JACC: CASE REPORTS VOL. 30, NO. 5, 2025

HEART FAILURE AND CARDIOMYOPATHIES

THE FOUR CORNERS: CLINICAL VIGNETTE CORNER

3D Visualization Technology for Cardiac Transplant Planning in a Patient With Failing Fontan Circulation

Madhusudan Ganigara, MD,[a] Kathleen Osea, MD,[a] Ann B. Nguyen, MD,[b] Narutoshi Hibino, MD, PhD,[c] Michael G. Earing, MD,[a,b] Stephen G. Pophal, MD[a]

ABSTRACT

Patients with complex single ventricle anatomy and failing Fontan physiology present unique anatomic challenges to heart transplantation. Cardiac computed tomography scans can be analyzed in a virtual reality environment to aid in understanding of the complex anatomy, perform virtual heart transplant, and help create virtual reality–assisted baffles. This paper presents a case that demonstrates the evolving role of advanced imaging and 3-dimensional virtual modeling in planning complex surgeries. (JACC Case Rep. 2025;30:103132) © 2025 The Authors. Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

CASE SUMMARY

A 34-year-old woman who underwent staged Fontan palliation for complex single ventricle anatomy presented with refractory atrial tachycardia, recurrent ascites, and hepatic cirrhosis. Given her significant symptoms, failing Fontan physiology and severe liver disease, she was listed for a combined heart and liver transplantation.

To delineate the patient's pretransplant anatomy, a cardiac computed tomography (CT) angiography was performed, that revealed abdominal and bronchial situs inversus with dextrocardia. There was a patent left-sided bidirectional Glenn shunt and patent left-sided inferior vena cava (IVC) to Fontan conduit. There was a mirror image of a right-sided liver with 3 hepatic veins joining the IVC. The liver morphology was consistent

TAKE-HOME MESSAGES

- Patients with complex single ventricle anatomy and failing Fontan physiology present unique anatomic challenges to heart transplantation.
- 3D modeling and visualization technology should be an integral tool for planning a heart-liver transplant in patients with unique or complex anatomy.

From the [a]Division of Cardiology, Department of Pediatrics, The University of Chicago, Chicago, Illinois, USA; [b]Division of Cardiology, Department of Medicine, The University of Chicago, Chicago, Illinois, USA; and the [c]Division of Cardiac Surgery, Department of Surgery, University of Chicago, Chicago, Illinois, USA.

The authors attest they are in compliance with human studies committees and animal welfare regulations of the authors' institutions and Food and Drug Administration guidelines, including patient consent where appropriate. For more information, visit the Author Center.

Manuscript received September 30, 2024; revised manuscript received November 11, 2024, accepted November 18, 2024.

ISSN 2666-0849 https://doi.org/10.1016/j.jaccas.2024.103132

ABBREVIATIONS AND ACRONYMS

3D = 3-dimensional

CT = computed tomography

IVC = inferior vena cava

VR = virtual reality

with chronic liver disease. The aortic arch was right sided with mirror image brachiocephalic branching. These findings were then analyzed with the surgical team in a virtual reality (VR) environment to aid in understanding of the complex anatomy, perform virtual heart transplant, and help create VR-assisted systemic venous baffles.

The VR setup included a Dell 5820 precision desktop (64GB RAM, NVIDIA Quatro RTX 5000 16GB). Segmentation, virtual reality visualization, and multiuser collaboration was performed using the Food and Drug Administration-cleared edition of Elucis software version 1.7 (Realize Medical). The resulting models were visualized using a Valve Index VR headset and controllers (Valve Corp). The 3D models were compared with the original CT images to confirm accuracy of the segmentation (Video 1).

Another cardiac CT data set of a patient with normal intracardiac anatomy and similar body size to our index case was also segmented using the Elucis software to use as a virtual donor heart. Virtual explantation of the patient's heart was performed, with care taken to preserve the native ascending aorta, pulmonary arteries, systemic veins, and pulmonary veins along with the posterior left atrial wall. The donor heart with levocardia was segmented so that the aorta beyond the proximal ascending aorta, the branch pulmonary arteries, systemic veins, and pulmonary veins along with the posterior left atrial wall were excluded. This donor heart was then virtually implanted in a levocardia position with an attempt to align the native and donor vascular structures as much as possible (Video 2).

The Elucis software was then used to generate systemic venous baffles connecting the native left-sided superior vena cava and native left-sided IVC to the donor right atrium. Using the surgical team's input, the baffles were fashioned to avoid any kinking or bends. This planning aided the surgical team preparation for the challenge of a complex transplant surgery.

The patient underwent a successful combined heart-liver transplantation and was discharged home after an uneventful 2-week hospital stay. A repeat postoperative CT to evaluate the transplant anastomoses and baffle pathways was segmented using the Elucis software for visualization (Video 3).

CONCLUSIONS

This case demonstrates the evolving role of advanced imaging and 3D virtual modeling to aid in the planning of any complex interventions.[1] The use of patient-specific models allows for precise surgical planning and preparedness.[2]

FUNDING SUPPORT AND AUTHOR DISCLOSURES

The authors have reported that they have no relationships relevant to the contents of this paper to disclose.

ADDRESS FOR CORRESPONDENCE: Dr Madhusudan Ganigara, The University of Chicago & Biological Sciences, 5841 South Maryland Avenue, Chicago, Illinois 60637, USA. E-mail: mganigara@bsd.uchicago.edu.

REFERENCES

1. Priya S, La Russa D, Walling A, et al. From vision to reality: virtual reality's impact on baffle planning in congenital heart disease. *Pediatr Cardiol*. 2024;45:165-174.

2. Sadeghi AH, el Mathari S, Abjigitova D, et al. Current and future applications of virtual, augmented, and mixed reality in cardiothoracic surgery. *Ann Thorac Surg*. 2022;113:681-691.

KEY WORDS Fontan, heart failure, heart transplantation, medical imaging, surgical planning

APPENDIX For supplemental videos, please see the online version of this paper.