Virtual three-dimensional model for preoperative planning in a complex case of a double outlet right ventricle

Swati Garekar[1], Alpa Bharati[2], Firoza Kothari[3], Sachin Patil[4], Shyam Dhake[4], Shivaji Mali[4], Amit Mhatre[5], Dilip Bind[5], Ashwini Joshi[6], Bharat Soni[7], Dhananjay Malankar[7]

[1]Division of Pediatric Cardiology, Fortis Hospital, Mumbai, Maharashtra, India, [2]Division of Radiology, BJ Wadia, Childrens Hospital, Mumbai, Maharashtra, India, [3]Anatomiz3D LLP, Mumbai, Maharashtra, India, [4]Division of Anesthesiology and Intensive Care, Fortis Hospital, Mumbai, Maharashtra, India, [5]Division of Intensive Care, Fortis Hospital, Mumbai, Maharashtra, India, [6]Division of Radiology, Fortis Hospital, Mumbai, Maharashtra, India, [7]Division of Pediatric Cardiac Surgery, Fortis Hospital, Mumbai, Maharashtra, India

ABSTRACT

A 3-year-old child with a complex variant of double outlet right ventricle achieved a successful biventricular repair after detailed delineation of the intracardiac anatomy on multimodality imaging. A virtual three-dimensional (3D) model based on computed tomography was used successfully in the absence of an actual 3D-printed model. This case report seeks to highlight and hence increase the utilization of the virtual 3D model in resource-limited settings.

Keywords: Double outlet right ventricle, surgery, three-dimensional printing

INTRODUCTION

Three D printed heart models are rapidly becoming essential in planning intra cardiac repairs of certain complex CHDs. A virtual model (essential precursor to a printed model) may suffice in certain instances.

CASE REPORT

A 3-year-old child weighing 10 kg presented with a history of repeated respiratory tract infections and slow weight gain. He had a peripheral oximetry of 93%, tachypnea, tachycardia, and a flow murmur. His electrocardiogram showed right axis deviation and predominant right ventricular forces. The chest radiograph showed cardiomegaly and increased pulmonary vascularity.

The echocardiogram showed a double outlet right ventricle (DORV) with normally related great arteries, a large remote inlet ventricular septal defect (VSD) and severe pulmonary hypertension. The semilunar valves' annuli were in continuity with each other and a broad posterior limb of trabecula septomarginalis separated VSD from the annuli. The two ventricles were adequate sized.

The only feasible option was a complex biventricular tunnel repair which was thought to be very challenging on the basis of the echocardiogram alone. Hence, a contrast-enhanced cardiac computed tomography (CT) scan was obtained to plan for a three-dimensional (3D)-printed heart model. It was hoped that the model would enable a detailed exploration of the intracardiac anatomy. However, a model could not be printed as funds were short.

The virtual 3D model was constructed from the CT data in digital imaging and communication in medicine (DICOM) format using Mimics (Mimics Innovation Suite, Materialise, Brussels, Belgium) software. The myocardial border was traced along with the septum and the valve apparatus. The model was exported and viewed as 3D PDF [Figure 1]. Virtual cut-planes

Access this article online

Quick Response Code:

Website: www.annalspc.com

DOI: 10.4103/apc.APC_141_18

How to cite this article: Garekar S, Bharati A, Kothari F, Patil S, Dhake S, Mali S, *et al.* Virtual three-dimensional model for preoperative planning in a complex case of a double outlet right ventricle. Ann Pediatr Card 2019;12:295-7.

Address for correspondence: Dr. Swati Garekar, RM 106, Division of Pediatric Cardiology, Fortis Hospital, Mulund-Goregaon Link Road, Bhandup, Mumbai - 400 078, Maharashtra, India. E-mail: swati.garekar@gmail.com

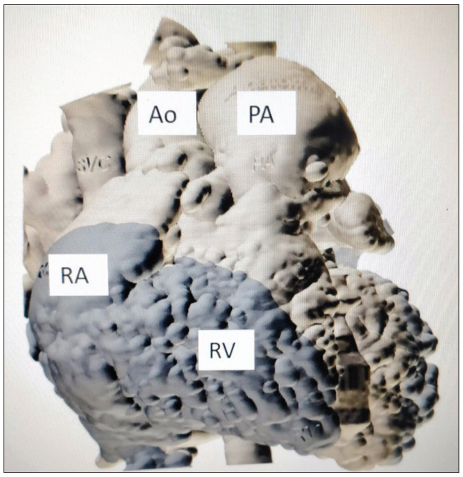

Figure 1: Frontal view of the virtual model of the heart. RV: Right ventricle, RA: Right atrium, Ao: Aorta, PA: Pulmonary artery

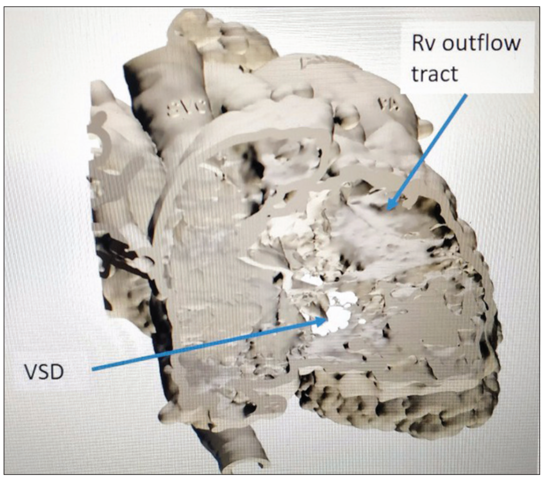

Figure 2: Slightly superiorly tilted view of the heart from the right ventricular aspect (right ventricular free wall removed). The ventricular septal defect is seen clearly. At the top right of the image is the area of the right ventricle leading up to the outflow tracts. RV: Right ventricle

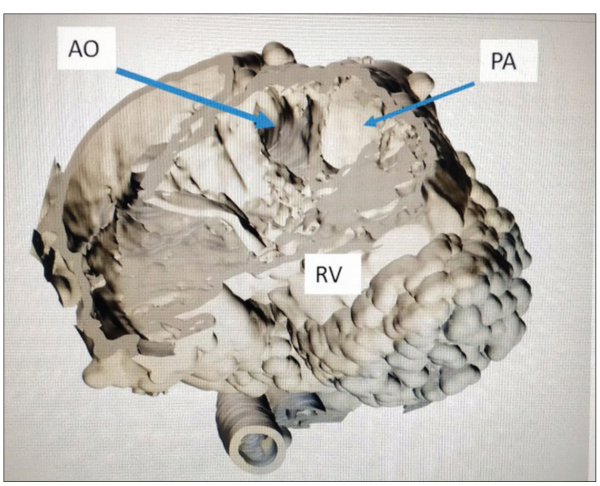

Figure 3: Superiorly tilted view of the heart from the right ventricular side showing the 2 outflow tracts close to each other. RV: Right ventricle, LV: Left ventricle, Ao: Aorta, PA: Pulmonary artery

were planned for visualization of the complex internal anatomy. The volume-rendered virtual model could be successfully reviewed to give in-depth view of the VSD in relation to the great arteries [Figure 2]. It was judged to be feasible to route the VSD to the aortic valve using an intracardiac baffle [Figure 3] (after enlarging the VSD anterosuperiorly) without causing obstruction to the outflow tracts or to the right ventricular inflow.

The intraoperative findings confirmed the diagnosis. The VSD was enlarged in the anterosuperior direction. A trans-right atrial (RA)–trans-right ventricular outflow tract (RVOT) approach was used to create the tunnel. The intracardiac tunnel was created using two-thirds diameter of a split open 14-mm collagen-impregnated, double velour, woven Dacron Hemashield tube graft (Meadox Medicals, Inc., Oakland, NJ, USA) to baffle the left ventricle to the aortic valve. The inferior, anterior, and the posterior margins of the baffle were sutured through trans-RA–trans-tricuspid valve approach while the superior aortic and the anterosuperior margins were sutured through a trans-RVOT approach. The RVOT was augmented by an autologous nonfixed pericardial patch. The child was weaned off cardiopulmonary bypass with low-dose inotropic support and in normal sinus rhythm. The postoperative echocardiogram showed an unobstructed left ventricular tract outflow with a straight course, unobstructed right ventricular inflow and outflow tract, and no residual VSD.

The child was extubated the same night and had an uneventful hospital course and discharge home on postoperative day 7.

DISCUSSION

Complex DORVs like the case described are challenging. Older age at diagnosis adds to the challenge as single ventricle palliation as an option may no longer be available. Conventional echocardiography fails to delineate the VSD, great artery relationship clearly in some cases. Real-time 3D echocardiography has limitations in terms of resolution and probe footprint size, and spontaneous respiration further creates stitch artifacts. The 3D-rendered images from CT Dicom images are surface displays and cannot create depth perception, visualize finer details, or measure actual distances. To accurately see the intracardiac structures, a dedicated 3D software for true volume-rendered images is a must.

3D printing of complex heart defects has increasingly shown utility in preoperative planning.[1,2] The process of conversion of a CT scan Dicom mode to a 3D printer compatible mode (stl) of images is multistaged and requires advanced software and close coordination between the clinical, imaging, and the software specialist teams. 3D printing is underutilized in third world regions due to a number of reasons inclusive of lack of awareness of its utility, cost constraints, and availability of the modality.

The 3D printer ready virtual heart model is the final step before actually printing the model on the 3D printer. In other words, it is an essential part of the workflow process of 3D printing. This virtual model can be viewed on a home computer screen. With the help of simple image-handling tools, the virtual model can be manipulated and measurements made.[3]

Surgical options in biventricular repair in DORV with remote VSD are either to route the VSD to the aorta or to route it to the pulmonary artery with an added arterial switch operation. Many approaches have also been described for these complex tunnel procedures such as trans-RA, trans-RV, transaortic, and transpulmonary and various combinations of these. 3D printing helps in deciding exactly where to route the VSD and what minimum approach or a combination of approaches need to be used to achieve the same, thus limiting the number of incisions on the heart.

Although a 3D-printed heart model is the best option, there are certain benefits of the virtual model. First, it significantly reduces the cost as no actual printing is needed. There are no additional steps taken to start using it. Second, the cross-sectional planes can be modified instantly as many times as needed to optimally visualize the intracardiac anatomy. This is of special significance when the printed model is opaque plastic (transparent model cost is higher). Third, the model can be shared as a 3D PDF file with multiple users. Other benefits include estimating the baffle length, baffle diameter, and size of VSD patch preoperatively. This exploration of the intended surgical technique has the potential to reduce the surgical times and improve outcomes. In our case, we could understand the anatomy with a virtual model, and a successful biventricular repair could be achieved with excellent immediate and short-term outcome. The major drawback of a virtual model that was specific to our case was that the area for safe resection of the VSD margin for its enlargement was hard to visualize on the virtual 3D model.

The use of the virtual model as against 3D-printed model may be considered a viable option for better preoperative planning in resource-limited settings. Improvements in availability, usability, and affordability of 3D software and incorporation of the same in CT imaging suites can be a promising new front in the management of complex congenital heart disease.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Yoo SJ, van Arsdell GS. 3D printing in surgical management of double outlet right ventricle. Front Pediatr 2017;5:289.
2. Garekar S, Bharati A, Chokhandre M, Mali S, Trivedi B, Changela VP, *et al.* Clinical application and multidisciplinary assessment of three dimensional printing in double outlet right ventricle with remote ventricular septal defect. World J Pediatr Congenit Heart Surg 2016;7:344-50.
3. Farooqi KM, Uppu SC, Nguyen K, Srivastava S, Ko HH, Choueiter N, *et al.* Application of virtual three-dimensional models for simultaneous visualization of intracardiac anatomic relationships in double outlet right ventricle. Pediatr Cardiol 2016;37:90-8.