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analysis must include, not only those who undergo the procedure, but also those in whom the procedure was deferred. In 2012, Joynt et al. attempted to answer this question by exploring the outcomes of all patients with myocardial infarction in states that adopted public reporting, compared with those that did not. They found that in states with public reporting, mortality rates were significantly higher for patients presenting with ST-segment elevation myocardial infarction ($p = 0.004$) with a trend toward worse outcomes for the larger cohort of all patients with myocardial infarction ($p = 0.10$). More recently, this same approach was applied to a much larger population, revealing a dramatic 21% increase in mortality for patients presenting with myocardial infarction in states with public reporting ($p = 0.013$) (5). This was driven primarily by an increase in mortality in patients in whom intervention was deferred. With these results, we must conclude that public reporting of procedural outcomes results in public harm.

We applaud Sherwood et al. (1) for their efforts. At the same time, we wonder whether the time has come to move away from procedure-based risk scores and toward diagnosis-based databases that examine the outcomes of all patients, not just those subgroups selected to undergo specific procedures.

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Left Atrial Appendage Closure Guided by Personalized 3D-Printed Cardiac Reconstruction

Percutaneous left atrial appendage occlusion (LAAO) with the Watchman device (Boston Scientific, Natick, Massachusetts) is currently conducted under fluoroscopic and transesophageal echocardiographic guidance. Multidetector computed tomography (MDCT) acquires a 3-dimensional (3D) dataset that provides better spatial resolution, allows unlimited reconstruction, and enables more precise procedural planning than 2-dimensional (2D) imaging (1,2). Nevertheless, the complex dimensions of the left atrial appendage and its variable morphology may result in procedural failure despite careful planning (3).

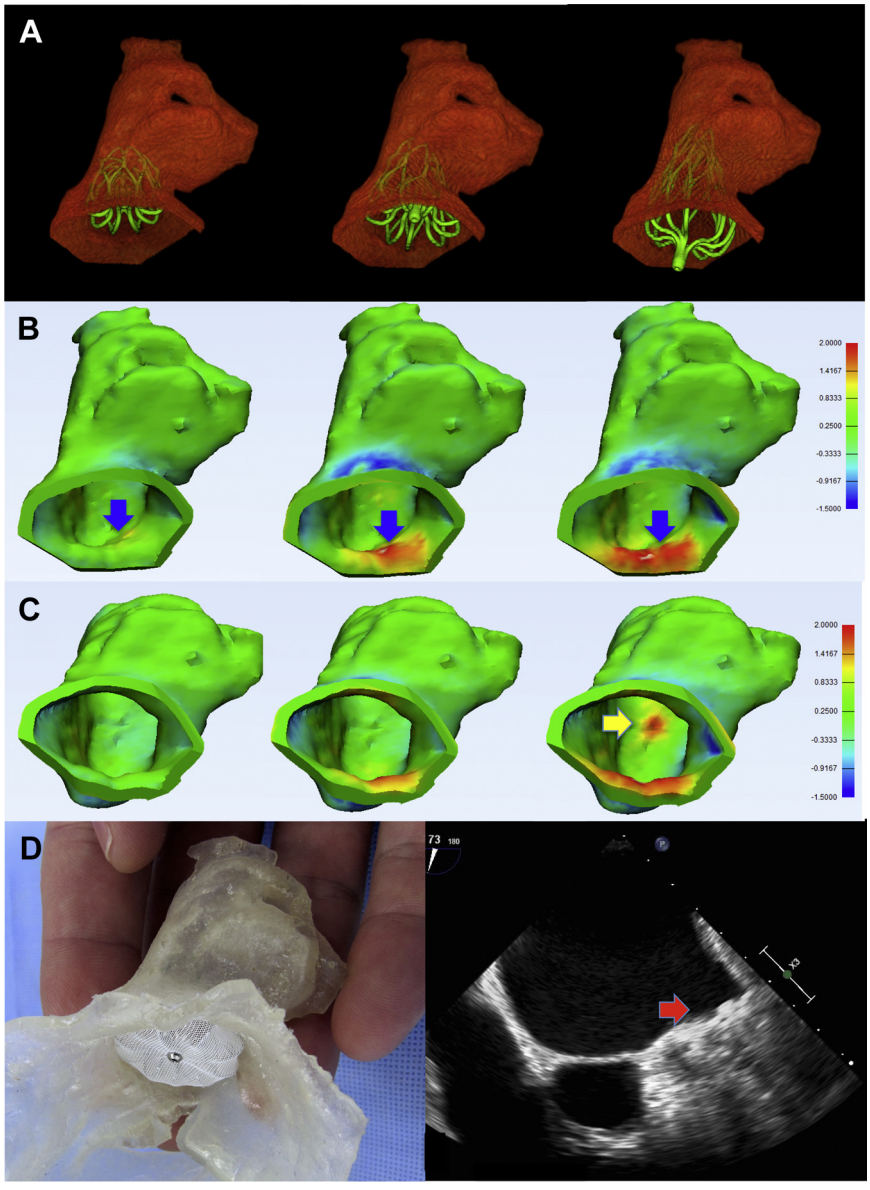
Three-dimensional printing (also known as rapid prototyping) allows an exact replica of a patient's anatomy to be created in a variety of materials, which may replicate underlying tissue characteristics. We describe the use of a patient-specific model to guide a left atrial occlusion procedure using the Watchman device.

A 74-year-old man with a history of paroxysmal atrial fibrillation and a CHA_2DS_2VASc score of 6, cerebrovascular events, ischemic cardiomyopathy, and intolerance of anticoagulation was referred to our institution for consideration of transcatheter LAAO.

In preparation for the procedure, MDCT of the left atrium and left atrial appendage, gated to atrial diastole, was performed. Semiautomated segmentation (Mimics v17.0, Materialise Software, Leuven, Belgium) generated a stereolithography file that was printed in a rubber-like material to simulate atrial mechanical properties (Tango Plus Material, Shore hardness 27A, Stratasys Objet Connex 500 printer, Stratasys, Eden Prairie, Minnesota). Watchman devices in sizes of 21 mm, 24 mm, and 27 mm were placed in the model, which was reimaged using clinical CT. Virtual rendered images were generated using Ziostation (Qi Imaging, Redwood City, California) (**Figure 1A**).

The imaged 3D printed replica atrial appendage with the devices in situ (**Figure 1D**) was analyzed (3-Matic 9.0, Materialise Software), and the anatomic deformation was calculated for each device, creating a 3D map color-coded according to the degree of deformation caused. This demonstrated the areas and extent of engagement of the device on the flexible atrial model.

FIGURE 1 Sizing of the Left Atrial Appendage Closure Device With Patient-Specific 3D-Printed Model



(A, left to right) Volume-rendered image of the Watchman device in sizes of 21 mm, 24 mm, and 27 mm deployed in the flexible atrial model. The 27-mm device is too large to retract into an anchored conformation. **(B, C)** The corresponding 3-dimensional deformation caused by the device. The 21-mm device applies minimal radial force at the appendage orifice **(blue arrow)**, whereas the 27-mm device barbs apply localized stress to the appendage wall **(yellow arrow)**. **(D)** The Watchman device placed within the flexible 3-dimensional printed model and **(right, red arrow)**, post-procedure transesophageal echocardiogram demonstrating complete closure with a 24-mm device.

On pre-procedural transesophageal imaging, the dimensions of the ostium of the left atrial appendage varied between 15 and 18 mm, whereas on left atrial appendage angiography, the dimensions varied between 19 and 22 mm. If the 2D transesophageal echocardiogram measurements had been used exclusively to guide device selection, a 21-mm device would have been chosen. Using the patient-specific 3D model for procedural simulation, deployment of the 21-mm device showed that it did not apply radial force or cause any significant deformation at the appendage orifice, which may have precluded secure anchoring and complete closure (Figures 1B and 1C). Conversely, deployment of the 27-mm device in the 3D printed

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model showed that the device was too large to achieve full retraction (**Figures 1B and 1C**). Furthermore, 3D strain analysis of the model showed localized distention on the wall of the appendage from an unretracted device barb. We hypothesize that clinical placement of this device may have led to post-procedural pericardial effusion, a recognized complication of transcatheter left atrial appendage closure.

The 24-mm device was therefore selected and deployed without incident. On intraoperative transesophageal echocardiography, the device appeared well positioned with no peridevice leak (**Figure 1D,** right).

This case demonstrates the potential clinical utility of 3D printing for both device sizing and avoiding procedural complications. Physical models are particularly pertinent to left atrial appendage occlusion where the anatomy is complex and the interaction between the device and the appendage is difficult to quantify, even using advanced imaging methods. Current 3D printing techniques offer a variety of materials, although limitations remain, and only approximate replication of underlying tissue properties may be possible. The rapid development of 3D printing technology suggests that the technique may be useful as an adjunct technology to optimize procedural planning.

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