Assessment of a mitral valve replacement skills trainer: A simplified, low-cost approach

David G. Greenhouse, MD, Eugene A. Grossi, MD, Sophia Dellis, BA, Joy Park, BS, David W. Yaffee, MD, Abe DeAnda, Jr, MD, Aubrey C. Galloway, MD, and Leora B. Balsam, MD

EDU

Objectives: Simulated mitral valve replacement may aid in the assessment of technical skills required for adequate performance in the operating room. We sought to design and assess a mitral valve replacement training station that is low-cost, nonperishable, portable, and reproducible as a first step in developing a mitral valve surgical skills curriculum.

Methods: Nineteen physicians (7 general surgery residents, 8 cardiothoracic surgery residents, and 4 attending cardiothoracic surgeons) underwent simulated mitral valve replacement testing. Simulated mitral valve replacement was performed on a training station consisting of a replaceable ''mitral annulus'' inside a restrictive ''left atrium.'' Eight components of performance were graded on a 5-point scale. A composite score (100 point maximum) was calculated by weighting the grades by procedural time. The effect of training level was evaluated using analysis of variance and post hoc Tukey honestly significant difference.

Results: The speed of simulated mitral valve replacement varied among general surgery residents, cardiothoracic surgery residents, and attending cardiothoracic surgeons (52.9 ± 9.0 vs 32.8 ± 4.7 vs 28.0 ± 3.5 minutes, respectively; $F = 25.3$; $P < .001$). Level of training significantly affected all 8 evaluation components ($P < .001$). Composite scores increased with level of training (general surgery residents 32.9 ± 11.4, cardiothoracic surgery residents 65.1 ± 11.5, and attending cardiothoracic surgeons 88.3 ± 7.8 of a possible 100 points; $F = 35.7$; $P < .001$). Cardiothoracic surgery residents who reported having performed 10 to 50 mitral valve replacements as the primary surgeon had a composite score of 65.0 ± 2.8 ($P < .01$ compared with attending cardiothoracic surgeons).

Conclusions: Simulated mitral valve replacement can be performed using this simple, affordable, portable setup. Performance scores correlate with level of training and experience, but residents who performed 10 to 50 mitral valve replacements still failed to reach attending-level proficiency. This training simulator may facilitate skills practice and evaluation of competency in cardiac surgery trainees. (J Thorac Cardiovasc Surg 2013;145:54-59)

Supplemental material is available online.

Cardiac surgery trainees are faced with specific challenges when learning to perform mitral valve surgery. Proper exposure of the valve must be established, with approaches ranging from conventional sternotomy to minimally invasive minithoracotomy. The geometric constraints of the surgical field, combined with the close proximity of the mitral valve to other critical cardiac structures, can make precise suture placement difficult or hazardous for the novice surgeon. Although procedural volume and experience have been shown to affect the choice of surgical technique and outcomes, mandatory duty-hour restrictions have led to decreased cardiac case volumes for cardiothoracic surgery residents.[1-3] Surgical simulators allow for technical skill development in a safe, controlled environment, which may translate into improved performance in the operating room.[4-6]

Previous mitral valve surgery simulators have used expensive proprietary models or perishable animal tissue.[7] We sought to design an inexpensive, reusable mitral valve replacement (MVR) skills training station (TS) using commonly found materials. We designed our TS to be easily portable with an adjustable yet reproducible setup configuration. This TS platform provides not only a tool to study the performance of residents and fellows at simulated MVR (sMVR) but also a practice station that can be easily distributed and used for home practice.

We aimed to assess the TS by relating the performance on sMVR to the level of surgical training. This study is a first step in the evaluation of this platform for teaching the basic

From the Department of Cardiothoracic Surgery, New York University School of Medicine, New York, NY.

Funding for this research was provided by a grant from the Thoracic Surgery Foundation for Research and Education (to Dr Balsam).

Disclosures: Authors have nothing to disclose with regard to commercial support.

Read at the 92nd Annual Meeting of The American Association for Thoracic Surgery, San Francisco, California, April 28-May 2, 2012.

Received for publication April 24, 2012; revisions received Aug 20, 2012; accepted for publication Sept 27, 2012; available ahead of print Oct 29, 2012.

Address for reprints: Leora B. Balsam, MD, NYU Medical Center, 530 First Ave, Suite 9V, New York, NY 10016 (E-mail: leora.balsam@nyumc.org).

0022-5223/$36.00

http://dx.doi.org/10.1016/j.jtcvs.2012.09.074

Abbreviations and Acronyms

ICC = intraclass correlation coefficient
MVR = mitral valve replacement
sMVR = simulated mitral valve replacement
TS = training station

steps of MVR, with a focus on correct suture placement in a geometrically constrained space. Studying the technical differences in sMVR performance between inexperienced and experienced subjects may lead to better understanding of the surgical learning process and identification of areas to focus training.

MATERIALS AND METHODS

Subjects

Nineteen surgeons from a single institution underwent sMVR evaluation: 7 general surgery residents, 8 cardiothoracic surgery residents, and 4 attending cardiothoracic surgeons. General surgery residents were in postgraduate year 2 (n = 3) or 3 (n = 4). Cardiac surgery residents were in postgraduate year 4 (n = 1), 6 (n = 4), 9 (n = 2), or 10 (n = 1). Two cardiac surgery residents were enrolled in an integrated 7-year cardiac surgery/general surgery training program, whereas 6 cardiac surgery residents were enrolled in a traditional fellowship program after completion of general surgery training. Two cardiac surgery residents had performed 10 to 50 MVRs as primary surgeon, whereas the remaining 6 had performed less than 10. Institutional review board approval was obtained for the conduct of this study.

Trainer Construction

The mitral valve trainer was constructed by hand from materials commonly found at a hardware store. A 3- to 4-inch polyvinyl chloride pipe adapter was lined with felt in 2 layers using hot glue. An additional 2-ply ring of felt was glued en face inside the adapter, creating an annulus-like structure. This polyvinyl chloride structure was then glued to a suction-based mounting arm (The Chamberlain Group, Great Barrington, Mass). To reproduce the geometric restrictions of the left atrium when working through a sternotomy, the assembly was placed within a rigid chest wall model (Heart Case, The Chamberlain Group) (Figure 1). By using ruler-tapes, a 3-dimensional coordinate system was constructed within the Heart Case to ensure reproducible ‘‘annular’’ positioning between tests (Figure E1). A suture organizer was placed around the opening of the Heart Case. The approximate cost of the trainer was \$40 (excluding the Heart Case), and it took approximately 15 minutes to construct each assembly.

Protocol

Before testing, all subjects watched an 8-minute demonstration video that illustrated the steps of sMVR on the task trainer and highlighted important technical details, including suture spacing, suture depth, and suture organization. The video is broken down into several segments: annular suture placement, suture organization, sewing ring suture placement, and knot tying. A narration accompanies the video. After viewing the video, subjects were instructed to wear their surgical loupes as usual and a headlamp-mounted video camera. The video camera tracked the operative field of view of the subject’s loupes, and video was recorded to a DVD. The subject was given standard surgical instruments (forceps, low-profile long needle driver, scissors) along with double-armed pledgeted 2-0 Ethibond suture (Ethicon, Somerville, NJ) material to complete the MVR using the sewing ring of an expired prosthetic valve. The subjects were provided an assistant who would hold the suture or sewing ring as directed by the subject. Times to completion of annular suture placement, sewing ring suture placement, and tying of the final knots were recorded. At the conclusion of the test, all samples were collected for grading (Figure E2). Subjects were unaware of the grading methods. All videos and sMVR samples were deidentified before assessment.

Grading and Assessment

Two blinded reviewers with surgical expertise assessed all video and sMVR samples in an independent fashion. An evaluation sheet was used to grade performance on a 1 to 5 scale (1 = poor, unable to accomplish goal, marked hesitation; 2 = below average, able to partially accomplish goal with hesitation; 3 = average, able to accomplish goal with hesitation, discontinuous progress and flow; 4 = good, able to accomplish goal deliberately, with minimal hesitation, showing good progress and flow; 5 = excellent, able to accomplish goal without hesitation, showing excellent progress and flow) in the following categories: suture bite size, suture spacing, needle driver facility, needle angle awareness, needle follow-through, awareness of geometric constraints, accuracy, and knot tying (Table 1). A composite score was calculated by adding the scores in each of the 8 subjective categories from both graders (80 points maximum) to a time to completion subscore (<30 minutes = 20 points; 30-35 minutes = 15 points; 35-40 minutes = 10 points; 40-45 minutes = 5 points; >45 minutes = 0 points) for a maximum score of 100 points.

In addition, graders recorded whether or not errors were made in each of 4 quadrants of the annulus during suture placement (anterolateral, anteromedial, posterolateral, and posteromedial quadrants). Tabulated errors included multiple needle reloads to achieve the necessary suture bite, incorrect suture bite size or depth, and malpositioning of pledgets. Observations were compared between graders, and if both graders reported errors within a quadrant, this was analyzed as an error. If there was no agreement between graders within a quadrant, it was analyzed as no error. Specific comments were recorded such that detailed feedback could be provided to the subjects at a later date.

Exit Survey

After the completion of sMVR, subjects were asked to complete a 14-item exit-survey regarding their experience. Items were rated by their agreement with or estimated value of the statement on a 1 to 5 Likert scale (1 = strongly disagree, 3 = neutral, 5 = strongly agree).

Statistical Methods

Scores were compared among levels of training using analysis of variance. Pairwise comparisons were analyzed using post hoc Tukey honestly significant difference. The presence of errors was compared between quadrants using a nonparametric Cochran’s Q test. Intergrader variability was analyzed using intraclass correlation coefficient (ICC).

RESULTS

The time required to complete sMVR varied among general surgery residents, cardiothoracic surgery residents, and attending cardiothoracic surgeons: 52.9 ± 9.0 versus 32.8 ± 4.7 versus 28.0 ± 3.5 minutes, respectively; $F = 25.3$, $P < .001$. Pairwise comparison demonstrated no significant difference between cardiothoracic surgery residents and attending cardiothoracic surgeons in time to complete sMVR, whereas general surgery residents versus cardiothoracic surgery residents and general surgery residents versus attending cardiothoracic surgeons were significantly different ($P < .05$) (Table 2).