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Cardiac resternotomy after cardiac surgery in kids: CRACK the chest

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Abstract

Objective: Emergent resuscitation of postoperative paediatric cardiac surgical patients requires specialised skills and multidisciplinary teamwork. Bedside resternotomy is a rare but life-saving procedure and few studies focus on ways to prepare providers and improve performance. We created a multidisciplinary educational intervention that addressed teamwork and technical skills. We aimed to evaluate the efficiency of the intervention to decrease time to perform critical tasks and improve caregiver comfort. *Methods:* A simulation-based, in situ resternotomy educational intervention was implemented. Pre-intervention data were collected. Educational aids were used weekly during day and night nursing huddles over a three-month period. All ICU charge nurses had separate educational sessions with study personnel and were required to demonstrate competency in all the critical tasks. Post-intervention simulations were performed after intervention and at 6 months and post-intervention surveys were performed. *Results:* A total of 186 providers participated in the intervention. There was a decrease in time to obtain defibrillator, setup resternotomy equipment and internal defibrillator paddles and deliver sedation and fluid (all $p < 0.05$). Time to escort family from the room and obtain blood was significantly decreased after intervention ($p < 0.05$). There was no difference in time to first dose of epinephrine, defibrillator pads on the patient, or time to call the cardiovascular surgeon or blood bank. Providers reported increased comfort in identifying equipment needed for resternotomy ($p < 0.01$) and setting up the internal defibrillator paddles ($p < 0.01$). *Conclusions:* Implementation of a novel educational intervention increased provider comfort and decreased time to perform critical tasks in an emergent resternotomy scenario.

Emergencies in the paediatric cardiac ICU require highly specialised care, understanding of complex physiology, and multidisciplinary teamwork. Complex scenarios involving numerous specialists including cardiac intensivists, cardiac surgeons, cardiologists, nurses, and respiratory therapists require not just cognitive and technical skill but also efficient communication, clear leadership, and coordination of care.[7] A break down in teamwork and communication and unclear responsibilities may contribute to medical error.[1] In situ simulation and Crisis Resource Management training in the paediatric cardiac ICU have been associated with improved comfort and team function during resuscitations.[2]

One such highly complex resuscitation scenario in the cardiac ICU involves emergency cardiac resternotomy. Emergent cardiac resternotomy is performed in 0.8–2.7% of all adult patients who have undergone cardiac surgery.[3] The number of emergent cardiac resternotomies performed in the paediatric cardiac surgical population is not well known. Both the European Resuscitation Council and the Society of Thoracic Surgeons Expert Task Force on Resuscitation after Cardiac Surgery suggest emergency resternotomy should be performed for non-ventricular fibrillation/ventricular tachycardia arrests that do not resolve after exclusion of airway or respiratory problems within 5 minutes.[3,4,10] The American Heart Association Scientific Statement for the Cardiopulmonary Resuscitation in infants and children with cardiac disease suggests early urgent opening of the sternum in the immediate postoperative period within the first minutes of resuscitation if indicated.[5]

In this study, we report a novel educational intervention performed in the cardiac ICU to train a multidisciplinary team to more efficiently perform cardiac resternotomy. We aimed to evaluate the efficiency of the intervention to decrease time to perform critical tasks and improve caregiver comfort.

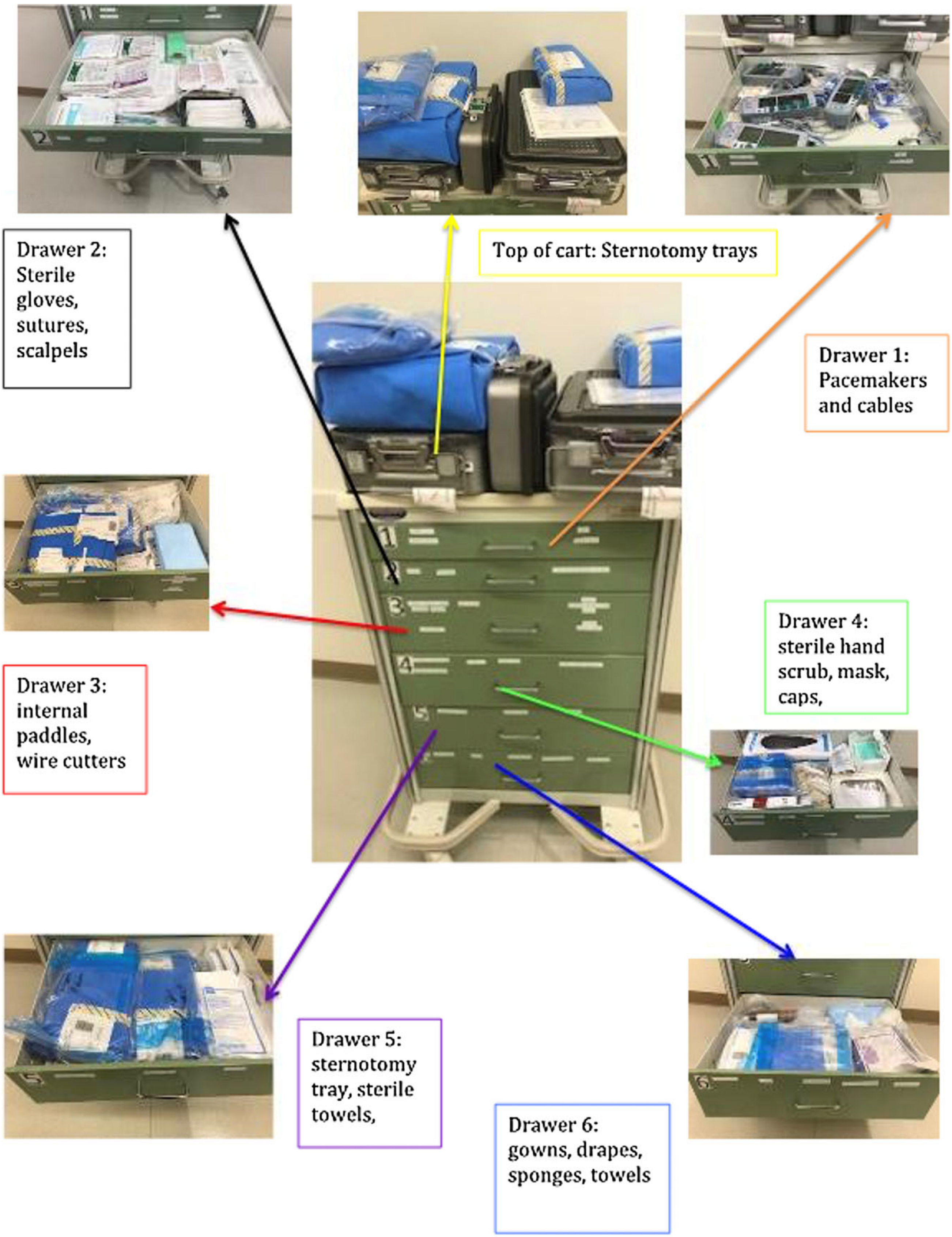

Figure 1. Resternotomy cart overview.

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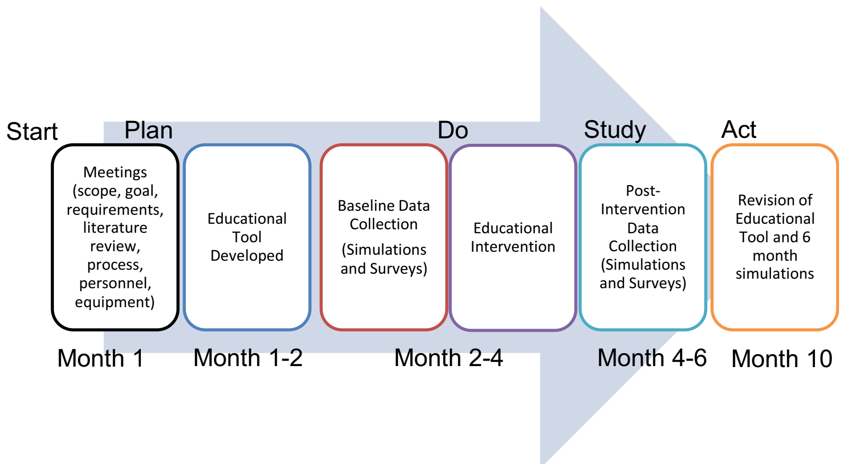

Figure 2. Flow chart of the educational tool development and implementation.

Materials and methods

Educational intervention design

First, the literature was reviewed to identify standardised resternotomy processes and reported challenges encountered during bedside cardiac resternotomy. Identification of key stakeholders and barriers to process improvement were discussed. Then a multidisciplinary meeting with cardiac ICU leadership including cardiac intensivists, cardiothoracic surgeons, cardiac ICU nurses, cardiovascular nurse practitioners, perfusionists, and nursing leadership was held to discuss and understand the current process and potential challenges. The scope, goals, requirements, equipment, and personnel required were delineated. The educational tool was then developed by the primary study personnel and reviewed and revised by the multidisciplinary group.

The final educational tool consisted of (1) Cards with seven clear roles and responsibilities for cardiac ICU nursing (Supplemental Table 1) (2) a labelled diagram of the sternotomy cart (Fig. 1) (3) a unit-specific video of a simulated resternotomy scenario with a demonstration of each role and responsibility. The roles and responsibilities and sternotomy cart were reviewed weekly via a standardised script over a three-month period during morning and evening nursing huddles. The video was circulated via the hospital educational module system and all nurses were required to view it.

In addition to the educational tools, direct educational sessions were performed weekly during morning and evening nursing huddles over a three-month period and encompassed all cardiac ICU nurses. Cardiac ICU charge nurses received personalised education and were required to demonstrate competence in performance of all seven key roles and performance of the critical tasks.

To collect pre-intervention data about the current practice, in situ simulations were conducted in the cardiac ICU. Simulations involved a low-fidelity simulator with a realistic sternal dressing, central line access, and endotracheal tube. The scripted scenario included a bedside nurse who was engaged in manually ventilating the patient and a cardiac ICU fellow who relayed the medical information to the responders and ran the code. One research assistant was responsible for timing all interventions with a standardised scoring sheet. Additional assistants answered the phone calls posing as the cardiovascular surgeon, operating room charge nurse, etc. The in situ approach used an actual cardiac ICU bed space and the same equipment (defibrillators, surgical instrument trays, supplies, code cart medications, medical dispenser) used for real patients. The cardiac ICU was not aware that a simulated scenario would occur but responded to the code button similar to a real code scenario. Participants were expected to perform the actual roles they would perform during a real scenario and were instructed to draw up and administer medications, perform cardiopulmonary resuscitation, and use sterile barrier precautions to enhance realism. Post-intervention simulations employed similar methods but included a structured debrief. In addition, additional simulations were performed 6 months after the initial intervention.

A pre-intervention survey was sent to all the nurses with questions involving their knowledge of resternotomy and comfort level with performing responsibilities and critical tasks and used a 5-point Likert scale. The scale was 1 = very uncomfortable, 2 = uncomfortable, 3 = comfortable, 4 = very comfortable, and 5 = extremely comfortable. Post-intervention surveys were again sent to all the nurses regarding their comfort level with the critical tasks. The study timeline is shown in Figure 2.

Statistical analyses were performed using analysis of variance to compare the different study timepoints and time to critical tasks. The Wilcoxon signed ranks test was used to compare pre and post-intervention survey results. For analysis, Likert scales 3,4, and 5 were grouped into a composite response of comfortable with task.

Results

A total of 186 providers participated in the intervention (168 nurses, 10 physicians, four nurse practitioners, and four respiratory therapists). A total of 10 pre-intervention simulations and 10 post-intervention simulations were conducted during both day and night shifts in situ in the cardiac ICU. Additional post-intervention simulations were performed 6 months after the initial intervention. The critical tasks were identified a priori during the multidisciplinary planning stage.

Median time in seconds to performance of critical tasks pre and post-educational intervention is detailed in Table 1. There was a decrease in time to have defibrillator in the room, setup the resternotomy equipment and internal defibrillator paddles, and decreased time to deliver sedation and fluid after the intervention that was sustained in the 6-month simulations (all $p < 0.05$). Time to escort family from the room and having blood at the bedside were significantly decreased after intervention and at 6 months ($p < 0.05$). There was no difference in time to first dose of

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Table 1. Pre, post, and 6 month intervention time to complete critical tasks during simulations

Critical Task	Pre-intervention time in seconds (n = 10)	Post-intervention time in seconds (n = 10)	6 months post-intervention time in seconds (n = 10)	*p*-value
First dose of epinephrine delivered	164 ± 46	129 ± 52	139 ± 21	0.13
Medication runner (delivered sedation and fluid)	467 ± 152	230 ± 33	267 ± 50	**<0.01**
Cardiac cart with resternotomy equipment setup	503 ± 184	379 ± 50	342 ± 43	**<0.02**
Defibrillator in room	257 ± 227	96 ± 44	131 ± 35	**0.03**
Defibrillator pads on patient	259 ± 158	174 ± 57	149 ± 30	0.05
Internal defibrillator paddles in room	530 ± 138	339 ± 62	333 ± 63	**<0.01**
Cardiovascular Surgeon called	184 ± 100	192 ± 75	134 ± 71	0.17
Family escorted out of room	510 ± 143	246 ± 82	327 ± 190	**<0.01**
Blood bank called	249 ± 81	201 ± 69	197 ± 43	0.16
Blood at bedside	534 ± 173	343 ± 50	427 ± 111	**<0.01**

Continuous variables presented as mean ± standard deviation.

epinephrine, defibrillator pads on the patient, or time to call the cardiovascular surgeon or blood bank.

The pre-intervention and post-intervention survey data were also collected and analysed.

Before the intervention was implemented, the lowest comfort level was reported in identifying equipment needed for resternotomy, setting up the defibrillator with internal paddles, selecting appropriate size paddles, and opening the resternotomy equipment. Table 2 shows the pre and post-intervention survey results. Nurse participants reported increased comfort in identifying equipment needed for resternotomy ($p = 0.007$) and setting up the internal defibrillator paddles (0.003) after the intervention. All respondents reported increased comfort after intervention.

Discussion

This report describes a novel educational intervention using in situ simulation to practice emergent cardiac resternotomy in the paediatric cardiac ICU. We have identified that it is feasible, decreases time to performance of critical tasks, and improves participant comfort.

Resuscitation of postoperative cardiac patients requires understanding of complex physiology, specialised skills, and multidisciplinary teamwork. Bedside resternotomy occurs rarely but is a specialised procedure required for resuscitation and little if any education is routinely performed to assist in this complex intervention. Provider inexperience, discomfort, and distress when the event occurs may lead to a chaotic situation.

The European Resuscitation Council and the Society of Thoracic Surgeons Expert Task Force on Resuscitation after Cardiac Surgery suggest emergency resternotomy should be performed for non-ventricular fibrillation/ventricular tachycardia arrests that do not resolve after exclusion of airway or respiratory problems within 5 minutes.[3,4] Multiple organisations have developed a postoperative cardiac surgical algorithm for resuscitation that includes emergent resternotomy.[3,4,11,15]

Utilising an adult Cardiac Surgical Advanced Life Support protocol Maccaroni et al. reported significantly improved survival in their postoperative cardiac surgical patients.[12] Cardiac resternotomy, which is a low frequency, high-acuity scenario, can be practised via simulation. Studies have shown that simulation is an effective teaching tool.[8,9,14] Simulation improves comfort, team skills, confidence, and communication.[1,2,6,14] Other paediatric studies report improved clinical performance and patient outcomes with high-fidelity simulation.[16–18] This is especially important in low-frequency and high-acuity scenarios such as cardiac resternotomy.

The American Heart Association Scientific Statement for the Cardiopulmonary Resuscitation in infants and children with cardiac disease suggests early urgent opening of the sternum in the immediate postoperative period within the first minutes of resuscitation if indicated.[4] For the first time, this guideline gives recommendations specifically for paediatric cardiac patients. Unlike the adult guidelines, a specific timeline is not proposed and very few studies detail a systematic approach to resternotomy education. Lo et al. report a low-fidelity simulation training scheme to evaluate standard paediatric resuscitation including cardiac pacing and chest re-opening.[13] In this study, new medical leaders took significantly longer to order chest re-opening than experienced team leaders. As noted previously, bedside paediatric cardiac resternotomy is a rare intervention and the opportunities for learning are few in most cardiac ICUs. In our cardiac ICU, 75% of nurses surveyed had never witnessed a cardiac resternotomy.

In our study, we found a significant reduction in time to performance of tasks needed for cardiac resternotomy including faster sterile setup of the resternotomy cart equipment for the cardiac surgeon and less time to sterile preparation of the correct sized internal defibrillator paddles. We found that most nurses knew where the actual cardiac resternotomy cart was located and performed well on standard resuscitation measures including time to initiate chest compressions, time to bring the code cart to the bedside, time for epinephrine delivery, and time to bring the defibrillator in the patient room. However, we did find significant improvement in tasks that were not only important for cardiac resternotomy but also tasks that were important for other emergent resuscitations. For example, after completion of the intervention, it took less time to deliver fluid, sedation, blood to the bedside, and family support. All of these tasks may be important during a paediatric medical resuscitation but receive less emphasis and education during code training than standard roles (code cart, recorder, etc.)

Table 2. Pre- and post-intervention survey results

	Comfortable with Task[a]		
	Pre-intervention (n = 51)	Post-intervention (n = 25)	*p*-value
Identify location of cardiac cart	46 (90%)	23 (92%)	0.72
Open prep bag using sterile technique	38 (75%)	21 (84%)	0.39
Open resternotomy equipment using sterile technique	30 (59%)	18 (72%)	0.31
Identify equipment needed for resternotomy	13 (25%)	15 (60%)	**0.007**
Select appropriately sized internal paddles off the cardiac cart	35 (69%)	19 (76%)	0.69
Draw up fluid, sedation, other medications from medication Omnicell	46 (90%)	23 (92%)	0.8
Setup defibrillator with external pads	36 (71%)	20 (80%)	0.55
Setup defibrillator with internal paddles	19 (37%)	19 (76%)	**0.003**
Draw up code medications	39 (76%)	22 (88%)	0.38
Obtain blood from blood bank in emergency	35 (69%)	18 (72%)	0.97
Identify correct form for blood bank in emergency	32 (63%)	17 (68%)	0.81
Notify appropriate personnel during resternotomy	32 (63%)	17 (68%)	0.85
Notify and direct family during resternotomy scenario	26 (51%)	12 (48%)	0.81

[a]Likert scale 3, 4, and 5.

The results of our survey showed that many nurses had never participated in a real or simulated cardiac resternotomy scenario. After the educational intervention, nurses reported significantly increased comfort in identifying equipment needed for resternotomy and setting up the defibrillator with internal paddles. All participants reported feeling that the intervention was useful and improved overall confidence.

Strengths of this study include the large number of participants and multidisciplinary input. Limitations include challenges of simulation education. This was a simulation scenario, not a real patient scenario. Although we demonstrated decreased time to perform critical tasks during simulation, we do not know if this improved performance translates to improved clinical performance or improved patient outcome. In addition, the educational intervention and feedback were primarily aimed at nursing staff, which may be a limitation of the study. Future studies focused on whether this educational intervention leads to improved clinical outcomes are needed.

Conclusion

This novel standardised educational intervention decreased time to perform critical tasks during emergent paediatric cardiac resternotomy and improved nursing comfort.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/S1047951124000891.

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Competing interests. None.

Ethical standard. The authors assert that all procedures contributing to this work comply will all ethical standards of the relevant national guidelines on human experimentation (United States National Institutes of Health Belmont report) and with the Helsinki Declaration of 1975, as revised in 2009, and have been approved by the Wayne State Institutional Review Board.

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