Cite as: Nieblas CO, Araujo Júnior E, Bravo-Valenzuela NJM, Giffoni MC, Pereira Leite MF, Werner H: 3D ultrasound of fetal congenital heart disease: findings from virtual and physical models. J Ultrason 2025; 25: 26. doi: 10.15557/JoU.2025.0026.

Submitted: 20.04.2025
Accepted: 13.07.2025
Published: 30.09.2025

3D ultrasound of fetal congenital heart disease: findings from virtual and physical models

Caroline Oliveira Nieblas[1], Edward Araujo Júnior[2], Nathalie Jeanne Magioli Bravo-Valenzuela[3], Marcela Castro Giffoni[4], Maria Fátima Pereira Leite[5], Heron Werner[4]

[1] *Discipline of Woman Health, Municipal University of São Caetano do Sul (USCS), Brazil*
[2] *Department of Obstetrics, Paulista School of Medicine, Federal University of São Paulo (EPM–UNIFESP), Brazil*
[3] *Department of Pediatrics, Pediatric Cardiology, School of Medicine, Federal University of Rio de Janeiro (UFRJ), Brazil*
[4] *Department of Fetal Medicine, Biodesign Laboratory DASA / PUC, Brazil*
[5] *Fetal Cardiology Sector, Fernandes Figueira Institute (IFF / FIOCRUZ), Brazil*

Corresponding author: Edward Araujo Júnior; e-mail: araujojred@terra.com.br

DOI: 10.15557/JoU.2025.0026

Congenital heart disease (CHD) is the most common congenital malformation[1]. Most CHD cases are classified as major, which means they require immediate care in the postpartum period by pediatric cardiology and pediatric cardiac surgery teams, not least because they are a leading cause of perinatal mortality[2]. Three-dimensional (3D) ultrasound of the fetal heart allows accurate assessment of cardiac anatomy[3].

We performed both physical and virtual 3D reconstructions, as well as virtual navigation, of fetal hearts with different CHD. Fetal heart volumes were acquired using 3D ultrasound with spatio-temporal image correlation (STIC) software on a Voluson E8 ultrasound machine (General Electric Healthcare, Zipf, Austria). These volumes were stored as volumetric format files (.vol) and subsequently converted to Nearly Raw Raster Data (nrrd). The data were imported into the 3D Slicer software (Birmingham, UK), and the physical reconstructions were made in resin using the MediJet J5 printer (Stratasys Ltd., Eden Prairie, MN, USA). Virtual models also were generated using Elucis software (Realize Medical, Ottawa, ON, Canada). These 3D reconstructions were performed at early diastole, before the opening of the atrioventricular valves (isovolumetric relaxation time). All cases were confirmed postnatally. 3D physical and virtual models of four fetal hearts with CHD were reconstructed: hypoplastic left heart syndrome (HLHS) with mitral and aortic stenosis, simple transposition of the great arteries (TGA), double outlet right ventricle (DORV) of the Fallot type with pulmonary stenosis, critical pulmonary stenosis, and total atrioventricular septal defect (AVSD) (Fig. 1). Previous studies have been demonstrating that 3D models enable better cardiac assessment and provide realistic images of CHD, as well as supporting interactive discussions between multidisciplinary teams[4–6].

In conclusion, in this study, we created 3D physical and virtual models of fetal hearts with complex defects, such as TGA, HLHS, DORV, and AVSD. This technology appears to be promising for the diagnosis, management, and treatment of complex CHD. Furthermore, the use of virtual navigation techniques enables the simulation of surgical procedures involving teams from diverse international locations, thereby facilitating the concept of "shortening distances".

Conflict of interest

The authors do not report any financial or personal connections with other persons or organizations which might negatively affect the contents of this publication and/or claim authorship rights to this publication.

Author contributions

Original concept of study: NJBV. Writing of manuscript: EAJ. Analysis and interpretation of data: MFPL. Final acceptation of manuscript: CON, EAJ, NJBV, MCG, MFPL, HW. Collection, recording and/or compilation of data: CON, MCG. Critical review of manuscript: HW.

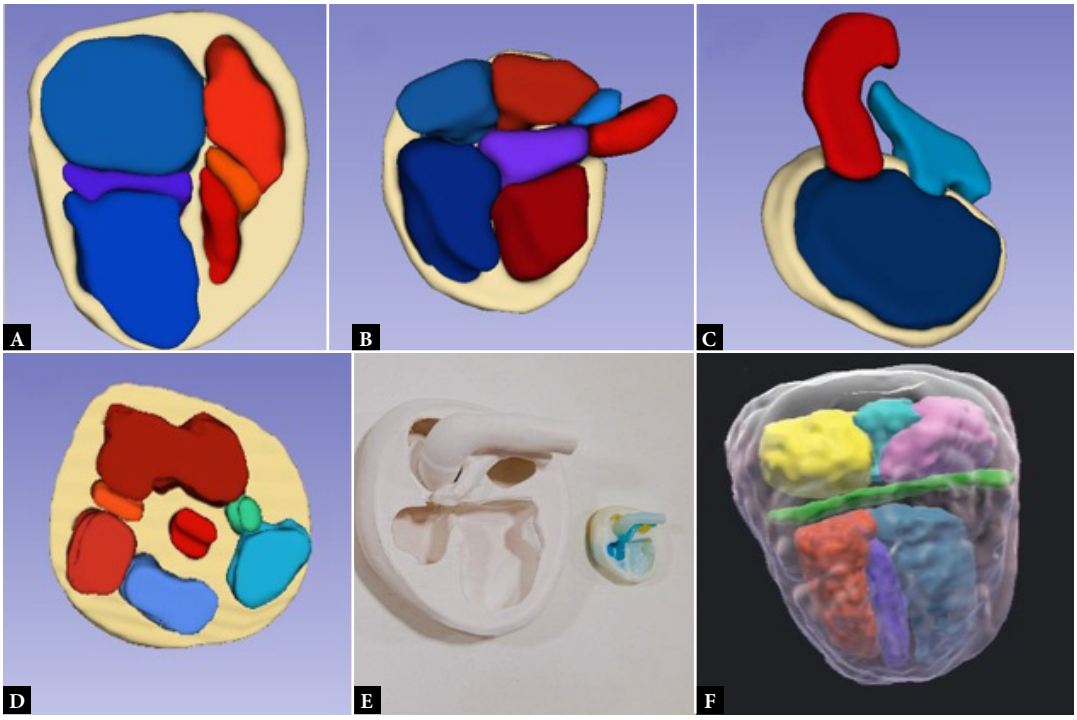

Fig. 1. A. *3D virtual model of a fetus with hypoplastic left heart syndrome (HLHS) with mitral and aortic stenosis; note the small left atrium (orange) and hypoplastic left ventricle (red), with the right ventricle marked in blue;* **B.** *3D virtual model of a fetus with simple transposition of the great arteries (TGA), in which the aorta (purple and red) originates from the right ventricle (dark blue), and the pulmonary artery (light blue) arises from the left ventricle (red), with the aorta located anteriorly and to the right of the pulmonary artery;* **C.** *3D virtual model of a fetus with double outflow right ventricle (DORV), Fallot type; note that both arteries originate from the right ventricle (dark blue);* **D.** *3D virtual model of a fetus with critical pulmonary stenosis; note the narrowing of the pulmonary valve (green) and the post-stenosis enlargement of the main pulmonary artery (blue);* **E.** *3D physical models (fivefold enlargement and life-size) of a fetal heart with DORV, Fallot type, showing the great arteries originating from the right ventricle with a small pulmonary artery and a ventricular septal defect;* **F.** *3D virtual model of an atrioventricular septal defect, showing common atrioventricular valve (green), left atrium (pink), and right atrium (yellow)*

References

1. Meller CH, Grinenco S, Aiello H, Córdoba A, Sáenz-Tejeira MM, Marantz P *et al.*: Congenital heart disease, prenatal diagnosis and management. Arch Argent Pediatr 2020; 118: e149–e161. doi: 10.5546/aap.2020.eng.e149.
2. McGovern E, Sands AJ: Perinatal management of major congenital heart disease. Ulster Med J 2014; 83:135–139.
3. Araujo Júnior E, Tonni G, Bravo-Valenzuela NJ, Da Silva Costa F, Meagher S: Assessment of fetal congenital heart diseases by 4-dimensional ultrasound using spatiotemporal image correlation: pictorial review. Ultrasound Q 2018; 34: 11–17. doi: 10.1097/RUQ.0000000000000328.
4. Bravo-Valenzuela NJ, Giffoni MC, Nieblas CO, Werner H, Tonni G, Granese R *et al.*: Three-dimensional ultrasound for physical and virtual fetal heart models: current status and future perspectives. J Clin Med 2024; 13: 7605. doi: 10.3390/jcm13247605.
5. Nieblas CO, Bravo-Valenzuela NJ, Araujo Júnior E, Werner H: Fetal transposition of the great arteries: 3D virtual and physical models from ultrasound datasets. Int J Cardiovasc Imaging 2024; 40: 1157–1158. doi: 10.1007/s10554-024-03106-x.
6. Pires GDV, Nieblas CO, Bravo-Valenzuela NJ, Araujo Júnior E, Castro PT, Werner H: Ebstein anomaly: 3D virtual and physical models from obstetrical ultrasound data. Echocardiography 2024; 41: e15806. doi: 10.1111/echo.15806.