Applying Existing Technologies to Vascular Applications

Examples of how current technologies in wearables, tissue engineering, and imaging and computer simulation could be applied to vascular care in the future.

BY DAVID H. DEATON, MD, FACS

A century ago, the only procedure offered to patients with end-stage vascular disease was amputation of extremities. There were no therapies for carotid, coronary, aortic, or mesenteric vessels and no ability to revascularize extremities. The 1950s through the 1980s saw an explosion of open techniques that allowed revascularization of all these vascular beds—albeit through open surgical exposure with its attendant risks in a population with severe comorbidities. In the last 30 to 40 years, endovascular techniques have rapidly evolved to the point that, either alone or in combination with less invasive open techniques, effective revascularization can be achieved without the major physiologic insult of a purely open surgical approach. What technologies will transform the care of patients with vascular disease over the next decades?

WEARABLES AND ARTIFICIAL INTELLIGENCE

A recent article by Miyashita and Brady reviews the multiple avenues where the near-ubiquity of wearable devices and their connection to the internet/cloud makes possible everything from impacting personal behavior and medical care compliance to identifying risk factors for hospital readmission.[1] Artificial intelligence applications allow for massive collaboration between health systems, health care professionals, and researchers to refine and improve risk factor pattern recognition, image analysis, and other metrics that allow earlier intervention and improved outcomes at less expense.

The treatment of lower extremity claudication represents an excellent opportunity for wearables. There is a large body of literature that documents the benefits of supervised and regular exercise programs for claudicants, and physicians universally recommend regular exercise to patients.[2] Unfortunately, a simple admonition in an office setting is rarely sufficient to change the habits of sedentary patients with claudication, and there is only trivial funding for a more intentional approach (eg, a supervised exercise program). Although still in rapid evolution, much has been learned about the features in a wearable device that drive motivation and engagement, critical elements in the efficacy and success of these applications.[3] There may be opportunities to improve the lifestyle habits and medical compliance of patients with vascular disease through these technologies, with significant benefits for clinical outcomes.

TISSUE ENGINEERING AND BIOPROSTHETICS

Tissue engineering has rapidly evolved over the last decade and has transitioned from benchtop success to real-world clinical applications. A broad variety of technologies and nomenclature describe these techniques, including words like *bioprinting*, *mechanobiology*, and *bioprinting chemistries*, along with more recognizable terms such as *decellularized organs*, *immunobiology*, and *pluripotent stem cells*.[4] All these techniques and disciplines come together in tissue engineering. One of the more remarkable successes has occurred in the vascular space, where researchers create tubes of cultured smooth muscle cells that are then decellularized for use as a vascular bioprosthetic. This basic science work led to the formation of a start-up company (Humacyte, Inc.) directed at creating a practical application for clinical care of vascular patients. Humacyte is currently conducting clinical trials of bioengineered human acellular vessels (Humacyl) in dialysis access and peripheral artery disease applications. A large body of basic science literature has documented these efforts, with Kirkton et al providing a particularly striking example of the potential of these manufactured bioprostheses.[5] The ability to access a manufactured vessel that would behave as an autogenous graft would open up an entirely new era in reconstructive vascular therapy when coupled with endovascular, laparoscopic, and robotic techniques.

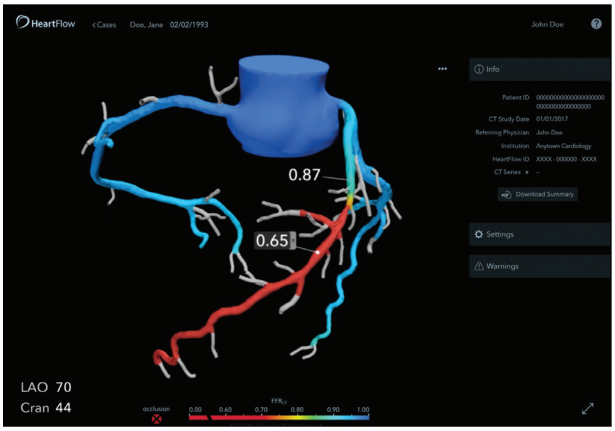
IMAGING AND COMPUTER SIMULATION

The mantra of open surgery is “exposure, exposure, exposure”—an indication of how vital visualization and the ability to perform techniques without physical impediment is to successful open surgical procedures. Endovascular and other minimally invasive techniques sacrifice the visualization afforded by open exposure in the name of minimizing physiologic impact. The ultimate realization of these techniques depends on visualizing both the disease and the results of intervention.

Although angiography is often referred to as the gold standard, it might also be termed the old standard because it represents the oldest meaningful way we have to visualize vascular structures but is fundamentally simply a silhouette of a three-dimensional (3D) organ and fails to identify many intraluminal defects. Newer techniques including ultrasound, intravascular ultrasound (IVUS), CT, magnetic resonance, and optical coherence tomography have provided new insights into diseased anatomy, the conduct of endovascular technique, and the results of those interventions. Although "a good arteriogram" is obtained at the conclusion of many procedures, a more intensive examination with IVUS often demonstrates significant defects from the desired therapeutic result and an indication for further therapy. Increasing resolution and availability of these new imaging modalities will surely enhance the technical result of our procedures.

Computer simulation applied to more detailed 3D diagnostic imaging will allow computational fluid dynamics (CFD) to be applied to vascular beds prior to intervention and thus achieve a physiologic evaluation of the lesions identified over various flow conditions rather than a static description of percent stenoses. The HeartFlow technology (HeartFlow, Inc.) is an excellent example of this possibility. The technology uses CT data to construct a virtual model of the coronary arteries and then uses CFD to assess lesions across a broad range of flow (Figure 1). The results are used to decide whether an intervention is warranted and thus avoids unnecessary invasive imaging, fewer and more effective interventions, and significant cost savings.

As in other fields (eg, oncology), the ability to accurately characterize and stage various lesions in their original or posttherapeutic state will allow for more accurate and informative clinical studies and determination of best therapy. Intraprocedural guidance is also in the early stages of a revolution, with computers merging multiple preoperative imaging modalities in the interventional suite and enhancing the technical accessibility of many procedures that were previously the province of the highly specialized few. Some devices are incorporating a camera mechanism into the therapeutic device itself, allowing the operator to "see" with the instrument of intervention (eg, the Pioneer Plus IVUS-guided reentry catheter [Philips] and the Pantheris imaged-guided atherectomy device [Avinger, Inc.]). These technologies ultimately rely on computer processing speed, which continues to increase exponentially, as described in



Courtesy of HeartFlow, Inc.

Figure 1. The HeartFlow analysis is provided as a digital, color-coded, 3D model of the coronary arteries, showing fractional flow reserve CT values where blood flow to the heart is impacted.

Moore's Law. This massive increase in computing power and proliferation of imaging techniques promises to continue to yield significant benefits in the diagnostic, therapeutic, and posttherapeutic monitoring of minimally invasive vascular techniques.

SUMMARY

The aforementioned examples of potential technologic impact in vascular disease are just a small part of the future for vascular care. Innovations and new horizons in fields outside of medicine may be incorporated into vascular care and transform our diagnostic evaluation, procedures, and long-term care in ways we cannot currently imagine. The future leaders of innovation in our discipline will be those who have a broader appreciation of technologic innovation across many disciplines and the ability to translate those advances into medical purpose. ■

1. Miyashita M, Brady M. The health care benefits of combining wearables and AI. Harvard Business Review. https://hbr.org/2019/05/the-health-care-benefits-of-combining-wearables-and-ai. Published May 28, 2019. Accessed December 19, 2019.
2. Hageman D, Fokkenrood HJ, Gommans LN, et al. Supervised exercise therapy versus home-based exercise therapy versus walking advice for intermittent claudication. Cochrane Database Syst Rev. 2018;4:CD005263.
3. Fitzgerald M, McClelland T. What makes a mobile app successful in supporting health behaviour change? Health Education J. 2017;76:373-381.
4. Khademhosseini A, Langer R. A decade of progress in tissue engineering. Nat Protoc. 2016;11:1775-1781.
5. Kirkton RD, Santiago-Maysonet M, Lawson JH, et al. Bioengineered human acellular vessels recellularize and evolve into living blood vessels after human implantation. Sci Transl Med. 2019;11:eaau6934.

David H. Deaton, MD, FACS
Chesapeake Vascular PC
Crownsville, Maryland
david@deaton.md
Disclosures: None.