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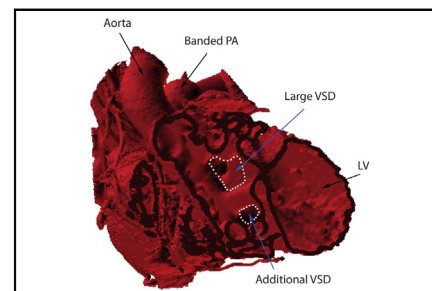


Commentary: Three-dimensional printing for preoperative planning—Beyond illustrating the obvious

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The often-stated benefits of 3-dimensional (3D)-printed reproductions of patient morphology in structural heart disease include (1) facilitation of surgical planning, (2) education of the broader team to better appreciate complex anatomy and its impact on physiology, and (3) enhancement of traditional teaching to correlate 3D structure with 2-dimensional echocardiographic images. The group responsible for this manuscript¹ have pioneered much of this work, incorporating “softer” materials and development of operable models to allow rehearsal of common procedures.²

Pattern recognition is a major element of what accumulated experience affords a surgeon. This is the ability to correlate preoperative imaging with the intraoperative appearance seen in previous cases. For example, the anatomy of a ventricular septal defect (VSD) is understood and anticipated by surgeons as part of a morphologic constellation, such as the subpulmonary VSD in Taussig–Bing anatomy. In unusual anatomy, rare pathology, or early years of surgical practice, pattern recognition may not be sufficient or optimal preparation for complex surgery. Experienced cardiologists perform their own correlation between preoperative imaging and early clinical outcomes but sometimes don't have a good sense of what the surgeon will



3D dataset of double-outlet right ventricle, demonstrating 2 important ventricular septal defects.

CENTRAL MESSAGE

3D printing of complex anatomy may improve patient outcome by optimizing surgical planning when imaging, cardiology, and surgical inputs are combined.

actually see. The most useful models then, will be those developed by a team of imaging, cardiology, and surgical experts collectively seeking to answer the main clinical question at hand.

In this study,¹ the combination of left superior vena cava to the left atrium and a coronary sinus atrial septal defect is the clinical problem. For such patients with uncommon morphology, the strengths and weaknesses of available technical approaches need to be evaluated, since technical imperfection will have important long-term consequences likely to result in reintervention. The models were constructed to address the specific questions of intra-atrial baffling versus extracardiac approaches. Although experienced surgeons would likely default to enlargement of the atrial septal defect and intra-atrial baffling, with the extracardiac approaches as a backup plan, the model-based analytic approach nicely demonstrates the step-by-step evaluation of the various approaches that could be employed to address more complicated pathology.

Early application of 3D models in assessment of routability of the left ventricular outflow through a VSD to the aorta has been encouraging.³ This is of particular importance in identification of patients in whom a 2-ventricle circulation can be achieved, where it is not immediately obvious that this is possible. However, preoperative definition of multiple muscular VSDs and questions involving valve-related anatomy remain problematic.⁴ This occurs mostly as a result of technical limitations in the speed of

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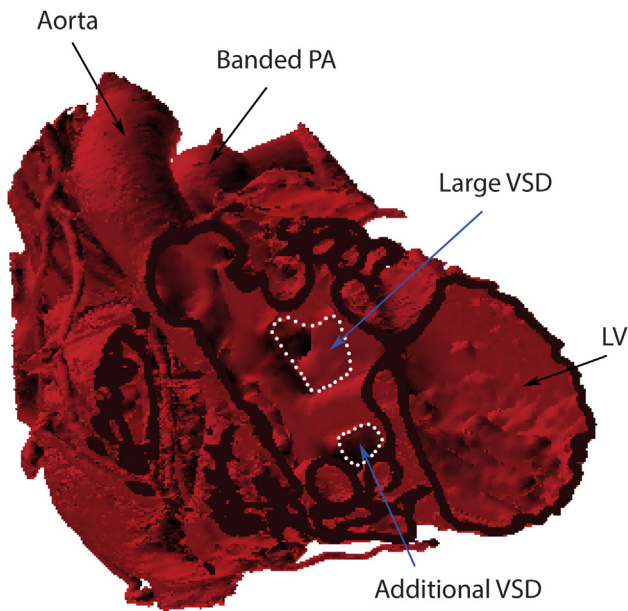


FIGURE 1. 3D dataset of double-outlet right ventricle, demonstrating 2 important ventricular septal defects. PA, Pulmonary artery; VSD, ventricular septal defect; LV, left ventricle.

acquisition and quality of the initial cross-sectional imaging rather than the process of segmentation that then describes the printed model. Evaluation of actual benefit to patient

care is in its early stages⁵ and manipulation of the 3D dataset in PDF format may obviate the need for physical printing in some cases (see the [Figure 1](#)).

What then is the future for 3D modeling in complex structural heart disease? Understanding the key question, high-quality image acquisition, and segmentation guided by clinical experts will enhance the yield of this promising approach. A good model cannot be “ordered,” it is evolved—collaboration inherent in this approach has many additional benefits in the creation and maintenance of a high-functioning team.

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