Article type : Brief Contribution

Title: Iatrogenic Critical Care Procedure Complication Boot Camp: A Simulation-Based Pilot Study

Title Page

Type of manuscript: Brief Contribution

Title: Iatrogenic Critical Care Procedure Complication Boot Camp: A Simulation Based Pilot Study

Running title: Iatrogenic Procedure Boot Camp

Authors:

Elaine Riefkohl-Ortiz, MD
Ocala Regional Medical Center
elaineriefkohlortiz@gmail.com

Jennifer A. Frey, PhD, CCRP
Summa Health System – Akron Campus, Akron, OH
The Ohio State University, Columbus, OH
Jennifer.Frey2@osumc.edu

Jennifer Yee, DO
The Ohio State University, Columbus, OH
jennifer.yee@osumc.edu

M. David Gothard, MS
BIOSTATS, Inc., Canton, OH
davegothard@sbcglobal.net

Patrick G. Hughes, DO, MEHP
Florida Atlantic University, Boca Raton, FL
hughesp3@gmail.com

Derek A. Ballas, DO, MHPE
Summa Health System – Akron Campus, Akron, OH
ballasd@summahealth.org

Rami A. Ahmed DO, MHPE
Indiana University School of Medicine, Indianapolis, IN
raaahmed@iu.edu

Corresponding author:
Rami A. Ahmed, DO, MHPE, FACEP
Professor of Emergency Medicine
Simulation Fellowship Director

This is the author's manuscript of the article published in final edited form as:

Riefkohl-Ortiz, E., Frey, J. A., Yee, J., Gothard, M. D., Hughes, P. G., Ballas, D. A., & Ahmed, R. A. (2019). Iatrogenic Critical Care Procedure Complication Boot Camp: A Simulation-Based Pilot Study. AEM Education and Training, 0(ja). https://doi.org/10.1002/aet2.10317

Department of Emergency Medicine
Indiana University School of Medicine
720 Eskenazi Avenue | FT 3
Indianapolis, IN 46202
317.880.3860 tel
raaahmed@iu.edu

Keywords: Iatrogenic; procedure; complication; error management training; EMT

Abstract

Background: Traditional medical education strategies teach learners how to correctly perform procedures while neglecting to provide formal training on iatrogenic error management. Error management training (EMT) requires active exploration as well as explicit encouragement for learners to make and learn from errors during training. Simulation provides an excellent methodology to execute a curriculum on iatrogenic procedural complication management. We hypothesize that a standardized simulation-based EMT curriculum will improve learner's confidence, cognitive knowledge, and performance in iatrogenic injury management.

Methods: This was a pilot, prospective, observational study performed in a simulation center using a curriculum developed to educate resident physicians on iatrogenic procedural complication management. Pre- and post-intervention assessments included confidence surveys, cognitive questionnaires, and critical action checklists for six simulated procedure complications. Assessment data were analyzed using medians, interquartile ranges, and the paired change scores were tested for median equality to zero via Wilcoxon signed rank tests with $p<0.05$ considered statistically significant.

Results: Eighteen residents participated in the study curriculum. The median confidence increased significantly by a summed score of 12.5 (8.75 –17.25) ($p<0.001$). Similarly, the median knowledge significantly increased by 6 points (3 –8) from the pre- to post-

intervention assessment ($p<0.001$). For each of the simulation cases, the number of critical actions performed increased significantly ($p<0.001$ to $p=0.002$).

Conclusion: We demonstrated significant improvement in the confidence, clinical knowledge, and performance of critical actions after the completion of this curriculum. This pilot study provides evidence that a structured EMT curriculum is an effective method to teach management of iatrogenic injuries.

Introduction

Traditional medical education strategies teach learners how to correctly perform procedural skills in a controlled, structured, and closely supervised manner that avoids errors and neglects addressing how to deal with errors when they occur.[1,2] Conventionally, procedure complication management has been learned either through initial procedural training or during clinical exposure, which creates varied experiences.[3] Emergency or critical care procedures are prone to iatrogenic injuries, which can lead to increased morbidity and mortality.[4] In many instances procedural complications are unavoidable and mismanagement of iatrogenic injuries can lead to devastating consequences. Furthermore, procedural complications are frequently underreported making their management crucial to enhancing patient safety.[5] The inevitability and variability of procedural errors has demonstrated the need for training in these clinical skills that incorporates crisis resource management and error management strategies.[6] A formal curriculum to train residents in the leadership and management of iatrogenic procedural errors is paramount to ensuring patient safety.[4,7-10]

Error management training (EMT) requires active exploration and encouragement for learners to make errors and learn from those errors.[1,11] EMT allows exposure to high-acuity, low frequency situations while enhancing the learner's thought process during clinical management.[2] Studies demonstrate that when the learner is encouraged to make mistakes during training they are able to recognize knowledge deficits without exposing patients to further morbidity.[1,11] Learning from errors enhances critical thinking and discussion of subsequent consequences, while creating memory consolidation of the appropriate management.[12] Another benefit of EMT is emotional control in subsequent situations due to the exposure in a controlled setting.[11] Simulation-based training is the ideal method to expose learners to difficult, infrequent situations and allow the learner to freely make mistakes without compromising patient safety.[1]

In recognizing the educational need, we developed a curriculum to provide foundational knowledge and leadership training for physicians in the management of iatrogenic injuries. In teaching the management of these iatrogenic injuries in the simulation environment, students may be encouraged to intentionally make errors in this controlled environment without any direct consequences to patients. The aim of this brief report was to identify if the use of this standardized novel curriculum would improve learners' confidence, cognitive knowledge, and performance with iatrogenic injury management.

Materials and Methods

Study Location and Equipment

The study was performed in a tertiary care, university-affiliated teaching hospital simulation laboratory. The three-day iatrogenic boot camp curriculum was designed for residents and fellows involved in performing critical care procedures. High-fidelity patient simulators were set-up to exhibit iatrogenic complications that learners were expected to recognize and manage as they entered the room. As dictated by the scenarios, the simulators were modified to reflect an iatrogenic injury and the subsequent manifestation of mismanaging that complication, i.e. results of student errors (Supplementary Figure 1). The simulation set-up included a simulated patient monitor, crash cart, intubation box, images to be provided as requested, 1-2 confederate actors who provided background and assisted the learner without providing guidance or suggestions, and other equipment for each scenario if requested by the learners. This study was deemed exempt from review by the local Institutional Review Board.

Curriculum Development

The curriculum consisted of three parts: pre-intervention, intervention, and post-intervention. The confidence survey, knowledge test, and critical action checklists were identical for both pre- and post-intervention evaluation. These evaluation elements were created and assessed by 5 emergency medicine trained faculty members after an extensive literature review was completed[13]. The critical action checklists were pilot tested with trial runs of each simulation case to ensure they were comprehensive, logical, and easy to use for faculty. Each participant was scheduled for 10 hours over three days. The cases included: propofol overdose, chest

tube placed below the diaphragm, tracheal laceration during attempted intubation, pneumothorax after attempted central venous catheter placement, central venous catheter placement in the carotid artery, and pneumothorax on the ventilator.

Participants, Faculty, and Staff

Residents and fellows from emergency medicine, pediatrics, surgery and pediatric emergency medicine were invited to participate. Two medical simulation fellowship trained emergency medicine physicians were present to assess the critical actions and lead the debriefing and intervention phase. A respiratory therapist with medical simulation training participated in the ventilator case debriefing. Each station required one simulation technician.

Pre-intervention Assessment

On study day one, each learner completed an 11 item confidence assessment on the management of iatrogenic injuries using a 1-5 Likert scale, a 21 question multiple-choice knowledge test, and four questions pertaining to the learner's personal exposure and management of actual clinical errors (See Appendix A and B). Learners individually engaged in six 10-minute simulation scenarios and were assessed using the predetermined critical actions checklist (See Appendix C). Feedback was not given during the pre-intervention phase and students were instructed to manage each simulated case to the best of their ability to assess baseline performance.

Educational Intervention

Study day two was the educational intervention in which learners went through each the six 10 minute simulations as a group with a subsequent faculty-led bedside debriefing and didactic lecture lasting 45-50 minutes (6 hours total). Learners were explicitly told of the objectives of the curriculum and were encouraged to make errors in the management of the iatrogenic errors that originated with each case. This was done to allow for a better understanding the manifestations of mismanagement and to gain further clarity on how to manage these errors.

Post-intervention Assessment

Learners completed confidence surveys and multiple-choice knowledge tests identical to the pre-intervention assessments on day three. Participants individually underwent the same six scenarios and were assessed using the same critical action checklists.

Statistical Analysis

Data were analyzed using Microsoft Excel and SPSSv24.0. Cohort specialty and training year designation were summarized using frequencies and percentages. Knowledge test, confidence scores, and critical actions were summed. The median, interquartile range (IQR), and range were used. The paired change scores were tested for median equality to zero via Wilcoxon signed rank tests with $p<0.05$ via two-sided testing considered statistically significant.

Results

A significant time investment by faculty, staff and students was required to develop, implement, and assess this iatrogenic injury management curriculum, including approximately 80 hours for development of the curriculum, simulation cases, assessments, and rehearsals plus 12 hours to create the simulator modifications. The students attended the curriculum for 10 hours each and overall the faculty and staff ran 228 simulation cases.

Demographics

Eighteen physicians in postgraduate training participated representing emergency medicine (11, 61.1%), pediatric emergency medicine (5, 27.8%), pediatrics (1, 5.6%), and general surgery (1, 5.6%). Their current postgraduate years (PGY) were 3 PGY-1 (16.7%), 4 PGY-2 (22.2%), 5 PGY-3 (27.8%), 3 PGY-4 (16.7%), 2 PGY-5 (11.1%), and 1 PGY-6 (5.6%).

Two (11%) learners reported having received any formal training on how to correct errors that have already occurred. Four (22%) reported having caused an iatrogenic complication during post-graduate training. With regards to assistance for an iatrogenic error, 2 (22%) learners required assistance from another medical provider for an iatrogenic injury and 3 (17%) have corrected/assisted another provider after they caused an iatrogenic error.

Simulations and Assessments

Overall, 228 simulations were performed for this study, including 108 for pre-intervention assessments, 12 for formative training, and 108 for post-intervention assessments. Each subject had significantly higher scores post-intervention for each assessment (Table 1). The

increased change in the knowledge assessment and confidence score ranged from 1 to 10 and 1 to 26 points, respectively.

Discussion

Despite the significant potential educational benefit, leadership training, and patient safety benefits, there is a paucity of iatrogenic complication management literature. This is likely due to the lack of familiarity with the concept and benefits of EMT, the lack of appreciation of the importance of formally training residents how to manage errors once they have occurred, and the time and effort needed to effectively execute a curriculum focused on this rarely discussed topic.

This three-day simulation-based curriculum demonstrated increased learner confidence, knowledge, and performance during high-fidelity simulated cases with iatrogenic injury management. A learning environment in which the learners are faced with premeditated complications and are encouraged to make errors while managing complications will eliminate leaving these experiences to chance during training. Strengths of this novel curriculum included the iatrogenic-based simulation scenarios, encouragement and ability to make errors without risk of harm to patients, repetition of the scenarios with debriefing, direct supervision with hands-on bedside training, and the focused didactic lectures on the appropriate management of iatrogenic procedural errors immediately after debriefing.

All learners demonstrated improved performance in each iatrogenic procedural complication scenario. Overall, the pneumothorax on the ventilator case has the lowest pre-intervention scores which may be attributed to the high reliance on respiratory therapists and intensivists to manage the ventilator. During the propofol overdose case, many learners performed initial management measures such as providing a fluid bolus and administering positive pressure oxygen, but did not provide more aggressive treatment such as intubation and vasopressor

support after vital signs deteriorated. The carotid artery cannulation case highlighted the need for iatrogenic error management training as many learners made the significant error of pulling the central venous catheter out of the dilated carotid artery, resulting in the development of a large neck hematoma with subsequent airway compromise and patient decompensation. The learners verbalized being unaware of the possibility of having airway compromise secondary to an expanding neck hematoma and did not recognize the need to urgently intubate the patient after making this error in management. In contrast, many critical actions were met on initial assessment of the misplaced chest tube, however learners routinely missed determining a need for blood transfusion and obtaining additional imaging which demonstrated limitations in making independent clinical management decisions.

Although not formally assessed in this curriculum, some residents lacked fundamental understanding of some procedures, which was highlighted when forced to manage associated complications. By teaching leadership skills and management of complications, learners may better understand the procedure and underlying pathophysiology, as well as enhance their critical thinking.

Post-curricular feedback indicated the learners felt the scenarios were realistic and that the repetition helped them to remember specific management strategies and increased their confidence. They appreciated that they had to provide orders, assess the patient, and manage the complication without assistance and subsequently felt more responsible for the patient management and remembered management specifics in greater detail. The learners suggested improved time management in the study as several unexpected delays occurred on the first day of pre-intervention assessments and wanted to know the "correct answers" of the day 1 scenarios and have reading material to enhance knowledge prior to the formative training sessions.

This study had several limitations. This was a small, single site pilot cohort study which utilized a convenience sample which was limited due to the three day commitment needed to complete the curriculum. Although all our assessment tools were developed by a panel of content experts, non-validated tools were utilized for assessment.

This curriculum was developed with the objective of establishing a formal and structured approach for the management of iatrogenic procedural complications. Knowing how to manage complications is a critically important patient safety objective. This curriculum serves as a guide for others to explore opportunities to improve patient safety, learner competence, and leadership and could be incorporated into an interprofessional curriculum. Overall, this study demonstrated significant improvement in the confidence, knowledge, and performance of critical actions after the completion of this curriculum and provides evidence that a structured curriculum is an effective method to teach the management of iatrogenic injuries.

References

1. Gardner AK, Abdelfattah K, Wiersch J, Ahmed RA, Willis RE. Embracing Errors in Simulation-Based Training: The Effect of Error Training on Retention and Transfer of Central Venous Catheter Skills. J Surg Educ 2015;72(6):e158-62.
2. Keith, N, Frese, M. Effectiveness of error management training: A meta-analysis. J Appl Psychol 2008;93(1):59-69.
3. Barsuk JH, McGaghie WC, Cohen ER, O'Leary KJ, Wayne DB. Simulation-based mastery learning reduces complications during central venous catheter insertion in a medical intensive care unit. Crit Care Med 2009;37(10):2697-701.
4. Hernandez MC, El Khatib M, Prokop L, Zielinski MD, Aho JM. Complications in Tube Thoracostomy: Systematic review and Meta-analysis. J Trauma Acute Care Surg. 2018;85(2):410-16.
5. McGee DC, Gould MK. Preventing Complications of Central Venous Catheterization. N Engl J Med 2003;348:1123-33.
6. Bair AE, Filbin MR, Kulkarni RG, Walls RM. The failed intubation attempt in the emergency department: analysis of prevalence, rescue techniques, and personnel. J Emerg Med 2002;23:131–40.
7. Sakles JC1, Laurin EG, Rantapaa AA, Panacek EA. Airway management in the emergency department: a one-year study of 610 tracheal intubations. Ann Emerg Med 1998;31(3):325-32.
8. Yoon DY, Annambhotla S, Resnick SA, Eskandari MK, Rodriguez HE. Inadvertent Arterial Placement of Central Venous Catheters: Diagnostic and Therapeutic Strategies. Ann Vasc Surg 2015;29(8):1567-74.
9. King A. Holder MG Jr, Ahmed RA. Errors as allies: error management training in health professions education. BMJ Qual Saf 2013;22(6):516-9.

10. Metcalfe J. Learning from Errors. Annu Rev Psychol 2017;68:465-89.
11. Levinson D. Hospital incident reporting systems do not capture most patient harm. Department of Health and Human Services, office of inspector general. 2012 Jan; Report (OEI-06-09-00091)
12. Nathwani JN, Fiers RM, Ray RD, et al. The relationship between technical errors and decision making skills in the junior resident. J Surg Educ 2016;73(6):e84-90.

Ahmed RA, Hughes PG, Wong A, et al. Iatrogenic emergency medicine procedure complications and associated trouble-shooting strategies: a narrative review. Int J Health Care Quality Assurance 2018. (in press)

Table 1. Knowledge, Confidence, and Critical Actions Assessments

		Pre-intervention		Post-intervention		Change in Assessment		
Assessment	N	Median	IQR	Median	IQR	Median*	IQR	p-value
Knowledge (number correct out of 21 questions)	18	11	9 - 12	16	15 – 17.25	6	3 - 8	<0.001
Confidence (max score = 55, 11 questions scored 1 to 5)	18	34	26.5 – 37.75	44	41.75 – 49.25	12.5	8.75 – 17.25	<0.001
Critical Actions	18							
Propofol Overdose (8 actions)		3.5	2 - 5	7	7 – 7.25	4	1.75 – 5	<0.001
Chest Tube Misplacement (9 actions)		6	5 – 7	8	7 – 8	2	0 – 2.25	0.001
Endotracheal Intubation Laceration (8 actions)		6	5 – 7	7.5	7 – 8	2	0 – 2.25	0.002
Pneumothorax After Central		5	4.75 – 6.25	8	7.75 – 9	2.5	1 – 4	<0.001

Venous Catheter Placement (10 actions)							
Central Venous Catheter Placement in Carotid Artery (8 actions)	4.5	3 – 5	8	7 – 8	3	2 – 4.25	<0.001
Pneumothorax on Ventilator (10 actions)	5	2.5 – 6.25	9	8 – 10	4	3 – 6	<0.001

*Post-intervention training value minus pre-intervention value