Title: Mini Mitral Simulation Simplified

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The Institutional Review Board (IRB) or equivalent ethics committee of the Duke University Hospital did not approve this study as the project does not involve any interaction or intervention with human subjects; therefore the project did not meet criteria for IRB Review. Patient written consent for the publication of the study was not received as no patients or other human subjects were involved in this study.

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Glossary of abbreviations: IRB (institutional review board), MIMVR (minimally invasive mitral valve repair), LA (left atriotomy), LV (left ventricular)

Central picture legend: Foam template facilitates practice of all steps of minimally invasive mitral valve repair

Central message: A low cost, easy-to-assemble simulator allows repetitive practice of the suture steps in minimally invasive mitral valve surgery, critical for the trainee’s ability to progress through the operation.

Perspective statement: Prior research in mitral surgery simulation has focused on placement of the annulus and valve repair sutures. However to learn the operation as a novice requires practice of all surgical steps. The simulator described is beneficial because of its low cost, easy assembly; this setup allows practice of every suture step, critical in the trainee’s ability to progress through the entire operation.

Abstract:

Objective: The purpose of this video is to illustrate the basic construction and use of a low cost, low fidelity simulator to be built by the trainee for in-home preparation in minimally invasive mitral valve repair surgery. To achieve technical proficiency, trainees must demonstrate competence with long shafted instruments before performing valve repair. The primary goal is to simulate every stitch that will be placed.

Case video summary: A simulator is constructed using a standard tissue box and three foam sheets at the box base. A drawn template is created to serve as a basis for placement of six suture types: pericardial retraction stitches, antegrade cardioplegia u-stitch, left ventricular vent u-stitch, annulus stitch, neochords, and left atriotomy closure. Practicing with long shafted instruments, the trainee can perfect needle angle, improve efficiency, and minimize errors. Simulation time from start to finish, and number of technical errors should be recorded for each iteration to set goals and achieve deliberate practice.

Conclusion: Using an inexpensive and low fidelity model, every suture step of a minimally invasive mitral valve repair can be replicated. The goal is to allow frequent practice and flatten the learning curve. Unlike all existing models, this setup allows practice of every suture step, critical in the trainee’s ability to progress through the entire operation.

Keywords: Minimally invasive mitral valve surgery; Simulation-based training; Simulator; Surgical skills; Surgical training
Background:

Minimally invasive mitral valve repair (MIMVR) is associated with less blood transfusion, reduced hospital length of stay, and shortened return to activity. However, adoption in the United States has been slow compared to our European counterparts with only 23% of mitral valve operations in this country performed via thoracotomy approach, and teaching residents this surgery has presented a challenge. The Leipzig group in their series found a learning curve of 75-125 cases, and thus simulation in combination with hands on operative experience plays a role in mastering the case today.

The first Heart Port Mitral Valve Replacement was performed in 1996 and Dr. Randy Chitwood presented a series of video-assisted mitral valve operations at the American Association of Thoracic Surgery annual meeting in 1997. It is said that anyone who worked with Dr. Chitwood was familiar with his tissue simulators for that operation. In 2012 a group from the Netherlands demonstrated how to construct a low cost, low fidelity simulator for 5 euros. In 2019 a group from Italy similarly published a video on a low cost model that can be used to simulate the operation. In 2019 in a moderate fidelity model a group from Germany showed that operative time and mistakes are reduced when residents practice this case. Finally Dr. Peyman Sardari has the most experience having established a two-day course using a patented high fidelity simulator. 99 surgeons having used the simulator noted close similarity to the operative procedure. Moreover in testing of those surgeons, time for 12 annulus stitches and number of changes in needle angle were reduced after the 2 day course.

However the focus of all simulators aforementioned has been on placement of annulus and valve stitches. The goal in this project was to create a low cost, low fidelity simulator that could be used at the trainee’s home to practice every step of MIMVR. The Institutional Review Board (IRB) of the Duke University Hospital did not approve this study; the project does not involve any interaction or intervention with human subjects and therefore the project did not meet criteria for IRB Review. The following outline describes in detail the materials necessary to construct a low fidelity simulator, building of the simulator, and step by step simulation (see Video). The trainee should practice every operative step that requires use of long shafted instruments. These six steps are: pericardial retraction sutures, antegrade cardioplegia, left ventricular (LV) vent, annulus stitches, valve repair stitches (e.g. neochords), left atriotomy (LA) closure.

Instruments Required:

A trainee needs a set of long shafted instruments at home, not in the operating room or a simulation laboratory at the hospital. Three ways to obtain these instruments are: 1. Obtain a demo set from the local device representative; these are typically reserved for wet labs and often lent to trainees 2. Ask the operating room staff to borrow a set of long shafted instruments 3. Purchase used long shafted instruments on a website such as eBay (San Jose, California). Note a full set of long shafted instruments is not necessary, only a needle driver grasping forceps and knot pusher.

Set up (see Table 1 for full list of materials required):

Use adhesive foam sheets (Hello Hobby adhesive foam sheets, $5.83 for a package of 40 sheets, trademark of Walmart Inc, Bentonville, AR). Take three pieces of foam. Cut the foam to the
width of a tissue box. Remove the plastic peripherally from the box. Place one foam sheet inside the box. Using a permanent marker, outline the working area. Then draw the practice template. Draw an “L” for the retraction sutures, 4 lines for the antegrade cardioplegia U-stitches, 2 lines for the LV vent U-stitch, and an oval for the annulus stitches. For the four neochords draw 4 dots, and finally one long line for the atriotomy closure. The foam sheet should look as shown in Figure 1. Next staple three sheets together, peel the backing off the bottom sheet, and lay this amalgamation on the bottom of the tissue box. Cut several one half centimeter cuts in the tissue box to serve as suture holders. The set-up is complete. The depth of the box allows a trainee to practice challenging suture placement at various needle angles under direct vision. This low cost model does not replicate totally endoscopic mitral valve surgery under videoscopic guidance.”

Operative steps (the following six operative steps should be practiced):

1. Pericardial retraction stitches: It is our practice to place pericardial retraction stitches as a backward “L,” 3 stitches in each part of the “L” for 6 total. These are placed forehand. In the actual operation each stitch is taken as an interrupted stitch, however it is expensive and time consuming to use 6 sutures, so for simulation run the suture with 3 bites going down, and 3 going across.

2. Antegrade cardioplegia: Two U-stitches are placed at right angles for the antegrade cardioplegia line. Practice the first U-stitch as a forehand, then pull the stitch through the foam and reuse the prolene to place the second u-stitch as a backhand. Note in the surgery the antegrade line is removed after Del Nido cardioplegia is given, and replaced just prior to coming off cardiopulmonary bypass.

3. Left ventricular vent: The LV vent is one U-stitch forehand. Note the vent in the operation is placed after the valve has been repaired and the ring is in place, but it is best to place the stitch early on before the cross clamp is applied to save time.

4. Annulus stitches: This is the hardest part for the trainee to perform efficiently and can be done a number of ways. It is our practice to place the posterior stitches first. These are backhand throws; then work counterclockwise. The 3 o’clock position needle angle is nearly a hook. The anterior leaflet portion is an upside down backhand. Finally come forehand down from the top and up from the bottom to complete the annular stitches. Figure 2 shows the order of stitch placement.

5. Neochords: Each set of neochords is a figure of eight stitch. For a P2 prolapse, one set is placed in the anterolateral papillary muscle, one set in the posteromedial muscle, and sometimes one set in the ventricular tissue between the two. Practice placing a figure of 8 stitch then bring each stitch once in an over and over stitch through the top of the tissue box to mimic the repair stitch in the leaflet. Repeat this process to practice 4 chords.

6. Left atriotomy closure: Use the straight line of the template for this portion. In the operating room, to save time we prepare 4 “quick knots” before starting the case (see Figure 3 for an illustration of a quick knot). A quick knot has 6-8 knots and a loop; this allows the surgeon to avoid tying a knot during the actual case. The LA closure will be a forehand stitch at the top with a quick knot, then suture downward. At the bottom place a forehand stitch with a second quick knot and suture upward. At first practicing all six steps will take the trainee approximately 40-60 minutes. Once facile, the goal is to complete all six steps in 30 minutes or less.

Knot tying:
Knot tying requires practice. With use of the quick knots, only 6-7 knots require securing with a knot pusher (1 knot for each set of neochords, 1 to close the LA, 2 to close the antegrade cardioplegia site, and 1 to close the LV vent.) To practice place one simple stitch and hand tie a knot, then secure the suture in a cut on the tissue box. This allows for practice without an assistant. Tie with the left hand and push the knot down with the right.

Practice:
Deliberate practice is the holy grail in achieving success with simulation. Key tenets in practice are: 1) Have the instruments at home and practice at least once per week 2) Use a timer and time from beginning to end how long all 6 suture steps take and 3) Record the number of fumbles or suture bobbles in each attempt.

Conclusion:
Using an inexpensive and low fidelity model, every suture step of a minimally invasive mitral valve repair can be replicated. The goal is to allow frequent practice and flatten the learning curve. Unlike all existing models, this setup allows practice of every suture step, critical in the trainee’s ability to progress through the entire operation.

References:


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**Legend:**

**Table 1:** Instruments and materials required for mini mitral simulator set up.

**Figure 1:** Foam template – the backward “L” is used for pericardial retraction stitches, 4 lines for the antegrade cardioplegia U-stitches, 2 lines for the left ventricular vent U-stitch, a hexagon for the annulus stitches, dots for the neochords, and one long line for the atriotomy closure.

**Figure 2:** The diagram illustrates the order and needle angle of annulus stitch placement.

**Figure 3:** A quick knot is constructed by tying 6-8 knots with prolene suture leaving a loop at the end. The stitch is pulled through the loop in surgery, creating a knot at the end of a running suture. This allows the surgeon to avoid using a knot pusher and can reduce cross clamp time during the case.

**Video:** This 8 minute video describes the materials necessary to construct a low fidelity simulator, building of the simulator, and step by step simulation of minimally invasive mitral valve repair.
<table>
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<th>Instruments Required</th>
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<tbody>
<tr>
<td>• Needle driver (long shafted)</td>
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<td>• Grasping forceps (long shafted)</td>
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<td>• Knot pusher (long shafted)</td>
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<table>
<thead>
<tr>
<th>Materials Required</th>
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<tbody>
<tr>
<td>• Tissue box</td>
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<tr>
<td>• Permanent marker</td>
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<tr>
<td>• Adhesive foam sheets (3)</td>
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<tr>
<td>• 4-0 prolene suture (8)</td>
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Two u-stitches for aortic cannulation

Line for left atriotomy closure

Hexagon for annulus stitches

Dots for neochords

One u-stitch for left ventricular vent

Backward “L” for pericardial retraction sutures
Two u-stitches for aortic cannulation

Line for left atriotomy closure

Hexagon for annulus stitches

Dots for neochords

One u-stitch for left ventricular vent

Backward “L” for pericardial retraction sutures
3. Upside down backhand

4. Forehand ↑ and ↓

2. Forehand/ hook ↑

1. Backhand →