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3D printing at the Jacobs Institute: an update

At the forefront of neurovascular and cardiac surgical modelling

How one healthcare innovation centre is making great strides with neurovascular and cardiac 3D printing for better, more economical care.

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The autumn 2016 issue of HealthManagement.org showcased the ways that the Jacobs Institute (JI), a non-profit medical device innovation centre in Buffalo, NY, is using 3D printing to create realistic patient-specific vascular flow models. Fourteen months on, the JI continues to use 3D-printed models for physician training, device testing, and pre-surgical planning. We have also continued to work with our partners including 3D printer manufacturer Stratasys, the University at Buffalo (UB), and the Gates Vascular Institute (GVI) to make the models more robust and clinically relevant. Further, we expanded our expertise to produce—in addition to patient-specific neurovascular and cardiac models—complex abdominal aortic aneurysm (AAA) models.

The JI partnered with Stratasys to test its next generation of rubber-like PolyJet materials that produce models that retain their realism, but are significantly stronger and easier to clean in post-processing than earlier models. One of these materials, Agilus30, was recently released publicly by Stratasys as part of its BioMimics Platform. According to Adnan Siddiqui, MD, PhD, chief medical officer at the JI, "The BioMimics capabilities enable a level of biomechanical realism and clinical sophistication not previously available in any vascular model."

Recently, the JI turned its efforts to creating 3D models of AAAs, using Agilus30 material. In this new frontier of 3D printing in medicine, the JI already had three to four years of experience in creating 3D models for neurovascular and cardiac intervention, such as transcatheter aortic valve replacement (TAVR) and heart attack intervention. Given the JI's location above a vascular hospital and the complex technologies being introduced to treat vascular disease, the vascular surgeons joined the neuro- and cardiac-interventionists in asking the JI to make 3D printed vascular models for training and planning purposes.

What is AAA and How Is It Treated?

The abdominal aorta is the main vessel in the abdomen, carrying oxygenated blood from the heart to the abdomen, pelvis, and legs. An AAA occurs when portions of the walls of these abdominal arteries become weakened and bulge out. In some cases, when the aneurysm grows rapidly and causes symptoms, they can rupture leading to bleeding and often death.

AAAs at risk of rupture can be treated either surgically or minimally-invasively. In surgery, a portion of the vessel is replaced with a graft made of a synthetic material. In a minimally invasive procedure, a graft is delivered through a small tube called a catheter in the patient's femoral artery and up to the aneurysm where it is expanded against the vessel wall causing blood to bypass the aneurysm, shown here in **Figure 1**.

> "THE NEXT GENERATION OF MATERIALS PRODUCE MODELS THAT RETAIN THEIR REALISM, BUT ARE STRONGER AND EASIER TO CLEAN THAN EARLIER MODELS"

History

In cases where the aneurysm is located close to where smaller arteries, collectively called visceral arteries, branch off from the abdominal aorta to supply blood to the kidneys or the duodenum and colon, a graft could block the flow of blood into these vessels. In order to treat these aneurysms, patient-specific grafts with special openings, called fenestrations, are used. Small stents are placed from the graft through the fenestrations where the smaller arteries branch off, in order to keep these arteries open. This procedure is known as a fenestrated endovascular aneurysm repair (FEVAR) shown here in **Figure 2**. Since FEVAR procedures are new and involve the concurrent use of a number of

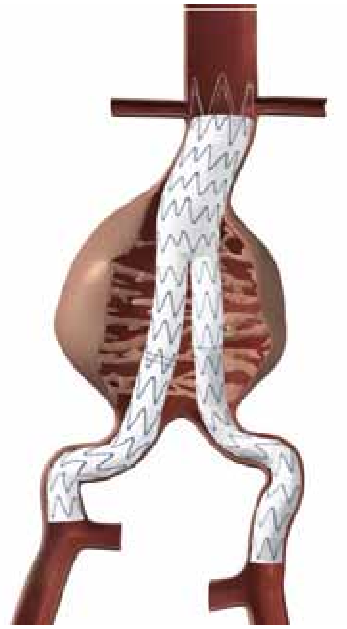

Figure 1. Endovascular Aortic Repair (EVAR) [1] (Medtronic)

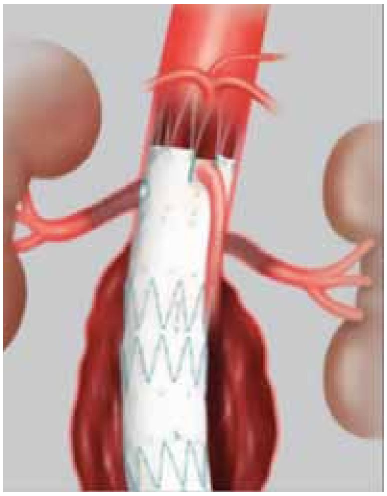

Figure 2. FEVAR to Treat AAA [2]

[1]Medtronic website: http://www.medtronic.com/us-en/patients/treatments-therapies/stent-graft-aaa/getting-a-device/surgery.html
[2]Cook Medical website: https://aortic.cookmedical.com/visceral/

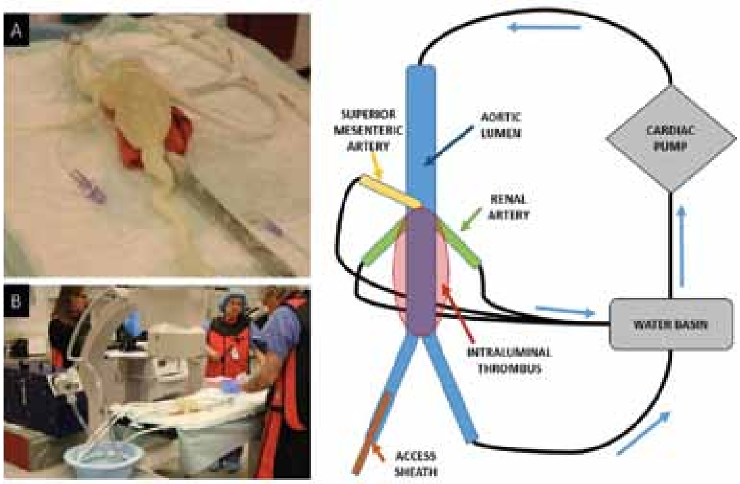

Figure 3. Experimental set-up at the JI including 3D AAA model with flow loop and system diagram depicting fluid recirculation system [3]

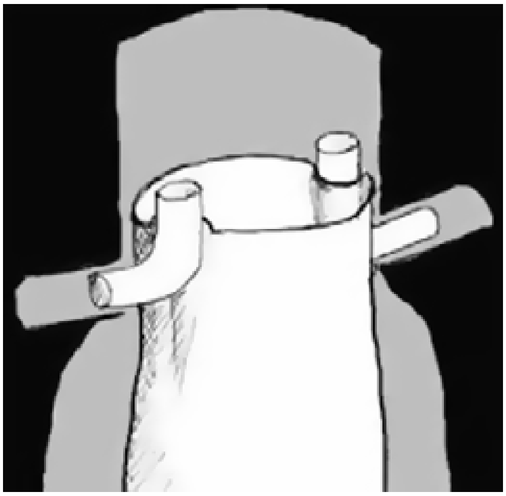

Figure 4. Example of two vessel (left and right renal) snorkelling technique[4]

[3]Meess, KM, Izzo RL, Dryjski, ML, Curl RE, Harris LM, Springer M, Siddiqui AH, Rudin S, Ionita, CN. 3D printed abdominal aortic aneurysm phantom for image guided surgical planning with a patient specific fenestrated endovascular graft system. Proc SPIE Int Soc Opt Eng. Proceedings Volume 10138; 101380P (2017).

different devices, as well as particular graft orientation techniques, 3D-printed models made from patient CT scans have been used by several GVI vascular surgeons to practice the procedure before performing their first FEVAR cases. The experimental set-up is shown in **Figure 3.**

Current AAA Challenges

Recently, the JI printed two AAA models using Stratasys' Agilus30 material. The models were used by GVI vascular surgeons to practice and plan for upcoming cases and to assess the feasibility of minimally invasive solutions to repair AAAs on patients with complicating factors. Traditional pre-surgical planning and feasibility assessments of treatment involve the review of patient CT scans and CT 3D reconstructions. The issue is that the precise geometry of the aorta and distances between the aneurysm and branch vessels may be difficult to appreciate in these scans. The models offer the physician the opportunity to gain a better understanding of these spatial relationships. One of the vascular surgeons requested a patient-specific model to see whether a FEVAR would be possible on a patient whose aneurysm had a very small diameter and two severe angles. The physician wanted to see if the graft would be able to navigate the 3D-printed model's angles and expand once it reached the proper location. In the course of the simulated case (**Figure 2**: Meess KM 2017) the physician not only learned that a FEVAR would be possible, but also what to do in the event of a twisted graft.

> “THE IMPROVED FEEL AND REALISM OF THE JI'S 3D PRINTED MODELS ARE SAVING TIME FOR THE PATIENT AND MONEY FOR THE HOSPITAL, WHILE ENSURING BEST TREATMENT”

Another anatomical challenge is stenosis, or narrowing, of arteries. With the much smaller, visceral arteries, stenosis precludes the use of a fenestrated graft. In these cases, physicians may opt to use a 'snorkelling' technique (figure shows "snorkel" stents enabling blood flow to branch arteries 2013) whereby the distal ends of the stents are placed within the smaller, visceral arteries and the proximal ends extend in to the aorta alongside the aortic graft so the kidneys and intestines can continue to receive blood. **Figure 4** illustrates the snorkelling technique.

Another vascular surgeon recently used a patient-specific, 3D-printed model to assess the feasibility of using the snorkelling technique on a patient with severe stenosis in her visceral arteries. The surgeon wanted to assess if access to the visceral arteries was even possible and verify if the selected sizing of the grafts would form a seal that would prevent endoleak, which is persistent blood flow outside the graft and into the aneurysm sack. The surgeon learned enough in the planning to decide that it was worth attempting to access the patient's visceral arteries, before resorting to the more invasive surgery.

The improved feel and realism of the JI's 3D printed models, developed in partnership with Stratasys, are making them increasingly valuable not only for surgical training and medical device testing, but also as a way for physicians to assess the feasibility of certain procedures before performing them on their patients. This saves time for the patient and money for the hospital, while also ensuring that the best treatment is selected for each patient. The JI will continue to advance 3D printing in vascular medicine, aiming to benefit, patients physicians, industry and start-ups. ■

KEY POINTS

- ✓ JI has several years experience in creating 3D models for neurovascular and cardiac intervention but further development was necessary to move into vascular intervention
- ✓ Treatments for FEVAR and stenosis cases were given focus
- ✓ The precise geometry of the aorta and distances between the aneurysm and branch vessels may be difficult to appreciate in these scans. The models offer the physician the opportunity to gain a better understanding of these spatial relationships
- ✓ The JI partnered with Stratasys on models that retain realism, but more robust and easier to care for in post-processing
- ✓ Improved realism of JI's 3D printed models are making them valuable for surgical training, medical device testing and procedure feasibility assessment
- ✓ More realistic models results in time and money savings while ensuring best patient treatment

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