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IMAGE

Fetal heart segmentation in a virtual reality environment

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Abstract
This study presents the initial results of a pilot project using the Elucis Virtual Reality (VR) platform for fetal heart segmentation. Twelve fetal heart cases, ranging in gestational age from 24 to 30 weeks, including various cardiac conditions, were reconstructed using 3D models facilitated by the Elucis platform's integration of automated algorithms and manual adjustments. The models, which were evaluated by four experts in virtual and 3D printed formats, were of high quality and offered improved visuospatial visualization and detailed anatomical insights. This research highlights the potential of VR technology to improve prenatal diagnosis and planning for complex cardiac conditions, suggesting significant implications for continuing medical education and clinical practice in fetal cardiology.

Keywords Fetal heart · Three-dimensional ultrasound · Models · Virtual reality

Image segmentations from exams such as ultrasound, magnetic resonance imaging, and computed tomography are used to enhance anatomical studies. They enable volumetric reconstruction of organs into three-dimensional (3D) virtual models, providing a more complete understanding of anatomy. In addition to improving anatomical understanding, these models facilitate virtual navigation, 3D printing, and use in augmented reality applications [1–4].

In the field of Fetal Medicine, the use of image segmentation has been ongoing for over 15 years [3]. With the development of new segmentation software, fetal organs, especially the heart, can now be reconstructed with significantly improved clarity. In fetal echocardiography, the implementation of Spatial-Temporal Image Correlation (STIC) allows the export of 3D volumes to various 3D modeling software. However, existing segmentation software primarily processes images in a two-dimensional (2D) environment, limiting the spatial information to flat representations displayed on screens manipulated by mouse and keyboard [4, 5].

Our aim is to present the first results of a fetal heart segmentation experiment using a virtual reality (VR) platform called Elucis (Realize Medical, Ottawa, ON, Canada). A pilot study was conducted using 12 cases of fetal hearts ranging in gestational age from 24 to 30 weeks. These cases included seven normal fetal hearts, one case of tetralogy of Fallot, one case of transposition of the great arteries, two cases of interventricular communication and one case of left ventricular diverticulum. All models were evaluated by four experts, both virtually and through 3D printing, with good quality observed in all cases (Fig. 1; Video S1 and S2).

The Elucis VR platform integrates automated algorithms with manual adjustments to improve the segmentation of medical images. Using DICOM blocks, the software employs a tool called "thresholding" to automatically identify specific pixel tones of cardiac tissue. This process is complemented by manual editing tools that allow specialists to refine and correct the segmentation in real time through an options menu. This allows for individual reconstruction of structures, incorporation of color and volume in selected anatomical regions, or grouping to create a comprehensive representation of the fetal heart.

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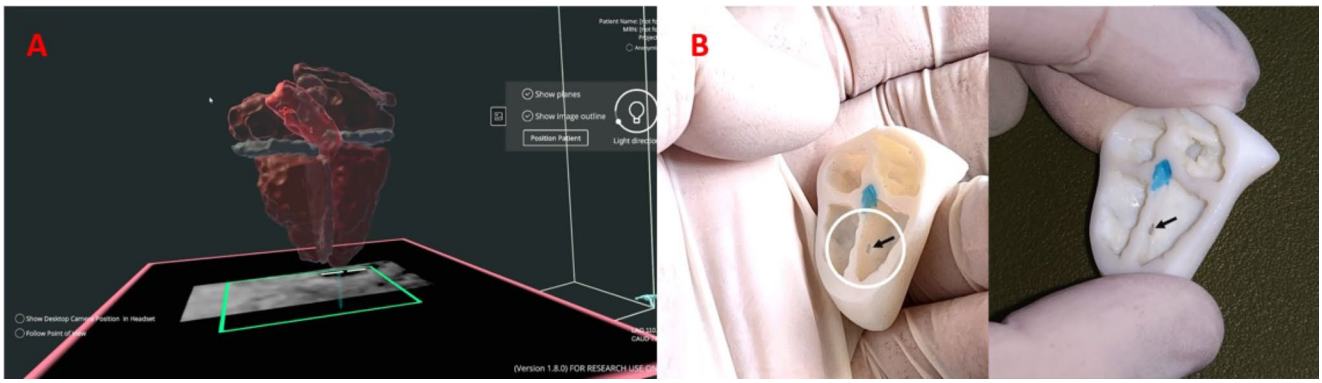

Fig. 1 Virtual (**a**) and printed model (**b**) of a fetal heart (26 weeks of pregnancy). Note interventricular communication (arrow)

Despite advances, virtual reality segmentation faces challenges. The quality and accuracy of the segmentation is highly dependent on the quality of the original DICOM images, which affects the accuracy of the 3D models. In addition, the need for manual interaction for fine-tuning can lead to operational variability depending on the user's experience with the platform. The time spent by the user working on the images and the cost of the software, which limits its accessibility, must also be considered. However, the advantages of virtual reality segmentation over traditional methods include greater visuospatial value of the fetal heart with 360-degree views, the possibility of bimanual interaction (facilitating virtual surgical planning), complete immersion in the virtual environment, magnification of structures for detailed navigation, and the ability to create three-dimensional medical content directly in 3D. This technology also improves image quality, optimizes time spent on each project, and provides broad connectivity between users, allowing models to be shared globally.

We believe that VR segmentation can serve as an exceptional tool for detailed reconstruction of fetal cardiac anatomy. The high-quality models produced by this technology facilitate multidisciplinary discussions and enrich medical education, especially considering the technical difficulties in diagnosing complex cardiac diseases and the need to invest in virtual surgical and hemodynamic training programs. The future is promising, with research aimed at developing algorithms that can automate and improve segmentation, reducing the need for manual intervention and increasing the accuracy of the models produced. Collaboration between cardiologists, radiologists and virtual reality specialists is essential to increase the clinical applicability of this innovative tool.

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Author contributions MCG collected dataGR prepared the Figure and VideosJL resourcesEAJ wrote and reviewed the textHW supervision.

Data availability No datasets were generated or analysed during the current study.

Declarations

Competing interests The authors declare no competing interests.

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