Ultrasound Obstet Gynecol 2018; **51**: 711–713
Published online in Wiley Online Library (wileyonlinelibrary.com). **DOI:** 10.1002/uog.18957

Editorial

Fetal Brain Tutor 4us: an app for interactive multiplanar navigation through the normal fetal brain

T. GHI[1]*, A. DALL'ASTA[1], R. CONTURSO[2], N. VOLPE[1], N. SCHIVARDI[3], V. MONOPOLI[4], A. PREZIOSA[5] and B. TUTSCHEK[6,7]

[1]*Obstetrics and Gynecology Unit, University of Parma, Parma, Italy;* [2]*Obstetrics and Gynecology Unit, Hospital Valduce Como, Como, Italy;* [3]*Forge Reply Company, Milan, Italy;* [4]*Ultrasound Application Health & Medical Equipment, Samsung Electronics Italy, Rome, Italy;* [5]*Medical Engineering, Samsung Electronics Italy, Rome, Italy;* [6]*Prenatal Zurich, Zürich, Switzerland;* [7]*Medical Faculty, Heinrich Heine University, Düsseldorf, Germany*
**Correspondence to: Obstetrics and Gynecology Unit, Department of Medicine and Surgery, Unit of Surgical Sciences, University of Parma, Via Antonio Gramsci 14, 43126 Parma, Italy (e-mail: tullio.ghi@unipr.it)*

Introduction

Comprehensive assessment of the fetal brain is one of the most difficult tasks of antenatal ultrasound. Specific expertise is required to obtain the non-axial planes in particular, and to assess the sonographic appearance of the cerebral structures at different gestational ages in order to rule out the presence of intracranial anomalies[1].

Multiplanar neurosonography is far more sensitive than is the standard axial approach in the detection of fetal brain malformations, and its use is recommended in cases at high risk for anomalies of the central nervous system[2,3]. In the last decade, it has been demonstrated that use of three-dimensional (3D) ultrasound can overcome most technical issues in fetal brain scanning, enabling the sonographer to acquire and display the sagittal and coronal planes for multiplanar assessment of the brain[4–7]. More recently, implementation of new visualization software has improved greatly the quality of reconstructed images and allowed automatic recognition, labeling and measurement of the main cerebral structures[8].

Creation of virtual 3D objects has been proposed as the last frontier of 3D ultrasound, with the aim of providing the sonographer with easy access to ultrasound datasets of normal and abnormal fetal anatomical specimens on a computer or mobile device[9–11]. Interactive navigation through an ultrasound-derived 3D object may represent a valuable tool for education and training purposes. An increasing amount of evidence supports the role of multimedia tools for both teaching and reference purposes[8]. In this Editorial, we describe the 'Fetal Brain Tutor 4us' app, a new tool developed for interactive multiplanar navigation through the normal mid-gestational fetal brain.

Creation of Fetal Brain Tutor 4us

Twelve Caucasian women with normal, low-risk, singleton pregnancy were recruited and gave their informed consent to participate. Series of fetal brain ultrasound volumes were acquired transabdominally in axial, coronal and sagittal planes, at a mean ± SD gestational age of 20.7 ± 0.49 weeks, using a Premium ultrasound system for prenatal diagnosis (Samsung WS80 Elite equipped with 1–8-MHz transabdominal transducer CV1-8A, Samsung, Seoul, Korea). The 3D function was preset for brain mode, and the scan angle was set at 65°. A sweep of 'extreme quality' resolution was used for volume capture. Each of the three planes of the fetal brain was acquired directly, not virtually reconstructed, with the aim of enhancing the quality of the sonographic images. Using dedicated post-processing software for ultrasound volumes (5D Viewer, Samsung) the sequence of images in each dataset was reviewed offline by two of the authors (R.C., T.G.), frame by frame, in each of the three planes of acquisition. The volume showing the highest-quality images was selected to construct the 3D object for the app.

For all three scanning planes, the selected fetal brain volume dataset was divided into individual frames, using a slice spacing of 0.5 mm, and one of the authors (T.G.) analyzed every frame. A cross-platform authoring tool (Unity Graphic Engine, Unity Technologies, San Francisco, CA, USA) was used to create interactive 3D content, and key anatomical structures appearing on the images were labeled. All pixels comprising such structures were made touch-sensitive through hyperlinks, so that their names could be displayed dynamically on the screen.

The entire sequence of images was transformed into a 3D object suitable for navigation along the three axes. An on-screen slider was also created to aid in navigating the volume. During analysis of the selected axis, a millimeter scale was placed in each frame (top left) in order to provide a spatial reference during navigation. This virtual 3D object represented a comprehensive sonographic view of the mid-trimester fetal brain on axial, coronal and sagittal planes. Once the technical settings, graphic editing and anatomical labeling were completed, the 3D object was used to produce the first app of fetal brain ultrasound imaging, 'Fetal Brain Tutor 4us', available on Android (Google play) and IOS (Apple Store) platforms for free download (Figure 1).

How Fetal Brain Tutor 4us works

The user navigates through the ultrasound images of a normal mid-trimester fetal brain within each of the three

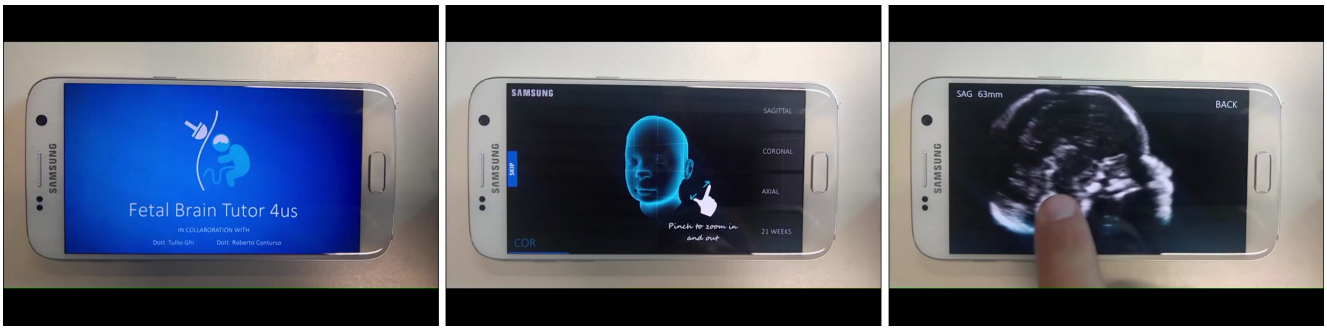

Figure 1 Example screenshots from Fetal Brain Tutor 4us app for interactive multiplanar navigation through normal fetal brain.

scanning planes by scrolling with a simple sweep gesture across the bottom of the screen. The names of the main fetal brain anatomical landmarks visible in the volume are displayed by tapping on different structures in the image; the app user is therefore provided with full knowledge of the name, shape and location of structures appearing within the sonographic images.

Briefly, after launching the app (Figures S1 and S2 in Appendix S1), the welcome page is replaced by an automated tutorial (Figures S3–S8), which can be stopped by selecting 'SKIP' on the left of the screen. 'SAGITTAL', 'CORONAL' and 'AXIAL' buttons are displayed top to bottom on the right of the screen, allowing the plane of interest to be selected by tapping the screen (Figure S9). Following selection, the plane being viewed is indicated in the top left of the screen (as SAG, COR or AXI), alongside the millimeter scale. Each plane of the brain volume dataset can be navigated by scrolling with the fingertip horizontally across the lower portion of the screen (Figures S10 and S11) and each frame can be zoomed in or out using two fingers and the pinch-to-zoom feature (Figures S12 and S13). Once the cerebral structure of interest is displayed and magnified, this can be tapped with the fingertip (Figure S14) and its name will appear in the bottom right corner of the screen (Figure S15). This can be performed in all three planes on any frame which has an anatomical structure displayed on the screen. The user can tap the 'BACK' icon in the top right corner of the screen to return to the home page and select other planes to navigate. A step-by-step guide summarizing how to use the Fetal Brain Tutor 4us app and its related tutorial can be found in the online version of this article (Videoclip S1 and Appendix S1).

How Fetal Brain Tutor 4us may help

We propose the Fetal Brain Tutor 4us app as a new teaching and self-study tool for interactive navigation through the normal fetal brain. This tool, produced by converting an ultrasound volume dataset into a virtual 3D object, is now available, for the first time, for standalone use as a mobile-device app. The Fetal Brain Tutor 4us app may be downloaded on any portable device, such as mobile phone or tablet, that uses the Android or IOS operating system. Fetal Brain Tutor 4us simulates an 'ideal' ultrasound scan of a normal mid-trimester fetal brain, allowing the operator to navigate within the fetal brain and identify the different cerebral structures in the correct plane.

Compared with previous publications on the use of such virtual 3D objects in fetal imaging[9–11], our Fetal Brain Tutor 4us has important novel aspects. It is an independent, standalone app that does not require an active internet connection. The different structures appearing during navigation may be labeled selectively at the tap of a finger, to ascertain which anatomical landmark is displayed. Furthermore, while this first version of the Fetal Brain Tutor 4us has been constructed using only mid-trimester ultrasound volumes from a normal fetus, volumes acquired at later gestational ages are currently being prepared for a future version of the app, which will allow the viewer to appreciate how the sonographic appearance of the normal fetal brain changes across gestation and how sulcation increases progressively from mid-trimester to term. Finally, the app presents several normal sonographic findings which are not in the checklist of the standard brain ultrasound examination, allowing the examiner to become familiar with them. Some, such as sulci and fissures, may be overlooked, especially in the third trimester, or may be misinterpreted as abnormal findings, simply because their normal sonographic aspect and their evolution in pregnancy are not familiar to all ultrasound practitioners.

In case of unusual findings during fetal brain imaging, the sonographer may have this pocket app ready on his mobile device, to review the normal appearance of the different intracranial structures in the mid trimester. Hence, suspicion of a brain malformation may be confirmed or excluded and the patient may be reassured or referred for a second opinion to an expert colleague. Furthermore, in an academic setting, Fetal Brain Tutor 4us may become a valuable tool for the education of trainees and practitioners in recognizing the complex appearance of the normal fetal brain, and, once future versions of the app are released, in recognizing gestational-age-related changes in appearance, enabling them to become familiar with the sonographic aspect of the intracranial structures without the need for multiple scanning of patients.

Finally, it is reasonable to speculate that Fetal Brain Tutor 4us may one day be integrated into the ultrasound machine as an intelligent navigator, enabling adjustment

or correction of scanning planes or guiding the operator in obtaining appropriate reference images of the main brain structures in the different scanning planes.

Conclusion

We have produced the first fetal brain ultrasound tutor, in the form of an independent app. This tool may be downloaded onto any Android or IOS mobile device and, with its capability for interactive multiplanar navigation, may help to improve recognition of the normal sonographic anatomy of the fetal brain.

Disclosure

This work was supported by Samsung Medison Healthcare, Milan, Italy.

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SUPPORTING INFORMATION ON THE INTERNET

The following supporting information may be found in the online version of this article:

Videoclip S1 and **Appendix S1** (containing screenshots (Figures S1–S15) from videoclip) present a tutorial and step-by-step guide summarizing how to use the Fetal Brain Tutor 4us app.

Download the app

Download Fetal Brain Tutor 4us for free from the App Store for Apple products or Google Play for Android devices.