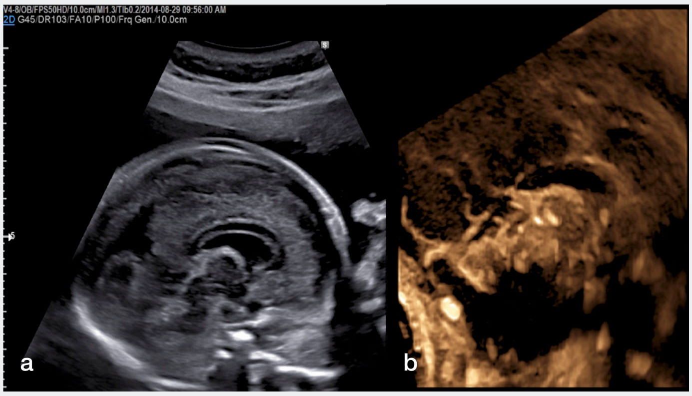

Figure 4. Ultrasound images showing corpus callosum and cavum septi pellucidi obtained in the same fetus by 2D ultrasound (a) and 3D ultrasound (b).

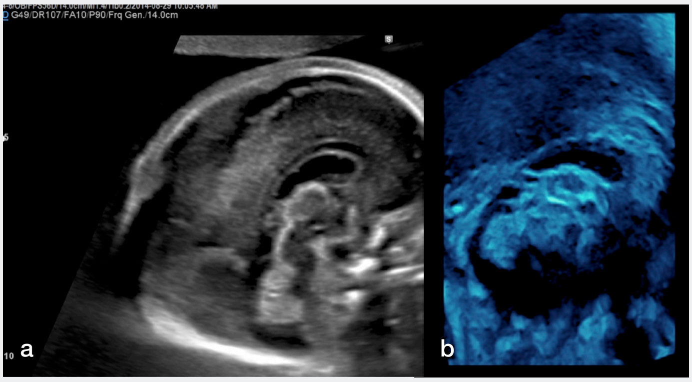

Figure 5. Ultrasound images showing cerebellar vermis obtained in the same fetus by 2D ultrasound (a) and 3D ultrasound (b).

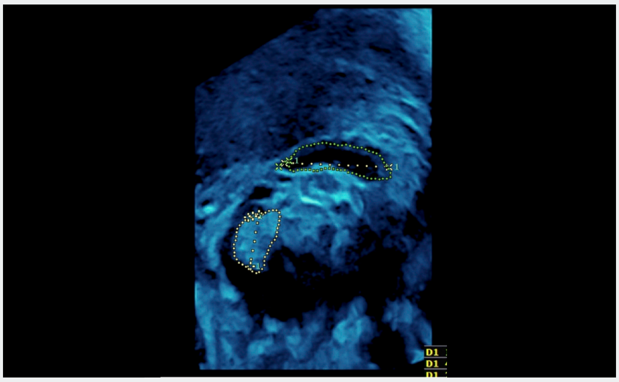

Figure 6. 3D ultrasound images showing the midsaggital view and the corpus callosum cerebellar vermis with their length and the measured circumference.

Diagnostic efficacy

The accuracy of diagnosing CNS congenital anomalies and the agreement among multiple centers have been recently tested by a multicenter trial[10]. The results indicate that in centers with technical expertise in 3D ultrasonography, this technique is an accurate and reliable approach for fetal neurosonography. Indeed, this trial demonstrates that volume-datasets obtained with 3D ultrasound contain enough anatomic information to distinguish normal from abnormal fetal brain, to identify the structural anomalies and to accurately diagnose the specific CNS defects (Fig. 7).

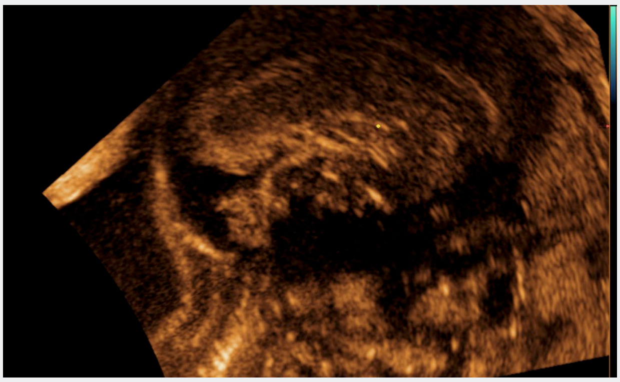

Figure 7. 3D mid-sagittal view of the fetal brain in a fetus with agenesis of the corpum callosus.

Semi-automated analysis of fetal brain volumes (5D CNS)

The multiplanar approach requires the operator's manual 'navigation' of the volume acquired, necessitating specific experience and skill in 3D orientation, and the subsequent retrieval of the diagnostic planes. A semi-automatic approach potentially simplifies 3D volume examination, thus reducing inter-observer variability. 5D CNS is a new software developed for the ultrasound equipment WS80A (Samsung Medison Co., Ltd) with the following objectives:

1) Standardization : automatically visualize brain diagnostic planes
2) Workflow efficiency : simplify fetal brain scan and reduce scan time
3) Diagnostic confidence : minimize the variability and operator dependency

The software works with a standard volume acquired from an axial plane, following the hereby reported technique, with the trans thalamic axial view in the A plane. Two marker points are then placed respectively in the middle of the thalami and the cavum septi pellucidum (Fig. 8a). The activation of the 5D CNS allows the automatic recognition of transventricular, transthalamic and transcerebellar planes, and the measurements of biparietal diameter (BPD), occipital frontal diameter (OFD) head circumference (HC), posterior lateral ventricle width (VP), transverse cerebellar diameter (TCD) and cisterna magna width (CM) (Fig. 8b, c, d).

Possible future developments may include the automatic recognition of the sagittal and coronal planes.

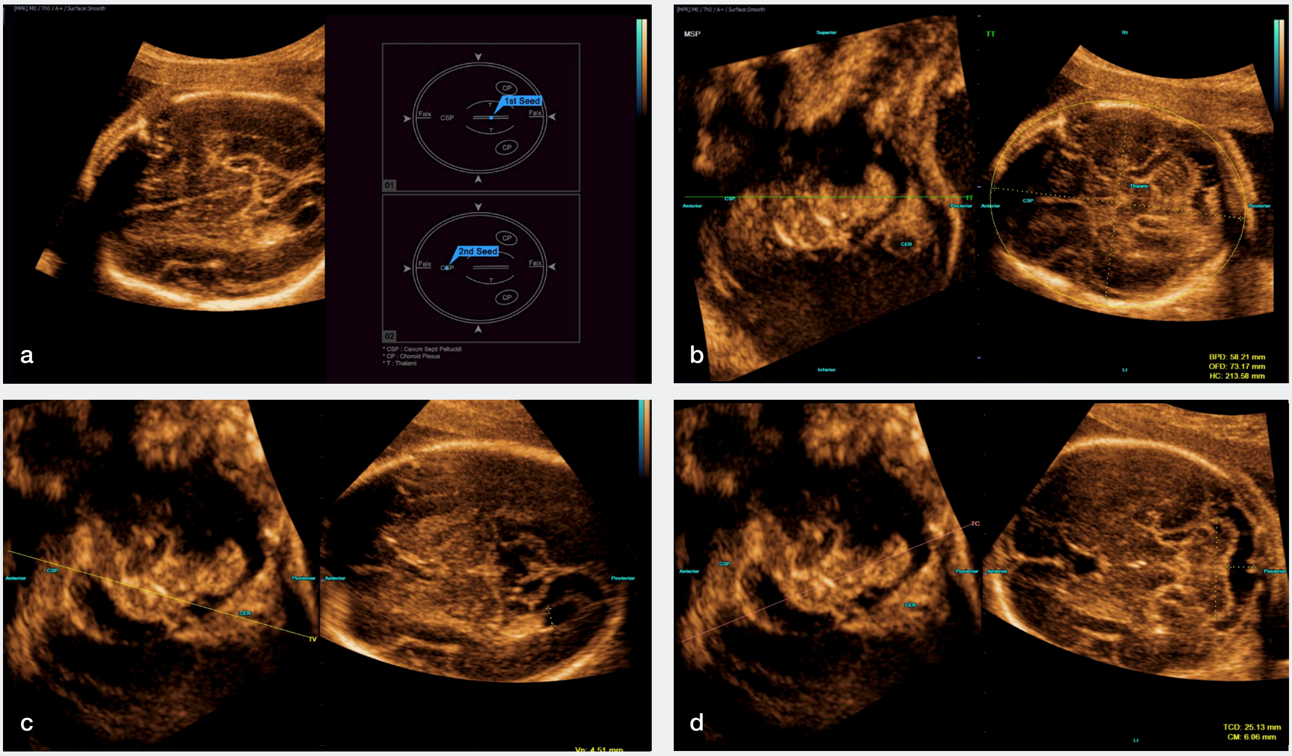

Figure 8. Application of the 5D CNS software. The two marker points (seeds) are placed by the operator in the cavum septi pellucidum and in the middle of the thalami (a). The software then reconstructs the trans-thalamic (b), trans-ventricular (c), and trans-cerebellar (d). Also, this software automatically provides all the diagnostic measurements.

Conclusion

3D ultrasonography can be used to visualize all the diagnostic planes in a fetal brain and the combination of 5D algorithms allows to obtain standard measurements semi-automatically. This approach simplifies the examination of a fetal brain and, reducing inter-observer variability may help to introduce coronal and sagittal planes in routine second trimester examinations, with the potential of improving the diagnostic efficacy of CNS anomalies.

Supported Systems

(1) WS80A with Elite

References

(1) von Wendt L , Rantakallio P. Congenital malformations of the central nervous system in a 1-year birth cohort followed to the age of 14 years. Child's Nervous System 2: 80-82; 1986

(2) Chytty LS, Pilu G. The challenge of imaging the fetal central nervous system: an aid to prenatal diagnosis, management and prognosis Prenat Diagn 2009; 29: 301-302

(3) International Society of Ultrasound in Obstetrics & Gynecology Education Committee. Sonographic examination of the fetal central nervous system: guidelines for performing the basic examination and the fetal neurosonogram. Ultrasound Obstet Gynecol 2007; 29: 109-116

(4) Montegudo A. Fetal neurosonography: should it be routine? Should it be detailed? Ultrasound Obstet Gynecol 1998; 12:1-5

(5) Correa FF, Lara C, Bellver J, et al. Examination of the fetal brain by transabdominal threedimensional ultrasound: potential for routine neurosonographic studies. Ultrasound Obstet Gynecol 2006; 27: 503–508

(6) Rizzo G, Capponi A, Pietrolucci ME, et al. An algorithm based on OmniView technology to reconstruct sagittal and coronal planes of the fetal brain from volume datasets acquired by three-dimensional ultrasound. Ultrasound Obstet Gynecol 2011; 38: 158–164

(7) Rizzo G, Pietrolucci ME, Capece G, et al. Satisfactory rate of postprocessing visualization of fetal cerebral axial, sagittal, and coronal planes from three-dimensional volumes acquired in routine second trimester ultrasound practice by sonographers of peripheral centers J Matern Fetal Neonatal Med 2011; August 2011; 24(8): 1071–1076

(8) Rizzo G, Pietrolucci ME, Capponi A, et al. Assessment of corpus callosum biometry at 18–32 weeks of gestation by three dimensional ultrasound. J Ultrasound Med 2011; 30: 47–53

(9) Rizzo G, Pietrolucci ME, Mammarella S, et al. Assessment of cerebellar vermis biometry at 18–32 weeks of gestation by three-dimensional ultrasound examination. J Matern Fetal Neonatal Med 2012; 25(5): 519–522

(10) Rizzo G, Abuhamad A, Benaceraff B, et al. Collaborative study on three-dimensional ultrasonography for the prenatal diagnosis of central nervous system defects. J Ultrasound Med 2011; 30:1003–1008

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