The future has arrived. Are we ready?

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There is nothing more powerful as an idea whose time has come... — Victor Hugo

Regrettably, at least according to recent history, the majority of high-impact technological advancements have been made to enable human beings to more effectively wage war against each other. The technology involving air and water travel, communications, as well as nuclear and atomic energy have all advanced during wartime. During times of peace, development of advanced technologies has centred on the entertainment industry to maximize and deepen our leisure-time experiences. But what about technology in health care? To date, the incorporation of technology in the medical field appears to lag behind, although promising advances in medical imaging have been witnessed in the fields of ultrasound, magnetic resonance imaging, and positron emitted tomography (PET). The work published in this issue of the European Journal of Cardiovascular Imaging by Bruckheimer et al.1 together with Realview Medical Imaging, and the Technion Department of Mechanical Engineering in Israel is innovative and refreshingly forward thinking. This group has applied the technology of digital holography to generate interactive, real-time, 3D holograms of cardiac imaging data based on rotational angiography and live 3D transoesophageal echocardiography. This new technology allows visualization of medical images in 3D without the need for 3D glasses. The operator can interact with the real-time dataset to crop, rotate, magnify, and move structures as they float in front of the operators who gain the advantage of appreciating depth and proximity of adjacent anatomy with greater ease. The potential of this technology to teach and understand cardiac anatomy in 3D will undoubtedly revolutionize the guidance of minimally invasive surgical and percutaneous procedures, which are currently being performed using 2D/3D images displayed on flat screens.

Dennis Gabor, a Hungarian-British electrical engineer and physicist, was awarded the Nobel Prize in Physics for inventing holography in 1971.2 Holograms, which have only been around since the latter part of the last century, enable the visual display of an object in three dimensions using light physics. Digital holography has been implemented in many areas including microscopy, data storage and processing, among others.3–5 The creation of holograms to aid medical clinical decision-making has been discussed in the literature for over two decades.6 In the implementation of holography, described in this paper, the object is the dataset collected with either 3D transoesophageal echocardiography or 3D rotational angiography. The advantage is real-time interaction with an anatomically accurate, volumetric dataset in the setting of a minimally invasive procedure where visualization of the patient’s anatomy is otherwise limited. To have the ability of being able to project dynamic holographic cardiac anatomy in this way gives us the aura of a science fiction movie.

3D imaging is routinely used in cardiac catheterization laboratories to guide percutaneous procedures such as the mitral clip, closure of atrial and ventricular septal defects, and prosthetic paravalvular leak closures, and it is anticipated that this technology will also be used in the near future to guide percutaneous transcatheter tricuspid valve procedures.7–9 3D transoesophageal echocardiography is also used pre-operatively for surgical planning of mitral valve repair and a variety of congenital surgeries. However, while 3D echocardiography provides depth by shading and illumination, it is still displayed on a flat screen. 3D printing of valves, conduits, as well as congenital and post-surgical anatomy is an active area of research that has been proposed for the planning of complex congenital repairs, reoperations, and to potentially help customize valvular and other prostheses.10–12 A 3D printed model can be held in the hand and manipulated, but the cast is static and is only readily available pre-procedure. In the future, 3D holography could allow the user to interact with, visualize, move, and crop cardiac anatomy in real-time before, during, and after the procedure. It provides superior appreciation of depth as the anatomy can be viewed from multiple angles. It could help with orientation and measurement. It could facilitate surgical planning and teaching at the point of care, especially when the task to be performed involves complex anatomy. Furthermore, this technique could be extremely useful to educate physicians on cardiac anatomy and decrease the learning curve associated with 3D conceptualization of defects.

It must be mentioned that optimization of input data quality is highly important when adopting a tool such as the one proposed by Bruckheimer et al.1 For example, structures such as the tricuspid and pulmonic valves and right ventricle are not well visualized with...
3D transoesophageal echocardiography. It is yet too premature to determine how these images would perform using digital holography. The ability to crop through a dataset largely depends on the integrity of the dataset and any dropout or image degradation could impair interaction with the dataset. It is not clear whether the authors encountered these problems with the datasets they analyzed which, in this manuscript, only included a limited variety of procedures in a small number of patients. In addition, no data was presented on whether anatomical evaluation during the procedure was incrementally improved when using the holographic interface compared with conventional data presentation. This limits the information available at this time to advocate for the use of holography during interventional procedures. Yet, the results so far appear promising and the potential impact of data presentation in this format is certainly exciting.

In the operating room, on the open heart, the surgeon is able to, to some extent, appreciate the value of the added dimension with his or her hands and eyes but, as we move towards a new surgical era of minimally invasive procedures, less-invasive transcatheter adaptations of previous open-heart surgeries, and more complex operations, it becomes even more important for the surgeon or interventionalist to understand the structures of interest from any perspective in a 3D format.6 Bravo to the authors for taking this first important step.

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**References**


