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# Aortic Valve Repair: A Portable, Low-Cost Simulator

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Simulation is a key adjunct to surgical training by allowing repetitive and deliberate practice. We created a low-cost, portable aortic valve simulator that can easily be re-created by any trainee. This simulator allows practice of the challenging hand movements and needle angles required in aortic valve repair and may facilitate acquisition of operating room skills and autonomy.

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Simulation plays an important role in surgical education, allowing skills to be taught and practiced in a low-stakes situation. Skills obtained during simulation training transfer to the operating room.[1] There are various types of simulation, ranging from simple bench models to virtual reality. Simple bench models have the lowest fidelity to actual surgical conditions but offer advantages in cost and accessibility.

Cardiac surgery is an optimal field for simulated learning, considering the high stakes and challenging nature of the operations. Trainee autonomy in the operating room is negatively affected with increasing difficulty of a case.[2] Furthermore, the breadth and complexity of cardiothoracic cases that must be learned by trainees are increasing, even while duty hour regulations reduce time spent in the operating room. Simulation is an increasingly important adjunct to operative training when considering these factors; however, there are barriers to simulation, including lack of time, high cost, and inconvenient access, that limit trainee use. Low-fidelity simulators address these barriers by providing a portable and inexpensive tool.

In this study, we aimed to create a low-fidelity aortic valve repair simulator that would allow trainees to master the basic technical steps of this challenging procedure. The repair can also be easily performed in a cavity with the simulator, allowing rehearsal valve repair in an anatomically realistic setting that requires accurate and precise hand movements and needle angles.

## TECHNIQUE

**SIMULATOR CONSTRUCTION.** Our goal was to create a simulator using low-cost materials that can be easily purchased from local stores or online. The total cost of the simulator is estimated to be less than $20. The simulator takes approximately 10 minutes to make; step-by-step instructions are provided in the Supplemental Material, and further details can be found at www.globalsurgbox.com, a free website created at our institution.

To create an aortic valve that realistically simulates human tissue, we used a silicone cupcake holder (Figure 1A). The silicone has similar thickness and give to an aortic valve annulus. First, a circle 3 cm in diameter is cut with sharp scissors or a scalpel across the bottom of the cupcake holder with small corners cut at 10 o'clock, 2 o'clock, and 6 o'clock. These represent the left coronary cusp, right coronary cusp, and noncoronary cusp (Figure 1B). The cupcake holder is attached with 2 sutures to a cardboard toilet paper roll (Figure 1C). The toilet paper roll can be fixed in place either flat to the wooden board over nails placed in a 4-point circle 4 cm apart or at an angle with alligator clips. Difficult needle angles can be replicated and rehearsed, including the backhand hook used by some surgeons at the noncoronary cusp (Figure 2).

For progressive challenge complexity and skill development, the valve on the toilet paper holder can be placed in the bottom of a coffee can to simulate operating at the depth of the pericardial well. For fixation to the coffee can, 2 strips of cardboard

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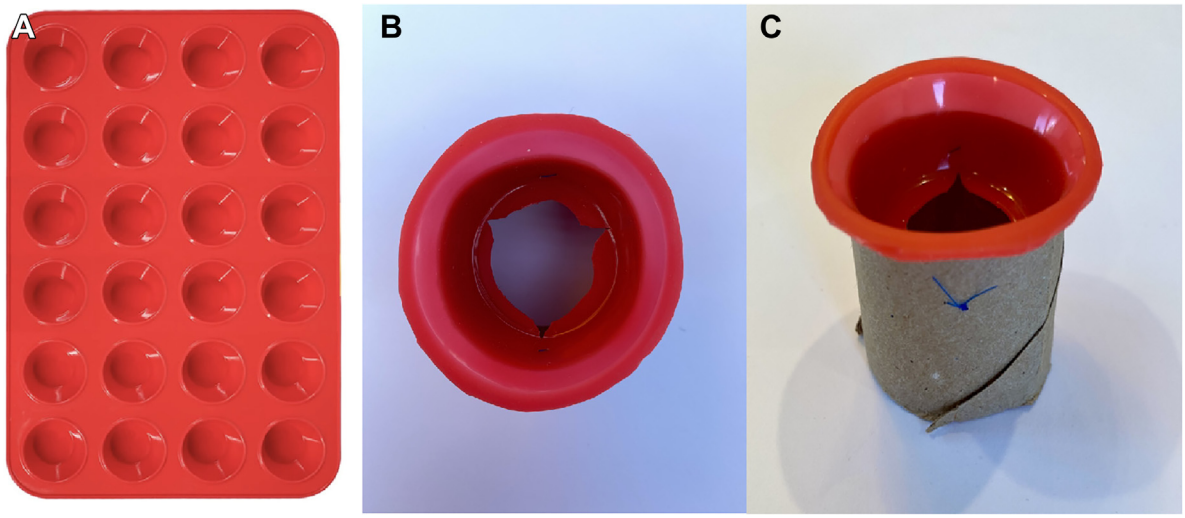


**FIGURE 1** (A) Silicone cupcake holder. (B) Bottom of cupcake holder with valve shape cut out. (C) Cupcake holder sutured into toilet paper roll.

approximately 9.5 cm in length are fixed to one another in the shape of an X (Figure 3A), then taped to the bottom of the can. Four small slits in the bottom of the toilet paper roll allow it to fit onto the X (Figure 3B), and this can then be placed into a coffee can to simulate a deep chest cavity (Figures 3C, 3D). The simulator is completely portable, allowing practice in any location.

**SURGICAL TECHNIQUE SIMULATION.** The simulator was used to simulate and to teach placement of aortic valve replacement sutures. The simulator is particularly useful for practicing the complex needle angles, including forehand, backhand, and "hook" angles. The needle angles used for aortic valve repair are not commonly learned before cardiothoracic surgery fellowship and require significant practice. Simulation aids the trainee in visualizing needle angles, properly loading needles onto the driver, and re-creating the arm and body position required to create each throw. The simulator can allow a trainee and mentor to discuss the nearby structures at risk of harm during aortic valve replacement and

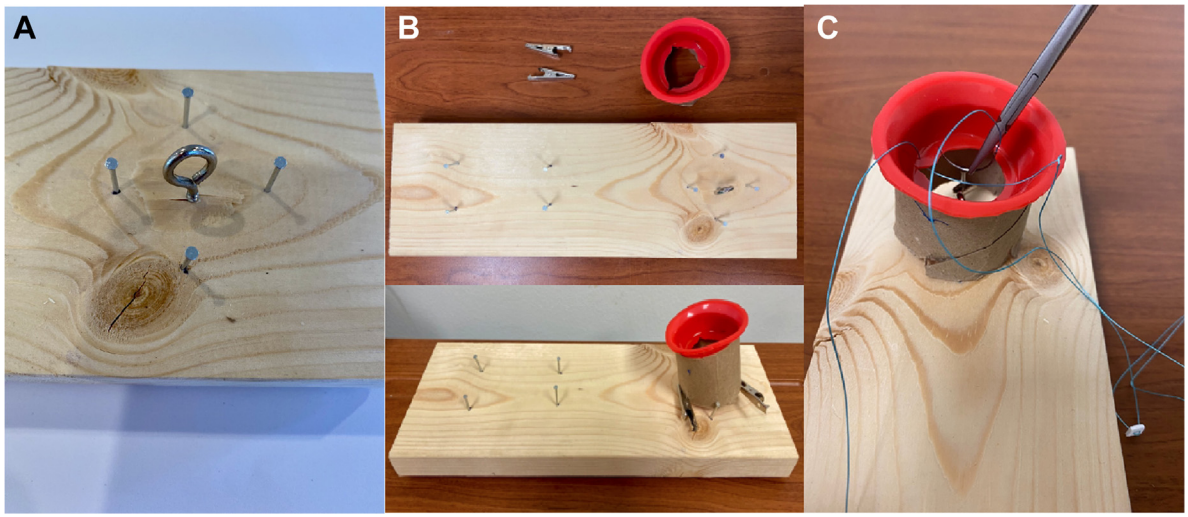


**FIGURE 2** (A) Four-point circle of nails, 4 cm apart, to hold valve. (B) Valve placed over nails and secured with alligator clip to imitate surgical angle of aortic valve. (C) Example of practicing the difficult backhand hook needle angle used by some surgeons for the "noncoronary cusp."

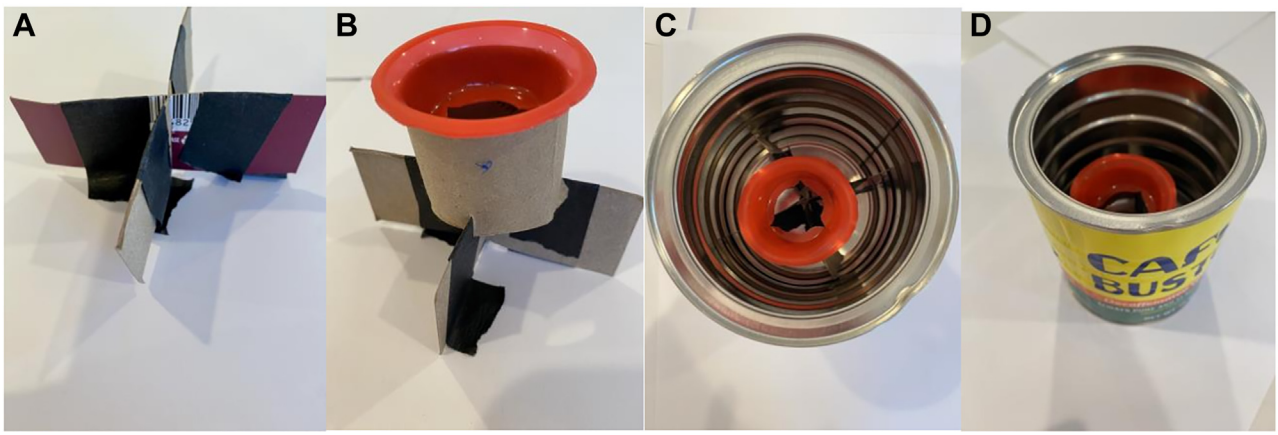


**FIGURE 3** (A) Cardboard X with tape for securing to the bottom of the can. (B) Valve with slits on bottom of toilet paper holder fits over cardboard X. (C, D) Valve sitting on cardboard in the bottom of a coffee can for "deep cavity" practice.

modification of tissue depth to limit complications while ensuring secure valve placement.

## COMMENT

This study describes a novel aortic valve surgical simulator that is inexpensive, easy to create, and accessible. Simulation is an important adjunct to training in the operating room, and cardiac surgery simulators increase skill acquisition.[3] Practice outside of the operating room facilitates intraoperative learning, and trainees with higher performance levels are more likely to be granted autonomy.

In comparison to other cardiac surgical procedure simulators, aortic valve simulators are relatively rare. Our simulator is low fidelity (not a complete replica of the operating room) but is low cost and accessible, theoretically increasing the frequency of deliberate practice. Skills such as needle angles and spacing are practiced on our simulator, and it is intended to represent a platform for modifications or the creation of simulators that allow many surgical skills to be practiced.

Said,[4] using latex gloves as the valvular structure, created a low-fidelity portable simulator that can be used for aortic valve replacement. Shaikhrezai and coworkers[5] created an aortic valve simulator using condom material. We believe the silicone cupcake holder is a more realistic replica of the aortic valve annulus and that providing a tool for practice at the depth of a pericardial well is essential. Furthermore, our model is lower cost than that of Shaikhrezai and coworkers, approximately $20 vs $65. Cost was not estimated by Said but is likely low. Hossien[6] created a low-cost portable aortic root simulator that similarly uses silicone but instead employs a clay mold for creation of the valve and aorta. Rocha e Silva and colleagues[7] also used silicone cupcake holders sutured into a sewer pipe sleeve to simulate the aortic valve; cavity simulation creation required a soldering iron. We believe both simulators are useful tools for aortic valve repair but that ours may be slightly easier and require less specific cardiac surgical anatomy knowledge to create. A higher fidelity aortic valve simulator was created by Rosa and coworkers[8] using surgical drape material and a wire valve mold that is anatomically accurate but does require 3-dimensional printing, which increases the cost and decreases accessibility significantly.

In conclusion, our simulator is simple to create and to use, and portability enables practice in any location. It facilitates a critical component of learning, namely, deliberate practice, which prepares the trainee both to understand the anatomy and to rehearse technical skills before performing them in the operating room.

The Supplemental Material can be viewed in the online version of this article [https://doi.org/10.1016/j.atssr.2022.11.011] on http://www.annalsthoracicsurgery.org.

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## DISCLOSURES
The authors have no conflicts of interest to disclose.

## PATIENT CONSENT
Not applicable.

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