Three-dimensional (3D) printing as a guidance tool for preprocedural planning of complex atrial septal defect closure

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OBJECTIVES

Three-dimensional (3D) printing is an advanced technology, enabling manufacture of a complex model with precision. We have recently been implementing the use of 3D printing for complex structural heart interventions. This project aims to investigate the dimensional accuracy and effectiveness of 3D printing models on complex congenital heart defects.

CASE

58 year-old female patient with known history of hypertension, presented with bilateral lower limb oedema for two weeks. Chest radiograph and thoracic CT showed evidence of pulmonary hypertension. Echocardiogram showed two separate secundum atrial septal defect (ASD) orifices with left-to-right shunts. Pre-operative cardiac CT confirmed the defects with accurate measurements. The raw CT DICOM files were transferred to an image processing software (Mimics by Materialise) for segmentation of the cardiac chambers. A 3D model was created.

The model helped the cardiologist in deciding whether percutaneous closure was feasible, the number of devices needed, as well as to assess the adequacy of the landing zones. It also allowed simulation training and practice of the procedure.

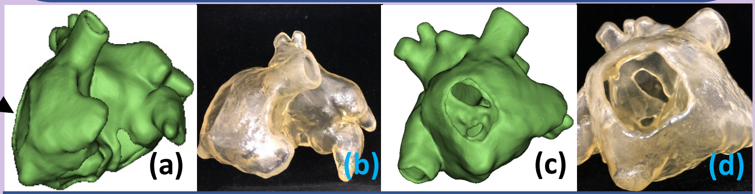

Fig 3: A patient-specific cardiac model including the left and right atria was created from a 3D printer using semi-transparent rubber-like material TissueMatrix™ resin. An artificial defect was created at the superolateral right atrial wall (arrow). Complex anatomy of the ASDs could be clearly visualised through the artificial defect (c and d)

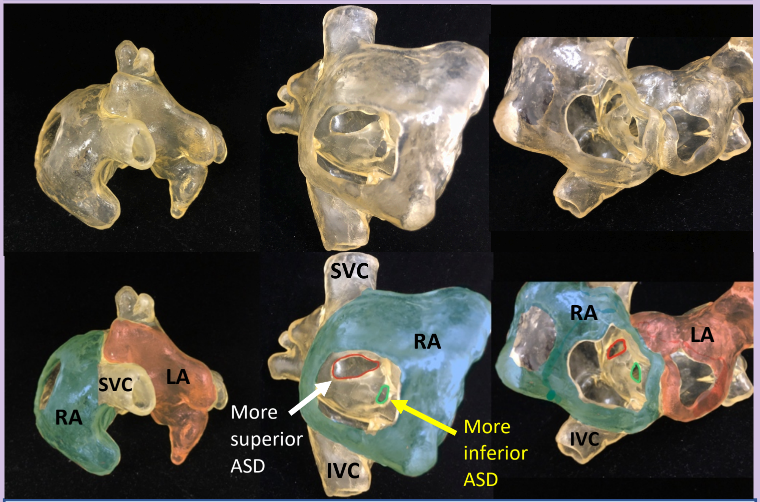

Fig 4: 3D model (Top row without annotation; bottom row with annotations)
Left: superoanterior view
Central: right lateral view through the superolateral right atrial artificial defect
Right: view from caudal aspect of the heart (tricuspid valve not included in the model)

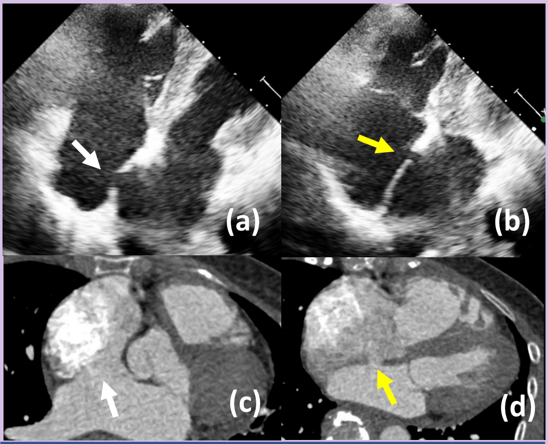

Fig 1: Apical 4-chamber view of echocardiogram showing the the larger, more superior ASD (a, white arrow) and the smaller, more inferior ASD (b, yellow arrow). Corresponding cardiac CT (c and d) demonstrating the respective defects.

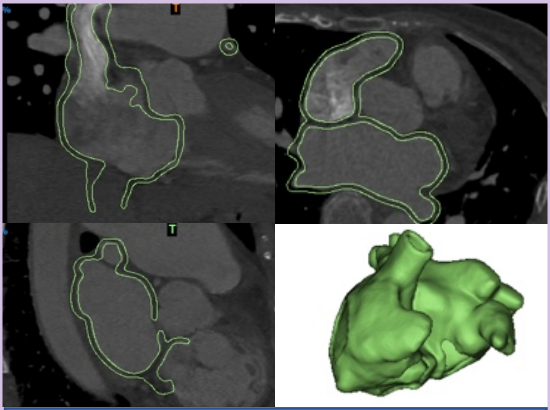

Fig 2: The image processing software segmented the left and right atria along axial, coronal and sagittal planes. Part of the SVC and IVC were included to provide an accurate anatomical pathway for the simulation of the procedure.

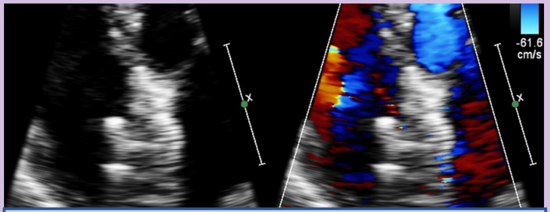

Fig 5: Apical 4-chamber view of echocardiogram post-procedure showing successful closure of the ASDs, with no doppler flow from LA to RA to suggest residual defects.

CONCLUSION

The complex detail of the atrial septal defect can be accurately depicted with patient-specific 3D printing models created from raw cardiac CT dataset. It can greatly aid cardiologists in planning the procedure for fluoroscopic-guided placement of the atrial septal defect closure devices. In the future, we foresee that the use of 3D printing will become more popular especially in the cardiac field, and more cost-effective materials can be developed for the model creation.