SIIM 2016 Scientific Session
Posters & Demonstrations
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3D Printing Techniques and Applications in Medicine

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Background

3D printing, first created in 1984 for rapid industrial prototyping [1], has evolved to providing a platform to produce complex anatomic models, device prototypes, and models for pre-surgical planning. Radiology plays a key role in the advances of 3D printing uses and technologies in medicine as the evolution of high resolution scans have paved the way for these types of applications. This article will cover the most common methods for 3D printing as well as the current applications in different medical specialties.

Evaluation

Universally, the 3D process in medicine starts with a high resolution DICOM [3] dataset from a MR or CT scan. Since the data contained within the scan is only a 2D representation, post processing must occur before the data can be sent to the printer. Software such as Osirix [6] can be used to generate a 3D model fit for printing. Once the datafile is suitable for printing there are multiple methods for creating a 3D model. The common 3D printing methods include Fused Deposition Modeling, Selective Laser Sintering, MultiJet Modeling, Binder Jet Technique, and Stereolithography. The primary considerations when choosing a platform for printing are cost, time to print, model strength, and degree of physical post processing.

Discussion

Applications

Given the flexibility, customization, and expediency of 3D printing it has the potential to impact multiple facets in the field of medicine.

Structural Heart

At our institution, in conjunction with the department of cardiology, 3D printing is used in pre-procedural assessment for a transcatheter caval valve implantation [4]. Starting with a contrast enhanced gated cardiac [Figure 1] CT a model of the targeted valve is printed. Using this physical anatomic mimic, different models of implant devices can be tested [Figure 2 & 3]. This can aid in the determination of optimal placement, assessment of a proper fit, and evaluation for leaks [4]. Such use can help to prevent repeat procedures and ultimately decrease morbidity and mortality of patients.

Figure 1

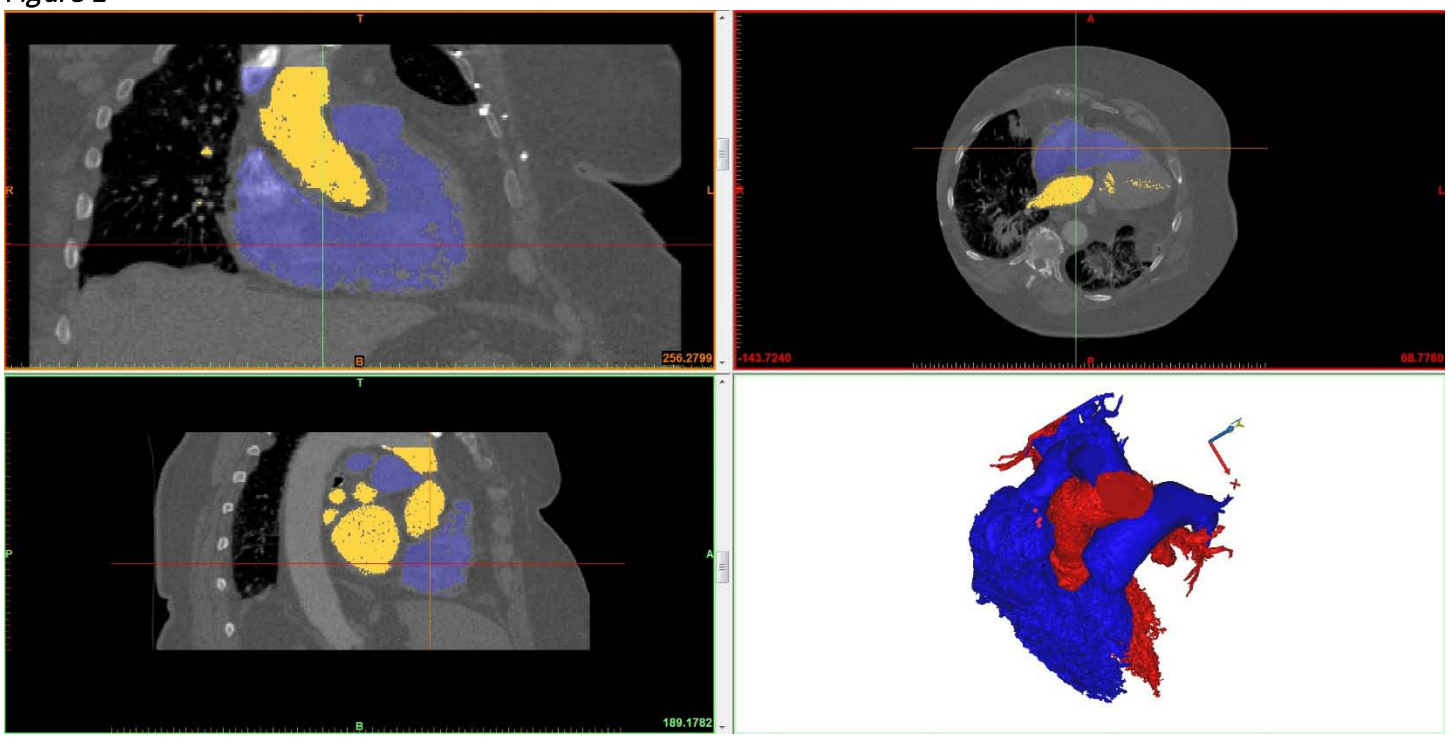
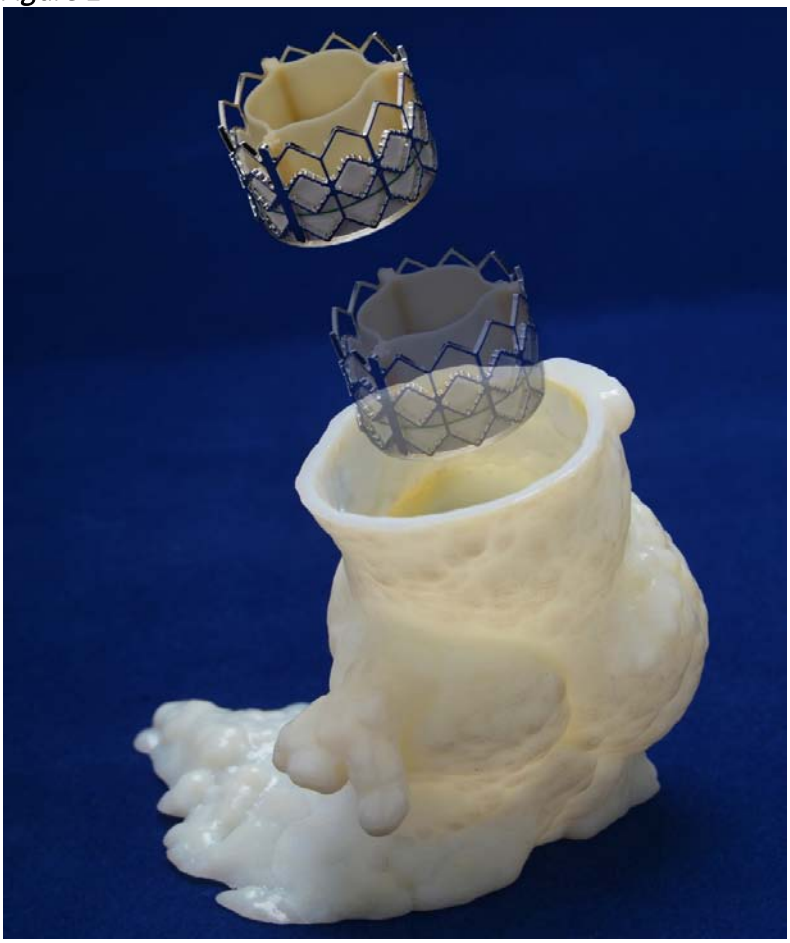


Figure 2



Tissue Engineering

Organ transplants involve some of the most complex care medicine has to offer. Extensive testing and evaluation is performed both before and after transplantation. The scarcity of compatible organs only further adds to the intricacy of the process. Modifying the concept of 3D printing, instead of using an inert spray or substrate, a "bioink" can be used to generate a scaffold and in some cases whole organs. While the science behind this is still in its infancy, the possible applications are endless. Given the ability to "print" organs based on an individual's DNA the concept of rejection could become an archaic term of the past [5].

Pharmacology

Similar to tissue engineering altering the substrate of the printer could open up a field of personalized pharmacology. Instead of the batch creation of a generic drug, a targeted dose of a drug could be printed for the patient at the point of care. This may prove to be the most beneficial in drugs with a narrow therapeutic window [5]. Allowing for differences in patients' metabolisms, a drug could be dosed to their exact needs.

Patient and Medical Education

Human anatomy is an intricate subject both for patients and the doctors in-training who are learning the material for the first time. 3D printing could provide very detailed models to aid in the understanding of the relationship of different structures. For patients who are about to undergo a surgical procedure, a model could be printed which would aid the surgeon in explaining the procedure to the patient. Instead of speaking in abstract terms the physician would have a concrete object the patient could directly interact with [2].

For medical students this could create an additional tool in anatomy. While the use of medical cadavers will likely never be replaced, 3D models can demonstrate both normal and variant anatomy in a physical form to aid in the learning process.

Prosthetics

Prosthetics provide improved quality of life and restoration of function to patients who have suffered the loss of a limb. This may be due to a genetic condition, infection, or trauma. Most patients are fit to their prosthesis using padding or minor design modifications. In a subset of patients, however, this is insufficient due to the complexity of their condition. 3D printing may provide a better solution for these patients, allowing the creation of a custom interface between each patient and the artificial limb. This can reduce friction and skin stress and ultimately provide an improved experience.

Challenges

Despite all of the promise offered by 3D printing, it is not without its challenges. At the heart of the process is the 3D model created from the original DICOM data. It is vital that the original 3D dataset be clean and accurate. Discontinuities in the model or inadequate post-processing can stop the process before it starts. While printer times have improved, they can still take days to complete a single job. Additionally, depending on the method of printing, significant post-processing maybe required. The object's "finish" may need smoothing. Any irregularities in the 3D model fed to the printer created from the original scan may need to be removed. A question of ownership also becomes relevant in discussing 3D printing. Does the model belong in the patient's chart/medical record? Does the patient own the physical model or does the hospital? Complicating matters further there is no FDA approved 3D printer, and currently there is no standardization to grade the printed models.

Conclusion

3D printing is evolving from its infantile manufacturing roots into the realm of medicine. While its uses are still experimental and many challenges still exist before implementation, the technology exhibits enormous promise. Radiology is poised to be at the center of the development and drive the clinical application of three-dimensional printing. It is with our high resolution CT and MR equipment that will provide the requisite imaging for the creation of anatomical models and structures that will be used across myriad fields of medicine.

Reference

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Keywords

3D Printing, CAD, Advanced Visualization