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Splitting Hairs – Improving Sternotomy Performance and Preparedness Among Trainees Using a Novel Simulation Program

Kaitlin Pardue

kaitlin-pardue@ou.edu

The University of Oklahoma Health Sciences Center https://orcid.org/0009-0006-8412-2831

Rachel Davis

The University of Oklahoma Health Sciences Center

Joy Trimble

The University of Oklahoma Health Sciences Center

Matthew Harter

The University of Oklahoma Health Sciences Center

Frank Wood

The University of Oklahoma Health Sciences Center

Rebecca Scott

University of Oklahoma: The University of Oklahoma

Jason Lees

The University of Oklahoma Health Sciences Center

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Abstract

Purpose Sternotomy remains a critical but increasingly rare procedure encountered by general surgery trainees, with many reporting low comfort levels with the procedure. Given the inherent risks associated with the procedure, practice using a novel sternotomy simulator offers an opportunity to improve preparedness for future operations. We hypothesize that the use of a novel sternotomy simulation model will improve trainee comfort, preparedness, and technical skills needed to perform this essential procedure.

Methods Following informed consent, participants performed a sternotomy to assess their baseline ability using our training model. A standardized instructional video was then shown, and participants repeated the procedure. Surveys were conducted before and after the initial sternotomy as well as at the completion of the simulation to assess preparedness for the procedure and effectiveness of the educational material using a 5-point Likert scale. For accuracy scoring, artificial sternums were marked with a colored grading scale on a 30-point scale. Participant videos were de-identified and technique scored by blinded faculty on a 4-point scale. Appropriate statistical tests were used to assess the difference in pre- and post-training scores.

Results 25 learners were assessed, the majority of whom were resident trainees (72%) and male (60%). None of the participants had performed a sternotomy prior to the stimulation, and the group reported low preparedness (Mean 1.2/5). 96% of participants reported improvement in preparedness following the simulation exercise, with an average 1.3-point score increase. Participants reported a significant decrease in anxiety score after completing the simulation exercise (2.76 vs. 3.72, $p=0.001$). Sternum accuracy score (22.36 vs. 15.64, $p=0.006$, max score 30) and video technique score (3.48 vs. 2.08, $p<0.0001$, max score 4) were significantly increased after completing the simulation.

Conclusion Due to the rare and high-risk nature of sternotomy procedures, simulation offers an excellent opportunity to build skills and confidence in surgical trainees. Furthermore, it provides a metric for assessing competence in trainees' ability to perform such procedures. In this study, use of a novel, reproducible sternotomy simulator in conjunction with directed teaching led to significant improvement in sternotomy performance, participant anxiety, and reported preparedness.

Introduction

Median sternotomy is a critical surgical exposure technique for many surgical specialties. The median sternotomy is rarely performed by general surgery residents, but, when necessary, it is vital to perform correctly. Sodha provides a commentary regarding his first experience performing a sternotomy as a general surgery intern, drawing attention to the current lack of formal training and assessment on performing sternotomies [1]. Both short- and long-term morbidity and mortality following sternotomy depend upon precise execution. This is emphasized by Reser et al who discuss the proper surgical technique in performing such procedure [2]. While variability exists according to surgeon preference, the overarching surgical steps and landmarks remain the same [2].

There are few affordable training simulators or grading systems available to utilize when learning how to perform a sternotomy. Often a trainee's first sternotomy is in an emergent setting. When it comes to literature on teaching tools for practicing a median sternotomy, it appears there is only one easily discoverable published paper on the topic. Vo et al performed a study focusing on training simulation for Canadian resident physicians in cardiothoracic surgery [3]. The assessment was conducted in two parts: initially without training followed by a 5-minute training video. This simulation did not utilize an objective scoring system when evaluating resident performance, rather a check list to ensure certain steps were followed. Participants were also given a questionnaire pre and post education to assess preparedness for sternotomy. This study found participants performance improved following training and found such education useful [3]. However, limitations to this study include its small sample size and participants overall familiarity with the procedure prior to use of the training model [3].

With these critiques in mind, the Department of Surgery at the University of Oklahoma Health Campus has partnered with the University of Oklahoma Biomedical Engineering Department to develop an educational sternotomy simulator. We hypothesize that a sternotomy simulation will give resident physicians an opportunity to evaluate themselves on their performance and improve their skills in a non-threatening environment. Our long-term goal is to provide not only a qualitative measure but a quantitative measure for teachers and trainees alike to assess improvement in resident performance.

Methods

First and second year general surgery residents as well as medical students at the University of Oklahoma Health Campus were invited to participate in the study between July and August of 2025. This study was reviewed and approved by the institutional review board at the University of Oklahoma (IRB# 15961).

Our sternotomy model was created using a box of wood planks with shelving edges to house the 3D printed sternum. A precut piece of model skin (silicone tattoo practice skin at 1.5mm thickness) is then placed over the sternum and secured in place with two vertical wooden slats that connect to the box with four heavy duty toggle clamps. This mechanism ensures the skin substitute and sternum remain in place. C clamps then secure the box to the table to prevent sliding of the box when performing sternotomy. Images of the model are available in Fig. 1. The materials required to perform the sternotomy simulation were laid next to the simulator: 10 blade scalpel, marking pen, and sternal saw (Stryker).

Sternotomy performances were scored according to quantitative and qualitative measures. The 3D printed sternums were marked with a color grading scale for every .25 cm from midline with midline being a best score of 5. The sternum was divided longitudinally into six quadrants for a best composite score of 30 (Fig. 2). For assessment of the technical aspects of the procedure, participants were de-identified by wearing gowns and gloves and performance video recorded. A grading rubric was created

by senior general surgery residents and reviewed for approval by core faculty surgeons (Table 1). The videos were randomized and scored by a single core faculty member.

Table 1
Grading rubric for sternotomy performance

Sternotomy Simulator Grading Rubric	
Unprepared/Critical Deficiency	1
- Does not successfully bisect the sternum	
Inexperienced with Procedure	2
- Does not incise skin or palpate landmarks	
- Divides sternum partially	
- Stands at head or foot of bed rather than at surgeon's side	
Intermediate Performance	3
- Palpates landmarks	
- +/- marks appropriate landmarks	
- Incises skin	
- Divides sternum	
Practice Ready Performance	4
- Palpates and marks appropriate landmarks	
- Incises skin	
- Completely divides sternum	
- Efficiently completes task	

All participants completed an initial questionnaire including demographic information. Following initial use of the simulator, candidates completed part two of the questionnaire assessing their anxiety and preparedness for sternotomy performance using a 5-point likert scale. Participants were then shown a short video tutorial on using the simulator and how to successfully perform a sternotomy. Participants then repeated the sternotomy using the simulator. Following the final sternotomy simulation, participants completed part three of the questionnaire to assess for change in both anxiety and preparedness, as well as feedback regarding the utility of the simulator. Questionnaire is available for review in Tables 2–4.

Table 2
Phase 1 of sternotomy simulator questionnaire.

Phase 1 – Sternotomy Simulator Questionnaire
1. Are you a resident or medical student?
2. What is your level of training?
- PGY – 1, 2, 3, 4, 5
- MS – 1, 2, 3, 4
3. What is your gender?
- Male
- Female
4. Have you performed a sternotomy?
- Yes (if yes, how many _____)
- No
5. How would you rate your anxiety when asked to perform a sternotomy?
- 1 – Not anxious
- 2 – Somewhat anxious
- 3 – Anxious
- 4 – Very anxious
- 5 – Extremely anxious
6. Please circle which aspects of performing the sternotomy cause anxiety?
- Risk of injury to vital organs
- Risk of going off midline
- Fear of handling the sternal saw
- Strength required to bisect the sternum
- Performance anxiety
7. What are the anatomical landmarks used to perform a midline sternotomy? Please list.
8. Do you feel prepared to perform a sternotomy without instruction?
- 1 – Not prepared
- 2 – A little prepared
- 3 – Prepared

Phase 1 – Sternotomy Simulator Questionnaire
- 4 – Very prepared
- 5 – No supervision needed

Table 3
Phase 2 of sternotomy simulator questionnaire.

Phase 2 – Sternotomy Simulator Questionnaire
1. How useful was the sternotomy simulator - 1 – Not useful - 2 – A little useful - 3 – Useful - 4 – Very useful - 5 – Should be required education for all trainees
2. How would you rate your anxiety when asked to perform a sternotomy? - 1 – Not anxious - 2 – Somewhat anxious - 3 – Anxious - 4 – Very anxious - 5 – Extremely anxious
3. If any, please circle which aspects of performing the sternotomy cause anxiety - Risk of injury to vital organs - Risk of going off midline - Fear of handling sternal saw - Strength required to bisect the sternum
4. Do you feel prepared to perform a sternotomy without instruction? - 1 – Not prepared - 2 – A little prepared - 3 – Prepared - 4 – Very prepared - 5 – No supervision needed

Table 4
Phase 3 of sternotomy simulator questionnaire.

Phase 3 – Sternotomy Simulator Questionnaire
1. How useful was the additional education - 1 – Not useful - 2 – A little useful - 3 – Useful - 4 – Very useful - 5 – Should be required education for all trainees
2. How useful was the video tutorial - 1 – Not useful - 2 – A little useful - 3 – Useful - 4 – Very useful - 5 – Should be required education for all trainees
3. How useful was the sternotomy simulator? - 1 – Not useful - 2 – A little useful - 3 – Useful - 4 – Very useful - 5 – Should be required education for all trainees
4. How would you rate your anxiety when asked to perform a sternotomy? - 1 – Not anxious - 2 – Somewhat anxious - 3 – Anxious - 4 – Very anxious - 5 – Extremely anxious
5. If any, please circle which aspects of performing the sternotomy cause anxiety - Risk of injury to vital organs - Risk of going off midline - Fear of handling sternal saw

Phase 3 – Sternotomy Simulator Questionnaire
- Strength required to bisect the sternum
6. Do you feel prepared to perform a sternotomy without instruction? - 1 – Not prepared - 2 – A little prepared - 3 – Prepared - 4 – Very prepared - 5 – No supervision needed
7. What are the anatomical landmarks used to perform a midline sternotomy. Please list.

Bivariate analysis was performed to assess demographic and clinical differences between comparison groups. For categorical variables, Chi-square and Fisher's exact tests were used to evaluate associations. Continuous variables were analyzed using the Student’s t-test for normally distributed data, and the Wilcoxon rank-sum test for non-normally distributed data. A p-value of less than 0.05 was considered statistically significant.

Results

A total of twenty-five learners consented for participation in the study. Participants were predominantly resident trainees (72%) and male (60%). None of the participants had previously performed a sternotomy. See Table 5 for demographic data.

Table 5
Demographic data of sternotomy simulator participants.

Characteristic	Result, n (%)
Level of training	
- MS 2	1 (4)
- MS 3	5 (20)
- MS 4	1 (4)
- PGY 1	14 (56)
- PGY 2	4 (16)
Gender	
- Male	15 (60)
- Female	10 (40)
Previous sternotomy	
- No	25 (100)

From a subjective standpoint, the participants reported low preparedness (mean 1.2/5) and high anxiety (mean 3.72/5) prior to the simulation. 96% of participants reported improvement in preparedness with an average 1.3 score increase following the simulation. Likewise, participants noted a significant reduction in anxiety following the simulation exercise (2.72 v 3.72, $p = 0.001$). As objective measures, both sternum accuracy scoring (22.36 vs. 15.64, $p = 0.006$) and video scoring (3.48 vs. 2.08, $p < 0.0001$) significantly improved following simulation. All users agreed that the simulator was useful.

Discussion

General surgery education has traditionally relied upon real time learning for progressing surgical technique. With the advent of the 80-hour work week restriction and thus truncated residency experience, trainees must learn via more efficient modalities [4]. Exposure to cardiac surgery in training has diminished to meet the evolving general surgery training paradigms [5]. This affords for fewer opportunities for general surgery residents to gain familiarity with overlapping skills such as sternotomy [5]. Sternotomy remains a fundamental exposure technique that general surgeons encounter in trauma, damage control scenarios, and rural surgical settings. Despite infrequent exposures in training, general surgeons should be prepared to not only perform such procedures but mitigate any commonly encountered challenges. Therefore, trainees must develop not only technical proficiency, but a strong understanding of the associated anatomy and operative principles.

As surgical education has evolved, there has been an increasing emphasis on the utilization of simulation-based learning. Simulation provides trainees the opportunity to hone their skills in a low stakes environment, allowing for repetitive exposure in otherwise seldom encountered surgical skills. Practice in simulated settings confers confidence and reduces anxiety as well as allows trainees to identify and correct errors without jeopardizing patient safety [6]. A systematic review by the British Journal of Surgery found strong evidence across the surgical literature to support that simulation training improved patient-based performance compared to trainees who had not participated in simulation [7]. These educational models emphasize repetitive deliberate practice and objective assessment, creating standardized methods for technical development. While laparoscopic and endoscopic simulation curricula are well established in surgical training, equivalent models for procedures such as median sternotomy remain relatively limited.

The current literature regarding sternotomy simulation is sparse. Existing models have demonstrated improvements in learner confidence and familiarity with the procedure. However, many rely upon subjective assessments or checklist-based evaluations rather than objective performance metrics [3]. These models are frequently specifically designed for cardiothoracic trainees or relatively cost prohibitive for broad use across programs. Our study sought to address this educational gap through the development of a low cost, reproducible sternotomy simulation model designed for early surgical trainees. By incorporating both qualitative and quantitative assessments, our model provides opportunity for trainees to gain confidence in practice while still providing opportunity for structured evaluation of procedural competency over time.

Rather than time serving as a metric for progression from training into practice, there is an increasing emphasis towards competency-based learning. Competency-based learning and evaluation focuses on critical roles within a set scope of practice including clinical decision making and technical skills [8]. There are defined benchmarks that must be reached rather than advancement based exclusively on time spent in training. Incorporating simulation into sternotomy education aligns with this educational philosophy by allowing trainees to practice procedural skills deliberately, receive targeted feedback, and demonstrate measurable improvement prior to performing the procedure in clinical settings.

Several limitations of the study should be acknowledged. The sample size was limited and participant experience levels were varied. Additionally, both medical students and residents were utilized as participants. We acknowledge there could be a difference between the two based on experience level, but utilization was necessary to reach an appropriate sample size. Further study is necessary to address the differences between these two groups. This was not a long-term study, and thus long-term retention of technical skills or translation of simulation performance to operative competency was not evaluated. Further studies should investigate longitudinal outcomes as well as simulation-based training on operative performance. Despite these limitations, our findings support the feasibility and educational value of a low-cost sternotomy simulation model for surgical trainees.

Conclusion

A low-cost sternotomy simulation model is a feasible educational tool for surgical trainees and may address the gaps from lower exposure to cardiac surgery during residency training. Simulation-based learning affords opportunities for deliberate practice, technical assessment, and improved procedural confidence in a safe learning environment. Additional studies are warranted to determine the long-term educational impact and translatability with operative performance.

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Figures

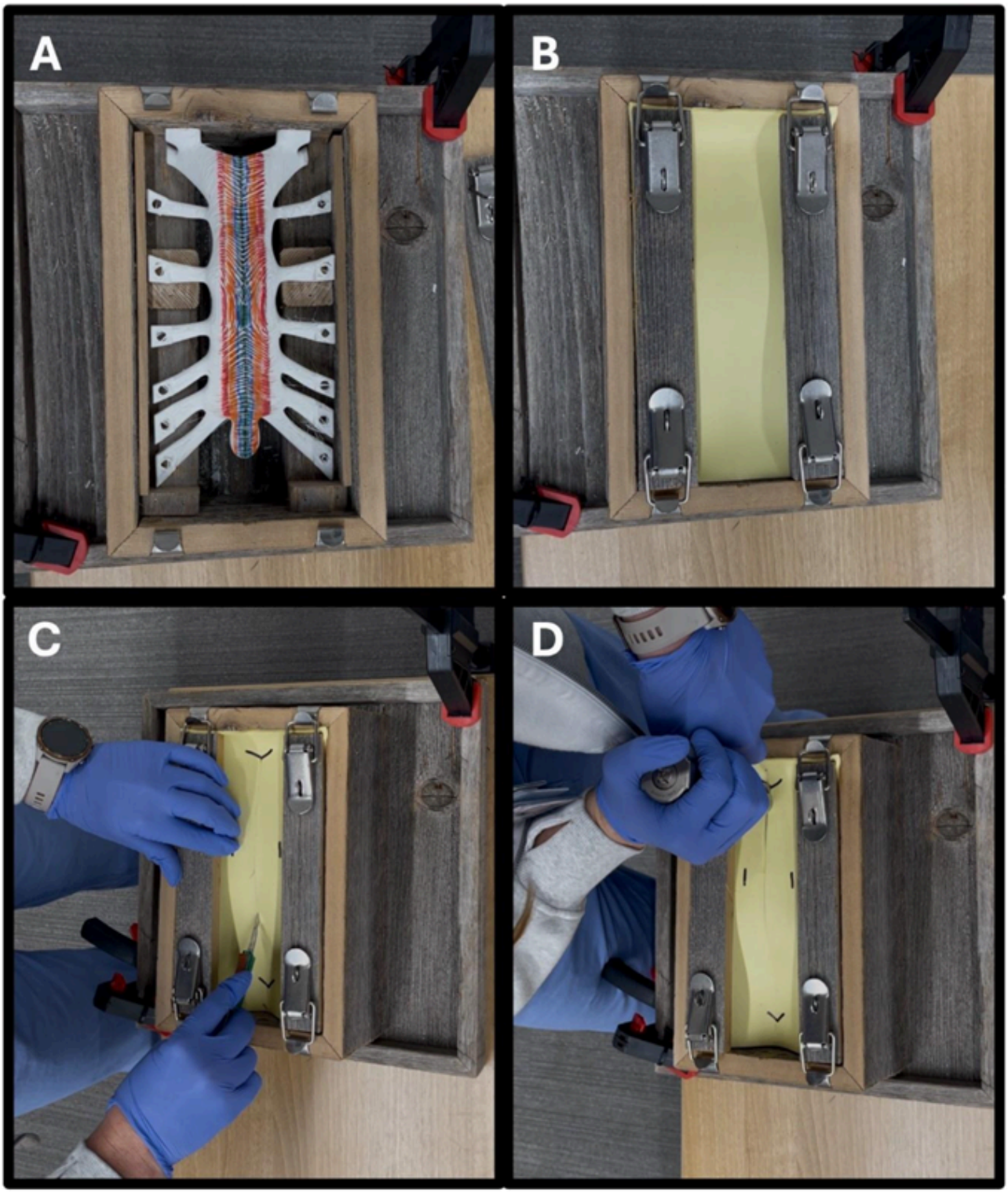


Figure 1

Sternotomy simulator with 3D printed sternum on shelving edge (A) and with model skin secured in place (B).



Figure 2

3D printed sternum with colored grading scale and division into six quadrants.