Virtual Reality Treatment Planning for Congenital Heart Disease

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EDITORIAL COMMENT

Virtual Reality Treatment Planning for Congenital Heart Disease*

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In this issue of *JACC: Case Reports*, Ghosh et al (1) describe their experience with virtual reality for planning surgical treatment of a complex congenital heart disease.

Although ventricular septal defect (VSD) is the most common form of congenital heart disease, multiple VSDs can be challenging, especially if they are not located in the typical position in the membranous part of the septum or the midmuscular region (2). VSDs in the membranous part of the septum are typically the domain of cardiothoracic surgeons, whereas VSDs in the midmuscular region, especially if they are located apically from the moderator band, can frequently be treated by an interventional cardiologist. In the presence of multiple defects, treatment becomes more challenging. A large patch to close all VSDs at once would not be contractile and could bulge toward the right ventricle during systole. Given that most VSDs are closed through right atrial access and the tricuspid valve to avoid ventriculotomy, placement of multiple patches may not be possible because of trabeculations in the pressure-loaded right ventricle (3). In these cases, ventriculotomy may be unavoidable (3). Depending on the anatomy, initial treatment may consist of either pulmonary arterial banding to protect the lungs from high pressure and volume overload or primary surgical repair, as reported by some groups with good results (4).

Long-term outcomes reported have been favorable for repair of multiple VSDs, even if the perioperative mortality is relatively high (approximately 10%) compared with single VSD. Long-term complications such as pulmonary hypertension have been described (4). Another technique used to avoid ventriculotomy is apical exclusion to overcome shunting at the apical muscular level (5).

In view of these difficulties, it is understandable that new technology to provide more insight has been used. Recently, 3-dimensional (3D) printed hearts derived from preoperatively acquired computed tomography have been used for surgical planning (6). The 3D printed models of the anatomy have been found useful for surgery of other complex congenital heart diseases such as double-outlet right ventricle (7). It has been reported that, in patients with complex VSD or double-outlet right ventricle the use of 3D imaging resulted in altering the surgical approach compared with planning on the basis of imaging alone (8). Interestingly, in terms of immediate clinical outcomes, time spent in the intensive care unit and duration of required postoperative ventilatory support were significantly shorter when 3D printed models were used for surgical planning (9). In coronary fistulas, catheter interventions could be carried out virtually before treatment of the patient in the catheter laboratory, thereby predicting difficulties and preventing potential complications by choosing the right equipment in advance (10).

All that said, 3D printing is not universally available and can be expensive (11). Emerging technology allows visualization of complex cardiac anatomy virtually without the need for 3D printing (12). The option to visualize not only anatomy, but also function ("4D") has also been described (13). Interactive

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virtual reality allows the physician or surgeon to move virtually within the heart and obtain an impression of the interrelationships of the different cardiac structures and defects (14).

In the presented case, Ghosh et al (1) have used a commercially available platform to segment the heart and make it virtually accessible. Segmentation and colorization of the different cardiac structures make this even more impressive. They could demonstrate that at least 1 of the VSDs would not be visible through an atrial access and that trabeculations would make location from a right ventriculotomy challenging. Creatively planning a hybrid approach to treat the remaining VSDs was carried out with guidewire placement from the left so the surgeons could find the exit of the VSDs within the trabeculation of the right ventricle (1).

Virtual reality images are mainly derived from cross-sectional imaging such as computed tomography or magnetic resonance imaging. The advantage is excellent anatomical information, but it cannot be used in real time (6,7). Additionally, the source of virtual reality imaging can be echocardiography (15). Even though current reports have used this technology mainly in retrospective settings, rapid processing may allow live visualization in the foreseeable future.

With increasing computational capacity and development of user-friendly programs and interfaces, virtual planning of treatment of complex congenital heart disease will gain wider acceptance and will not be restricted to highly specialized institutions. Wider use requires programs that can use many different data sources and potentially combine the raw data from different imaging modalities into virtual heart models. A prospect to look out for…

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REFERENCES

1. Ghosh RM, Mascio CE, Rome JJ, Jolley MA, Whitehead KK. Use of virtual reality for hybrid closure of multiple ventricular septal defects. *J Am Coll Cardiol Case Rep*. 2021;3(14):1579–1583.

2. Pradat P, Francannet C, Harris JA, Robert E. The epidemiology of cardiovascular defects, part I: a study based on data from three large registries of congenital malformations. *Pediatr Cardiol*. 2003;24(3):195–221.

3. Sakurai H, Nonaka T, Sakurai T, et al. Swiss-cheese ventricular septal defect closure by combination sandwich patch. *Asian Cardiovasc Thorac Ann*. 2021;29(6):555–557.

4. Shetty V, Shetty D, Punnen J, et al. Single-stage repair for multiple muscular septal defects: a single-centre experience across 16 years. *Interact Cardiovasc Thorac Surg*. 2017;25(3):422–426.

5. Perez-Negueruela C, Carretero J, Mayol J, Caffarena JM. Surgical closure of multiple large apical ventricular septal defects: how we do it. *Cardiol Young*. 2017;27(3):588–591.

6. Mendez A, Gomez-Ciriza G, Raboisson MJ, et al. Apical muscular ventricular septal defects: surgical strategy using three-dimensional printed model. *Semin Thorac Cardiovasc Surg*. 2018;30(4):450–453.

7. Vigil C, Lasso A, Ghosh RM, et al. Modeling tool for rapid virtual planning of the intracardiac baffle in double-outlet right ventricle. *Ann Thorac Surg*. 2021;111(6):2078–2083.

8. Bhatla P, Tretter JT, Ludomirsky A, et al. Utility and scope of rapid prototyping in patients with complex muscular ventricular septal defects or double-outlet right ventricle: does it alter management decisions? *Pediatr Cardiol*. 2017;38(1):103–114.

9. Zhao L, Zhou S, Fan T, et al. Three-dimensional printing enhances preparation for repair of double outlet right ventricular surgery. *J Card Surg*. 2018;33(1):24–27.

10. Velasco Forte MN, Byrne N, Valverde Perez I, et al. 3D printed models in patients with coronary artery fistulae: anatomical assessment and interventional planning. *EuroIntervention*. 2017;13(9):e1080–e1083.

11. Illmann CF, Hosking M, Harris KC. Utility and access to 3-dimensional printing in the context of congenital heart disease: an international physician survey study. *CJC Open*. 2020;2(4):207–213.

12. Salavitabar A, Figueroa CA, Lu JC, et al. Emerging 3D technologies and applications within congenital heart disease: teach, predict, plan and guide. *Future Cardiol*. 2020;16(6):695–709.

13. Mena KA, Urbain KP, Fahey KM, Bramlet MT. Exploration of time sequential, patient specific 3D heart unlocks clinical understanding. *3D Print Med*. 2018;4(1):15.

14. Ong CS, Krishnan A, Huang CY, et al. Role of virtual reality in congenital heart disease. *Congenit Heart Dis*. 2018;13(3):357–361.

15. Pushparajah K, Chu KYK, Deng S, et al. Virtual reality three-dimensional echocardiographic imaging for planning surgical atrioventricular valve repair. *JTCVS Tech*. 2021;7:269–277.

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