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Application of 3D printing in medicine

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1. What is 3D printing?

3D printing (a.k.a. rapid prototyping or additive manufacturing) is the process of creating solid, 3D objects from a collection of images in the form of a digital file. The printer deposits layers of a material (such as plastic, resin, or metal) in a volumetric manner such that an exact replica of the object is obtained. This innovative technology is likely to revolutionize our knowledge and understanding of structural heart disease and may have therapeutic applications as well.

2. How does it work?

It is a technology that uses a machine called a 3D printer to build three-dimensional models one layer at a time. It lays down one thin layer of material, which bonds with another thin layer of material. Over time, a model is built up from the bottom. The model is based on a computer-aided design. The model is designed with a computer program, sent to the printer, and the printer prints it over time. The printer may use plastic, liquid resin, gypsum powder, or even metal that is melted together with a laser.

3. How do you create a 3D model of the heart or valves?

To create a model of the heart or any body part, first an imaging modality is chosen; it can be either CT or MRI. From multiple images, a volumetric data set is obtained. A data set has a stack of images that can be put together without any gaps in the anatomy. After the anatomy has been segmented out of the images, it is sent to another program to be processed. In this step, any noise that was in the model would be smoothed out and any enhancement can be planned. Further, the model can even be verified, so the portion that is done can again be overlaid onto the images that were initially acquired, to verify that the model corresponds to the patient's anatomy. Once a requisite model (made of a collection of images) is selected, it can be sent to a print, the total process taking anywhere between a few minutes to a few hours, to even days (Fig. 1).

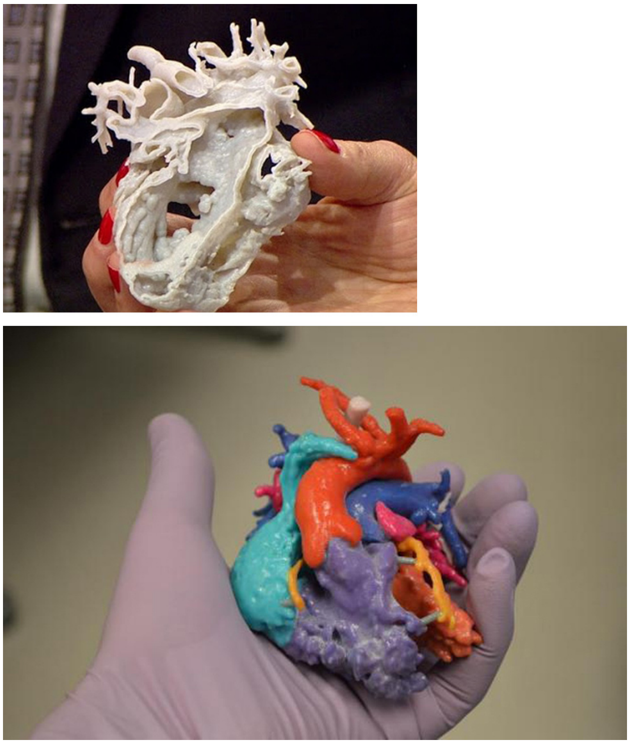

Fig. 1 – 3D model of heart.

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4. Advantage of the model

It gives a true spatial relationship to allow tangible manipulation of the cardiac structures. A few case series and many case reports have demonstrated that this technique may improve safety and decrease operator time in complex cardiac surgeries and interventional procedures. Another advantage could be while obtaining informed consent, because patients can be better explained regarding the surgical or interventional technique. Finally, it could lead to an overall cost saving as well by reduction of the complications as also the procedure time.

5. Application of the technology

Current applications include developing patient-specific implants, prostheses, and realistic anatomic models for surgical–interventional education and planning. In cardiac surgery, patient-specific 3D models of hearts with congenital defects and aortic root hold value as task trainers and in preoperative planning. For example, in a point with VSD and pulmonary atresia with multiple collateral arteries coming off the aorta and going to the lungs, the model may help determine where the collaterals are. This may aid in deciding which collaterals would require to be connected to the main pulmonary artery and which would require to be ligated. Another use could be in complex interventional procedures like TAVR, or LAA closure device, because ''the anatomy is complex and the interaction between the device and the appendage is difficult to quantify, even using advanced imaging methods.''

Another application could be ability to print implantable devices, such as cardiac valves that will be custom-sized to the patient, or conduits, and these have the potential to be printed with biological material that could grow with the patient. An international team of biomedical engineers and materials scientists have created a 3D elastic membrane made of a soft, flexible, silicon material that is precisely shaped to match the heart's epicardium, or the outer layer of the wall of the heart. They can then print tiny sensors onto these membranes and can precisely measure temperature, mechanical strain, and pH, among other markers, or deliver a pulse of electricity in cases of arrhythmia. Those sensors could assist physicians with determining the health of the heart, deliver treatment, or predict an impending heart attack before a patient exhibits any physical signs. Some ''dreamers'' have even opined that they will be able to 3D print a functional beating heart.

Conflicts of interest

The author has none to declare.