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EDITORIAL COMMENT

The Gutenberg Revolution in Cardiovascular Medicine

Personalized 3D Printing in Planning Aortic Valve Surgery*

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The invention of the printing press had a significant democratizing effect on society, known as *The Gutenberg Revolution*. The simple yet extraordinary concept of movable types paved the way for the era of mass communication, which permanently altered the structure of society.

The relatively unrestricted circulation of printed ideas transcended borders and ultimately led to the spread of revolutions such as the Protestant Reformation, the Age of Enlightenment, and the establishment of the industrial society in Europe. By 1620, the English philosopher Francis Bacon wrote in his *Instauratio Magna* that the 3 inventions that "have altered the face and state of the world" were gunpowder, the nautical compass and the printing press (1). Indeed, the printing press was a key factor in establishing a community of scientists who could easily disseminate their discoveries through scholarly journals, and eventually helped standardize language, grammar, and spelling in the scientific world. However, when Johannes Gutenberg built the first printing press in approximately 1436, he was certainly not aware of the immense revolution his invention would have been responsible for: Gutenberg died penniless and his presses were impounded by his creditors.

Similarly, 3-dimensional (3D) printing has entered clinical research as a tool with potentials that clinicians have not completely explored yet. The application of 3D-printed patient-specific models in cardiovascular medicine has a potential role in several areas (2,3). This technology represents a powerful teaching tool, which can rapidly convey a complex anatomic arrangement to trainees or which can make patients reach a higher level of awareness about their structural heart disease.

Also, 3D-printed models represent an outstanding tool for surgical or interventional preoperative planning and simulation; they can also be used as functional models to investigate intracardiac flow, and they have a tangible role in testing and innovating new surgical and transcatheter devices.

In this issue of *JACC: Case Reports*, Shearn et al. (4) from the Bristol Heart Institute reported the use of 3D-printed, computed tomography-derived, patient-specific aortic root models for the preoperative planning of neocuspidization surgery (Ozaki procedure) in 2 patients with bicuspid aortic valve (BAV). Neocuspidization surgery has gained popularity over the past 10 years as a novel technique in which, during surgery, the autologous pericardium of a patient is molded into 3 different leaflets to create a competent aortic valve (5). Potential advantages of such technique are several: first, the absence of a stent allows molding of a neo-aortic valve with excellent hemodynamics made by all biological material, so theoretically it is less prone to develop endocarditis; second, the design of the valve creates a large coapting surface between the leaflets allowing to maintain a competent valve even if the aortic root will grow (children) or dilate in the future. Finally,

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the use of autologous pericardium offers a potential superior durability respect of the xenogenic biological material used for commercially available prosthetic valves, making this technique attractive for young patients with aortic valve disease. All these advantages are waiting to be reported and verified by groups other than Ozaki himself who has the largest experience and has published excellent midterm results of this technique.

Shearn et al. (4) should be complimented for their excellent short-term outcomes in applying 3D printing technology to the surgical planning of the Ozaki procedure in BAV morphology. BAV anatomy represents indeed an extra technical challenge for the neocuspidization technique in which a trileaflet valve needs to be constructed in a previously bicuspid annulus by creating a new commissure within the aortic root: the success of this type of procedure heavily relies on the technical experience of the surgeon, as demonstrated by the midterm outcomes of Prof. Ozaki (6). The possibility given by 3D printing technology to bench test the surgery on a patient-specific anatomy represents a unique opportunity for aiming at high-quality reconstructions.

Interestingly, the authors claimed that the pre-sized leaflets were larger than those ultimately implanted in vivo in both patients raising some concern about the fidelity of the model created. Nevertheless, it would certainly be worth further investigating the efficacy of this 2-step approach in a larger series of patients (comparing the observed-versus-expected leaflet sizing and evaluating the long-term follow-up), with a standardized computed tomography scan protocol and cycle time acquisition for the 3D modeling (because the aortic root anatomy changes in shape throughout the cardiac cycle [7]).

Although the tendency in cardiovascular medicine has been focused on investigating different treatments for a specific disease (surgical aortic valve replacement vs. transcatheter aortic valve replacement, repair vs. replacement, mechanical vs. biological, coronary artery bypass grafting vs. percutaneous coronary intervention, surgery vs. percutaneous treatment); the future of medicine is shifting to a clinical practice extremely oriented to a patient-specific, tailored approach, in which bench simulation will guide which device or which technique can better address that patient's specific anatomy and disease.

The paper by Shearn et al. (4) perfectly represents this paradigm: *from bedside to bench, and from bench to bedside again*.

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