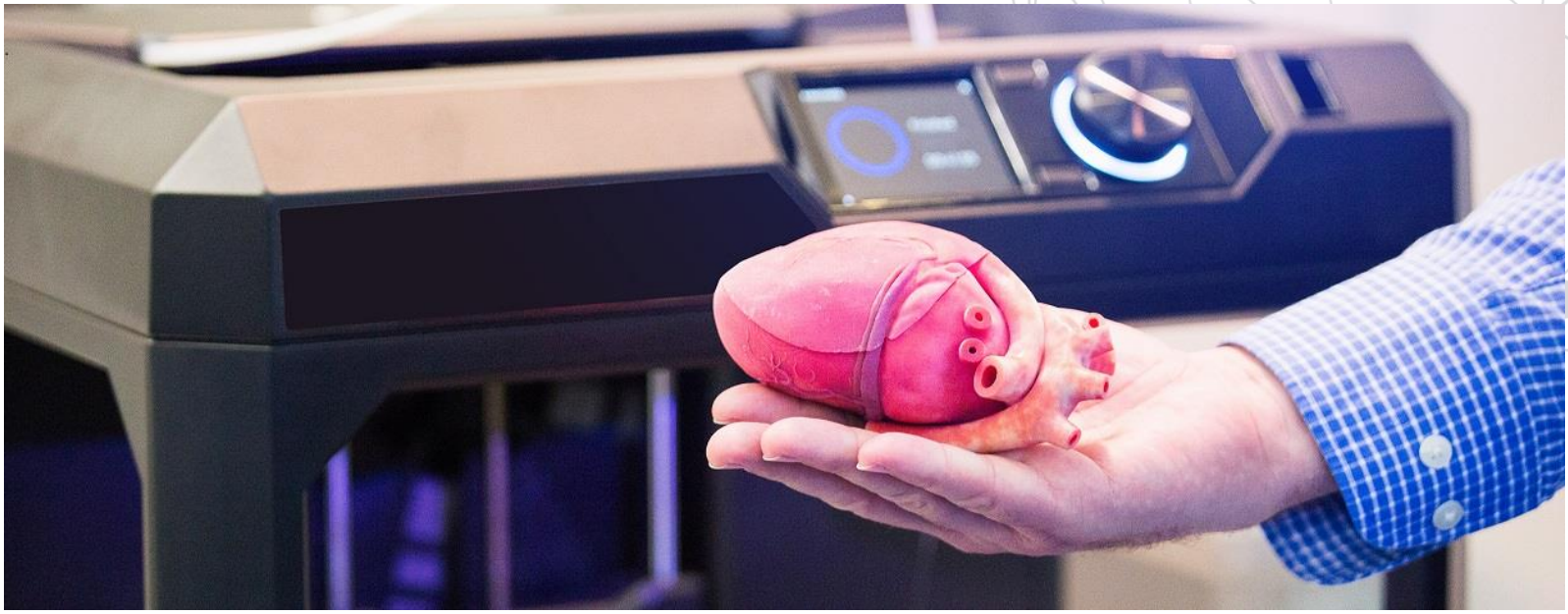

Tech Insight: 3D Printing III

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Three-dimensional (3D) printing, or 3DP, is an emerging and evolving technology used at the Department of Veterans Affairs (VA) to improve the Veteran health care customer experience. In simple terms, 3DP uses a digital file to make 3D solid objects. The 3DP process is also known as additive manufacturing since an object is made by adding one layer at a time. As one of several computer-aided manufacturing processes using digital images, 3DP applications for health care include innovations in creating tissues and organoids, surgical tools, patient-specific surgical models, and custom-made prosthetics. In this *Tech Insight*, we discuss the current benefits of 3DP at VA, including inspiring success stories, and the resulting 3DP efforts at VA.

Benefits of 3DP

Single-Step Manufacturing

Without the availability of 3DP technologies, a Veteran requiring surgery may need to travel to a VA medical facility, undergo a scan, wait while physicians review the scan and diagnose the medical problem, and schedule surgery for a later time, requiring the Veteran to return to the facility. Dr. Christopher French, a VA dentist, said that if physicians and health care professionals can take a patient scan at a local facility, they can upload the scan to the main office with the use of an enterprise image sharing[1] platform. This would enable the Veteran to travel to the main facility just once for surgery with one day of recovery, thereby reducing travel time by three to four days, while increasing medical accuracy, and providing better care quality for the Veteran over the long term. The advantage of 3DP is that it saves the dentist time and generates a 3D visualization of patients' mouths, compared to the 2D view offered by traditional X-rays. 3DP scans are more efficient, precise, and in depth than traditional methods.

[1] Interview with Dr. Christopher French

Efficiency and Cost Reduction

Another example where 3DP has been crucial to surgical success is in repairing the mandible, the lower jaw bone.[2] For patients who have tumors, chronic injuries, or deformities of their jaw bone, the solution is typically a two-part surgery. The surgeon first removes a portion of the mandible, then cuts into the patient's leg to harvest a portion of a leg bone, the fibula. The fibula is then cut into the shape of the mandible and used as a replacement. This surgery is time consuming and challenging.

To improve the process, the patient's mandible can be 3D printed prior to surgery. This allows the surgeon to study it and plan pre-operatively before performing the fibular surgery and creating the mandible.[3] In each of the few cases performed, patients were under anesthesia two hours less than usual and surgeons were standing for less time—two factors that improve the patient's health outcome and reduces surgical fatigue, while reducing the costs of the procedure. With VA operating room costs estimated at $80 per minute in 2019, the time saved accounts for $9,600 in savings, with a model that costs less than $1,000 to produce.

Customization

3DP implementation not only includes bodily implants for Veterans, but at-home medical devices. At many Veterans Health Administration (VHA) facilities, Veterans who suffer from diabetes and lose feeling in their feet can obtain custom orthotics at the time of their visit, rather than waiting weeks to have them manufactured.

Sustainability

Mr. Christopher Richburg, a VA engineer, states an estimated 450,000 patients[4] are at risk for foot sores. It typically takes two to three weeks to manufacture insoles, and they last about three months. Mr. Richburg is involved in a project that is implementing the 3DP process internally by scanning the foot, processing the insoles the same day, and creating insoles that last for a year.

In rural areas, Veterans can save a trip back to a VA medical facility because 3DP capabilities can manufacture the insoles the same day or overnight while the Veteran waits. This cuts down the total time from two to three weeks to only one to two days.

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[2] https://www.oit.va.gov/library/files/whitepapers/3DPWhitePaper.pdf
[3] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6115481/
[4] Interview with Christopher Richburg

3DP Success Stories at VA

Risk Mitigation, Planning, and Education

Perhaps the greatest power of 3DP stems from the ability to accurately replicate a non-accessible internal structure, such as an organ, and place it in the hands of physicians. Numerous studies have demonstrated both the feasibility and utility of 3DP in essentially all subspecialties of medicine. 3DP development uses two-dimensional planes, stacking them on top of each other to build a 3D object.

The 3D printed model of a patient's organ or tumor starts from computerized tomography (CT) or magnetic resonance imaging (MRI) scans that contain all the information needed about the patient's anatomy. First, a clinician uses software to outline the anatomy on each image slice. Next, those traces are stitched together into a digital 3D blueprint of the anatomy. Then, this digital blueprint is sent to a 3D printer, where the anatomy is physically recreated to scale. The result is a near-perfect replica of the patient's anatomy that the surgeon can hold in their hands and inspect from all angles.[5] By harnessing the power of 3DP with a rich data set, physicians can pull images out of the screen and into their hands, allowing them to interact.

One of the first uses for 3DP in a VA facility was in early 2017, when an interventional cardiologist and a surgeon were given a life-sized realistic 3D model of a Veteran's diseased heart valve. The model enabled the physicians to discuss whether the Veteran could be a candidate for a simpler surgery or less invasive procedure. Rather than looking at images several times for 20 to 30 minutes, the surgeon was able to lift the model with his hands and turn it over to determine a course of action in 15 or 20 seconds.

In addition, VA physicians were able to take the 3D printed model to their patient for education, enabling the Veteran to better understand and discuss the complex procedure. Surgeons were then able to bring the 3DP model into the operating room to use it as a guide for actions throughout the procedure.

VHA medical staff have also used 3DP to make model kidneys for Veterans with renal cancer to aid in pre-surgical planning. To date, VA has produced more than 20 3D models for surgical planning. The ability to access an internal organ through 3DP has helped VA physicians decrease operating room time, aided in determining the suitability of proposed interventions, and reduced time while increasing confidence in planning.

Administration of 3DP within VA Mission

VA is the largest integrated health care system in the United States, and 3DP helps improve VA's ability to target its efforts toward key mission areas such as the adoption of specialty-care transformational initiatives. 3DP technology allows VA health care providers to manufacture

[5] https://www.blogs.va.gov/VAntage/56207/3d-printing-helps-veterans-surgery/

point-of-care solutions at the Veteran bedside, thereby personalizing treatment, devices, and other solutions.

There are currently more than 100 3DP facilities across VHA, including those in the Veterans Integrated Services Networks (VISN), where health care services are delivered through 18 geographically divided administrative areas.[6] This is up from just three in 2017. The VHA facilities' locations include Puget Sound, Wash.; Albuquerque, N.M.; Richmond, Va.; San Antonio; New Orleans; Orlando, Fla.; and San Francisco. The facilities vary from printing structural parts for equipment, to parts for custom assisted living devices, to anatomical tissues for procedural planning. There are also centers that focus on prosthetics, education, and pre-surgical planning.

Current plans for 3DP at VA include the creation of an artificial lung at VA Ann Arbor Healthcare System in Michigan[7]. The lung will be used for Veterans waiting for a lung transplant with an attempt to replicate the structure and size of the blood vessels, and constructed of substances that are compatible with the human body to reduce immune responses. Additionally, the artificial lung will be used for patients who need help breathing when recovering from a respiratory illness.

VA Centers with existing 3DP interests have formed a workgroup, the VHA 3DP Advisory Board, led by Dr. Ripley. The Board includes a representative from VA Innovation Center (VIC) to assist with building a coordinated program for interconnectivity between the 20 VA hospitals that facilitate 3DP labs and the 9 million patients within the VA health care network. The Board goals are to improve 3DP quality, effectiveness, and value, while ensuring a lean program through shared services. For example, the group is currently exploring the best methods of file transfer, based on security requirements and network capacity, to determine the best file storage methods. This national workgroup effort anticipates a three- to five-year implementation period. To learn more about 3DP health care initiatives at VA, refer to our *3DP at VA White Paper*.

Conclusion

3DP is the next optimization in medicine at VA. To provide Veterans the ability to access personalized 3DP body part replicas and assistive technology devices, it is crucial for VA Medical Centers to be connected to the correct 3DP tools and for staff to be adequately trained. VA's vision is for 3DP to be available at all 168 VA hospitals[8] across the nation to provide Veterans with the world-class benefits and services they have earned.

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[6] https://www.data.va.gov/dataset/veterans-integrated-services-networks-visn-markets-submarkets-sectors-and-counties

[7] https://www.annarbor.va.gov/features/VAAAHS_Doctor_Conducts_3D_Lung_Research.asp

[8] https://www.blogs.va.gov/VAntage/36409/vas-center-innovation-using-3d-printing-create-devices-help-veterans-feel-whole/

VA radiologists specializing in cardiology, oncology, orthopedics, and other areas will continue to use 3DP and related software to develop new 3D imaging approaches and techniques to deliver improved precision health care to our nation's Veterans. While software that is designed exclusively for the 3DP medical community is still limited, the use of 3DP to manufacture orthopedic implants and guide surgical cutting, with peer-reviewed research on potential impact in patient care, has expanded exponentially. It is exciting to learn of the major changes VHA has already implemented to improve Veteran health care.

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