Stereolithographic Biomodeling of Congenital Heart Disease by Multislice Computed Tomography Imaging

Isao Shiraishi, MD; Yo Kajiyama, MD; Masaaki Yamagishi, MD; Kenji Hamaoka, MD

Recently devised 3-dimensional (3D) diagnostic modalities such as magnetic resonance imaging and multislice computed tomography (CT) allow visualization of the heart and great vessels from any angle of view and perspective. In complicated congenital heart disease, however, substantial discrepancies still remain between interpretation of the reconstructed 3D images and the real structures of anatomy. One possible way to overcome these problems is to construct tangible replicas that reproduce the real structures of the disease. Stereolithography is a rapid-prototyping technology whereby an ultraviolet laser beam selectively polymerizes and solidifies a photosensitive, polymeric liquid-plastic solution. By using this technique, 3D volumetric image data can be converted into plastic models that enhance spatial perception of the real anatomy and pathology. After data acquisition by 16-multislice CT (Aquillion 16, Toshiba, Tokyo, Japan), 3D images were generated by image analysis software by defining the volume of interest (X-Tension, Toshiba; ZIO M900, Amin, Tokyo, Japan). The reconstructed 3D data were transferred to a stereolithography biomodeling company (JMC, Yokohama, Japan) and were used to guide the ultraviolet laser beam for polymerizing a selectively photosensitive, polymeric liquid-plastic (for hard biomodels) or a liquid-urethane (for flexible biomodels) solution. The manufactured biomodels clearly reproduced the volume data and demonstrated the anatomy of complicated congenital heart disease, such as asplenia with total anomalous pulmonary venous drainage (Figure, A and B), hypoplastic left heart syndrome (Figure, C and D), and pulmonary atresia and ventricular septal defect associated with major aortopulmonary collateral arteries (Figure, E and F). These 3D models are very informative for surgical repair of the vertical vein, the Norwood procedure, and the unifocalization of major aortopulmonary collateral arteries. Stereolithographic biomodels allow simulation of an individual surgical approach for a specific anatomic disorder or for designing innovative surgical procedures in complicated congenital heart disease. This technique is also suitable for the education of medical students and trainees; furthermore, biomodels are informative for patients and their parents. If stereolithographic devices became widespread, cardiologists and cardiac surgeons could share these tangible 3D replicas of rare cardiovascular anomalies or novel surgical procedures by obtaining digital information via the Internet, resulting in the survival of many children with complicated congenital heart disease.

Disclosures

None.

Reference

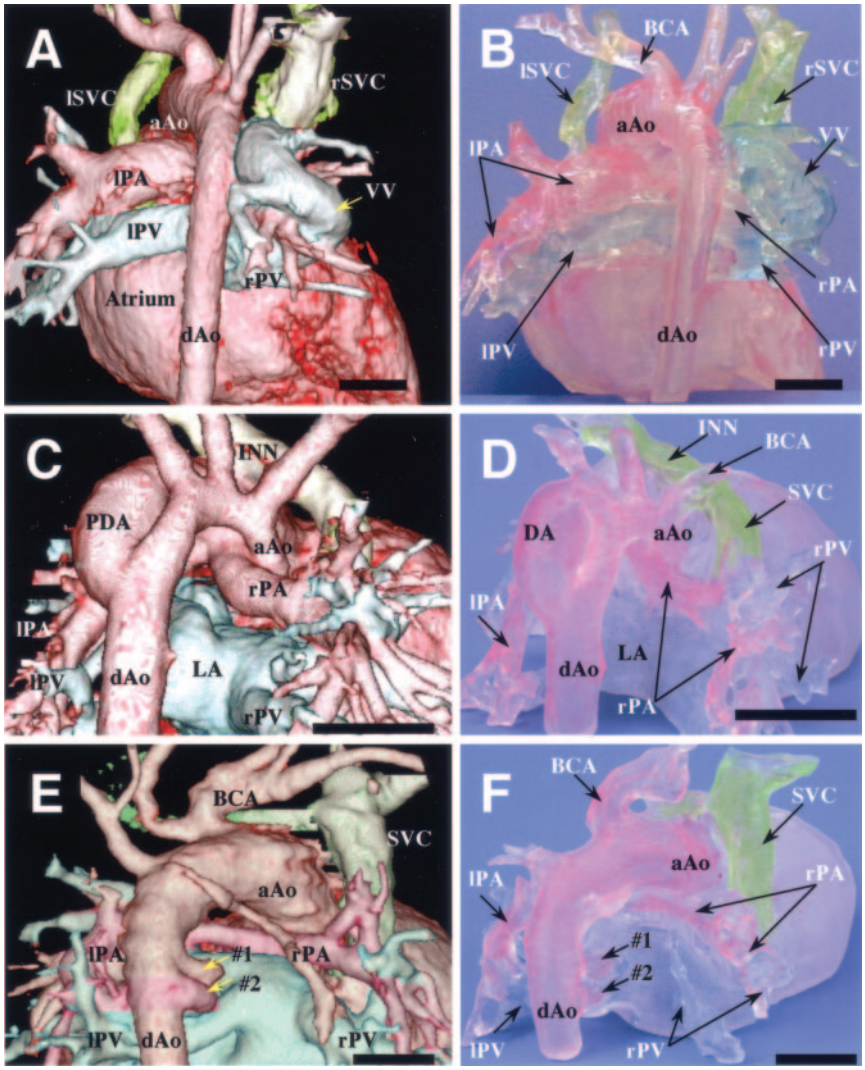
1. Craig JM, Darling RC, Rothney WB. Total pulmonary venous drainage into the right side of the heart; report of 17 autopsied cases not associated with other major cardiovascular anomalies. *Lab Invest.* 1957;6:44–64.

From the Departments of Pediatric Cardiology and Nephrology (I.S., Y.K., K.H.) and Pediatric Cardiovascular Surgery (M.Y.), Kyoto Prefectural University of Medicine, Graduate School of Medical Science, Kyoto, Japan.

Correspondence to Isao Shiraishi, MD, Department of Pediatric Cardiology and Nephrology, Kyoto Prefectural University of Medicine, Graduate School of Medical Science, Kawaramachi-Hirokoji, Kamigyo, Kyoto, Japan 602-8566. E-mail isao@koto.kpu-m.ac.jp

(*Circulation.* 2006;113:e733-e734.)

***Circulation* is available at http://www.circulationaha.org** **DOI: 10.1161/CIRCULATIONAHA.105.538801**



Multislice CT volume-rendering images of complicated congenital heart diseases (A, C, and E) and the corresponding stereolithographic biomodels (B, D, and F, shown in the same colors as the CT images). A and B, A 6-month-old infant with right isomerism, a single atrium, single right ventricle, common atrioventricular canal, pulmonary stenosis, total anomalous pulmonary venous drainage type Ib,[1] and a bilateral superior vena cava. The pulmonary veins constitute a tortuous vertical vein (VV) that drains into the right superior vena cava (rSVC), which are clearly reproduced in stereolithography. C and D, A 5-day-old neonate with hypoplastic left heart syndrome. Spatial relationships among the hypoplastic aortic arch, ductus arteriosus (DA), and the right and left pulmonary arteries (rPA and lPA, respectively) are clearly reproduced. E and F, A 1-month-old infant with pulmonary atresia and ventricular septal defect. Two major aortopulmonary collateral arteries (#1 and #2) appear to have originated from the descending aorta (dAo) and supplied pulmonary blood flow to both lungs via the right and left pulmonary arteries. The origin of the major aortopulmonary collateral arteries and the spatial relationships among the pulmonary arteries are clearly recognized by stereolithography. PV indicates pulmonary vein; LA, left atrium; BCA, brachiocephalic artery; INN, innominate vein; and aAo, ascending aorta. Bars in A through F are 1.0 cm.

Stereolithographic Biomodeling of Congenital Heart Disease by Multislice Computed Tomography Imaging

Isao Shiraishi, Yo Kajiyama, Masaaki Yamagishi and Kenji Hamaoka

Circulation. 2006;113:e733-e734
doi: 10.1161/CIRCULATIONAHA.105.538801
Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231

Print ISSN: 0009-7322. Online ISSN: 1524-4539