that includes “shrink-wrapping” deformation, noise averaging, and outer/inner surface creation using viewing windows. Although these steps are essential to model extraction, each step steers us further away from source data. At what point does the anatomic model become an aesthetic sculpture?

This is illustrated by our own 3DP experience. We derived a 3D model of an aortic root with anomalous coronaries from a cardiac computed tomography angiography image using a Siemens Sensation 64-slice scanner (Siemens Medical Solutions Inc., Malvern, Pennsylvania) and printed it on a Stratasys Dimension Elite station (Stratasys Ltd., Minneapolis, Minnesota) using acrylonitrile butadiene styrene plastic. Our model was not manually edited. Figure 1A shows a fracture due to fragility at a previous stent site (arrow). Since the contrast-endovascular interface is nonuniform, variability in extraction results in “holes” in the model (Figure 1B). Image processing can “fix” these holes and offset fragility; however, this diverts us away from true anatomy.

Lastly, the elasticity of print materials must be validated against that of cardiac tissues. Without this, physical interaction with models is unreliable. The material properties of the IVC model of O’Neill et al. (1) are unclear. In this case, printing with stiff plastic, rubber, or metal could potentially alter device selection. Recently, a mitral valve was printed with pliable materials. As elucidated in this work, using materials mimicking tissue properties could lead to applications in ex vivo device testing and training. In our own aortic root model (Figure 1B), for example, printing with a pliable material could enable preliminary test interactions with transcatheter valves.

In conclusion, we share the enthusiasm for the potential of 3DP in SHD. However, multiple technical aspects must be first standardized and validated before meaningful clinical strides can be made with 3DP in the clinical domain.

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First, CAD3DP application is only as usable as the quality of the CT raw source DICOM data that it is being applied from, as demonstrated by the artifact on the model of Mathur and colleagues. For this to be avoided, there needs to be significant investment in education for scanning technique and scan implementation at the level of the CT technologists. For structural heart interventions, we tailor our CT scans to the specific valve or area of interest (Table 1). We use a contrast-enhanced, retrospectively electrocardiogram-gated CT angiography acquisition on a General Electric Discovery CT750 64-slice scanner (General Electric, Waukesha, Wisconsin). Additionally, targeted cardiac phases are identified for reconstruction, as this affects the size, geometry, and functionality of the area of interest. Our models are printed on the Objet30 (Stratasys Ltd., Minneapolis, Minnesota) using Rigid Opaque photopolymers (Stratasys Ltd.).

Second, there is no current U.S. Food and Drug Administration-approved medical 3D printer for use. The absence of elastic printed materials that mimic human tissue should not preclude the advancement and adjunctive clinical application of this technology to current transcatheter procedures for physical periprocedural information gathering and planning. Technology for the future bioprosthetic 3D printed heart valve does not yet exist, but periprocedural clinical application of CAD3DP in structural heart interventions is the beginning to developing the platform to reach that ultimate goal.

We therefore caution comparing medical 3D printing in its infancy with “esthetic art.” There is a vast difference in the amount of procedural planning awareness generated between the ability to view an image magnified on a computer monitor compared with handling a to-scale reproduction of a patient’s anatomy with tolerances that do not modify or deform. Moving forward, we will continue to develop and advance CT CAD3DP imaging innovation to enhance the care of our patients requiring high-risk advanced structural heart interventional therapy.

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REFERENCE