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Towards a more accurate planning of invasive procedures: the emerging 3D technologies offer a new approach to the management of complex congenital heart disease

Pluchinotta F.R. (1), Giusti G. (1), Giugno L. (1), Sturla F. (2), Frigiola A. (3), Piazza L. (1), Saracino A. (1), Chessa M. (1), Butera G. (1), Fernandez J. (1), Arcidiacono C. (1), Micheletti A. (1), Giamberti A. (3), Pome' G. (3), Negura D. (1), Redaelli A. (2), Carminati M. (1)
Department of Pediatric Cardiology and Adult Congenital Heart Disease, IRCCS Policlinico San Donato, Milan, Italy (1)
Department of Electronics, Information and Bioengineering, Politecnico di Milano, Milan, Italy (2)
Department of Cardiac Surgery, IRCCS Policlinico San Donato, Milan, Italy (3)

Background. Three-dimensional (3D) printing technology can be successfully used to create heart prototypes of congenital heart disease (CHD). The use of 3D cardiac models allow for previously unavailable visualization, understanding, handling, and analysis of anatomy of complex cardiac disease. Here we present a virtual cardiac laboratory we recently created in collaboration with the Politecnico University in Milan to facilitate surgical and interventional procedure.

Methods. Based on CT and MRI images performed in selected patients with complex CHD, the cardiac anatomy was segmented using the Mimics software (Materialise, Leuven, Belgium). Out of each patient's data set we generated a virtual computer model and an STL-file that was printed as a 3D plaster model.

Results. We printed three 3D models and created nine virtual models of patients with CHD. Two patients had a complex intracardiac anatomy (one patient with DORV and one with isolated ventricular inversion with VSD and severe PS) and the models helped the echocardiographers to better understand the spatial orientation of the intracardiac structures, and the cardiac surgeons to identify risk structures, and to plan in detail the surgical strategy reducing the on-pump time. Virtual models of 9 patients with right ventricular outflow tract dysfunction candidate to percutaneous pulmonary valve implantations (PPVI) were created. Data were sheared with our team of engineers to set up a computer simulation of PPVI release and implantation that could predict distortion of the cardiac anatomy and risk of coronaries compression.

Conclusions. The clinical use of 3D models allows to assess, plan, and simulate in-vitro interventions necessary in case of complex congenital malformations. These skills are especially important for young doctors and surgeons in training. In our experience, the printed 3D models had helped the medical-surgical team to gain a better understanding of the technical problems that had to be addressed improving the surgical procedure. The simulation program for PPVI is a useful tool to improve patients' selection and to eliminate any potential surprise during the procedure in vivo. Multi-center studies should be set up to evaluate the impact of cardiac 3D models on medical decisions, the quality of care, and the patients' outcome.