Received: 15 June 2023 | Revised: 27 September 2023 | Accepted: 8 October 2023

DOI: 10.1002/aet2.10917

AEM Education and Training

ORIGINAL CONTRIBUTION

An investigation into emergency medicine resident cricothyrotomy competency: Is three the magic number?

Joseph S. Turner MD[1] | Lauren K. Stewart MD[1] | Andrew C. Hybarger DO[1] | Timothy J. Ellender MD[1] | Tyler M. Stepsis MD[1] | Edward A. Bartkus MD[1] | Paul Garverick II MD[2] | Dylan D. Cooper MD[1]

[1]Department of Emergency Medicine, Indiana University School of Medicine, Indianapolis, Indiana, USA

[2]Western Michigan University, Homer Stryker M.D. School of Medicine, Kalamazoo, Michigan, USA

Correspondence
Dylan D. Cooper, Department of Emergency Medicine, Indiana University School of Medicine, Indianapolis, IN 46202, USA.
Email: ddcooper@iu.edu

Abstract

Objectives: Cricothyrotomy is a high-stakes emergency procedure. Because the procedure is rare, simulation is often used to train residents. The Accreditation Council for Graduate Medical Education (ACGME) requires performance of three cricothyrotomies during residency, but the optimal number of training repetitions is unknown. Additional repetitions beyond three could increase proficiency, though it is unknown whether there is a threshold beyond which there is no benefit to additional repetition. The objective of this study was to establish a minimum number of simulated cricothyrotomy attempts beyond which additional attempts did not increase proficiency.

Methods: This was a prospective, observational study conducted over 3 years at the simulation center of an academic emergency medicine residency program. Participants were residents participating in a cricothyrotomy training as part of a longitudinal airway curriculum course. The primary outcome was time to successful completion of the procedure as first-year residents. Secondary outcomes included time to completion as second- and third-year residents. Procedure times were plotted as a function of attempt number. Data were analyzed using descriptive statistics, repeated-measures analysis of variance, and correlation analysis. Preprocedure surveys collected further data regarding procedure experience, confidence, and comfort.

Results: Sixty-nine first-year residents participated in the study. Steady improvement in time to completion was seen through the first six attempts (from a mean of 75 to 41 sec), after which no further significant improvement was found. Second- and third-year residents initially demonstrated slower performance than first-year residents but rapidly improved to surpass their first-year performance. Resident mean times at five attempts were faster with each year of residency (first-year 48 sec, second-year 30 sec, third-year 24 sec). There was no statistically significant correlation between confidence and time to complete the procedure.

Presented at the Council of Residency Directors in Emergency Medicine Academic Assembly, Las Vegas, NV, March 2023; and the Society for Academic Emergency Medicine Annual Meeting, Austin, TX, May 2023.

Supervising Editor: Esther Chen

Conclusions: Additional repetition beyond the ACGME-endorsed three cricothyrotomy attempts may help increase proficiency. Periodic retraining may be important to maintain skills.

INTRODUCTION

Cricothyrotomy is frequently listed among the most important potentially lifesaving procedures performed by emergency providers.[1] Though the "can't intubate, can't ventilate" scenario that may warrant cricothyrotomy remains a possibility within emergency medicine (EM), new advances in airway management equipment and techniques have resulted in decreased incidence of an otherwise already infrequent procedure.[2–4] A recent retrospective review conducted within two university-based hospitals identified an average hospital-wide incidence of cricothyrotomy over an 11-year period to be 2.3 per 1000 tracheal intubations. Of those performed, most occurred within the emergency department.[5]

Because the procedure is rare, simulation is often used to train residents to increase competency and comfort with this lifesaving procedure.[6] Specifically in EM, simulation-based procedural training provides an opportunity for learners to develop and demonstrate mastery.[7,8] The effectiveness of simulation-based procedural training can be enhanced through deliberate practice, whereby the learner performs goal-oriented, repetitive practice under direct supervision.[9] A recent study found improved cricothyrotomy performance time with deliberate practice and mastery learning.[10]

The ACGME requires performance of three cricothyrotomies during EM residency training.[11,12] However, the number of procedures reported by residents is not directly related to competence.[13] Several surrogates for competency have been utilized including performance speed. Previous studies have used time-based proficiency performing cricothyrotomy using percutaneous kits performed by anesthesiologists or intensive care trainees.[14,15] Both found that, after five procedures, there was no further significant improvement in time to performance of a successful airway intervention. A more recent study again involving anesthesiologists measured time to gain and maintain proficiency with transtracheal jet ventilation, bougie cricothyrotomy, and percutaneous cricothyrotomy, showing that intentional focused training and practice can improve skill performance to 100% from less than 20% and retain up to 80% at 15 months.[16] However, there is very little evidence for EM resident training in this sphere, despite the larger base of uncontrolled airway scenarios and higher potential for cricothyroidotomy.

Our study was a prospective observational study among EM residents with an objective of establishing a minimum number of cricothyrotomy attempts beyond which additional attempts did not increase proficiency. We hypothesized that repetitions beyond three would increase proficiency as measured by time to complete the procedure.

METHODS

Study setting and participants

The study was conducted during three consecutive EM resident airway labs held annually in July from 2020 to 2022 at the simulation center. All EM residents in attendance were eligible to participate in the study. Those who chose to participate provided written consent and completed a survey on demographics, prior experience, and perceived confidence and comfort with the procedure. (Data S1) The survey was developed by expert airway faculty and based off a prior published intubation study survey and was administered to all participating residents.[17]

The cricothyrotomy training was one of four procedure stations and utilized a 3D-printed trainer (SIMS Solutions) with simulated skin. Residents were provided with a scalpel, gum-elastic bougie, 6.5 cuffed endotracheal tube (ETT), and 10-mL syringe. First-year EM residents (R1) were then provided instructions on cricothyrotomy in groups of 6 residents with one to two faculty. The faculty demonstrated the procedure, followed by coaching each resident through one successful untimed practice procedure with individual feedback. The same faculty member who is board-certified in EM and critical care medicine taught cricothyrotomy each year of the study. Procedural steps included (1) identification of landmarks with nondominant hand, (2) incision of skin, (3) identification and incision of cricoid membrane, (4) insertion of bougie, (5) advancement of ETT over bougie, (6) removal of bougie, and (7) inflation of ETT balloon. Successful placement was confirmed through direct visualization of the 3D-printed model. Each resident then completed multiple attempts under direct faculty observation with faculty feedback following. Second- and third-year residents (R2, R3) were not provided the initial faculty demonstration or initial guided practice procedure but did receive faculty feedback following each attempt. These residents had previously completed the initial cricothyrotomy training as R1s.

Study protocol

During the annual airway session, residents were each allowed to complete as many cricothyrotomy attempts as they chose within a 30-min period. An EM faculty member directly observed each cricothyrotomy and provided feedback on performance immediately following. The other trainees in each session were present during feedback. Each cricothyrotomy attempt was defined as initial skin incision through ETT cuff inflation. Attempts were timed through video review (2020) or in person (2021–2022) by the faculty member who observed and provided feedback and volunteer study personnel. Each resident was identified by a four-digit code to track performance through all 3 years of training. Survey and timing data were transferred to an electronic spreadsheet by volunteer study personnel.

Data analysis

Statistical analysis was performed using SAS software (Version 9.4). The primary outcome of interest was the mean time to perform cricothyrotomy, which was compared between each attempt with repeated-measures analysis of variance (ANOVA) testing. We utilized Pearson correlation to compare times of initial cricothyrotomy attempt based on self-reported survey responses for prior experience, confidence, and comfort. The study was deemed exempt by the institutional review board at a large Midwestern medical school.

RESULTS

This study included a total of 69 R1 participants over 3 consecutive years (2020, 2021, and 2022; Table 1). We first analyzed all R1s together, which included 23 residents from each of the three classes. The R1 group had a mean time to completion of 75 sec for their initial attempt. Steady improvement in time to completion was seen through the first six attempts. After the sixth attempt, the mean time to completion then remained at 41 sec for Attempts 7–9. Mean times for each attempt are displayed in Table 2. Although included in the table, mean times for Attempts 10–12 were limited by the small number of resident participants. Repeated-measures ANOVA was performed to compare the effect of attempt number on time to complete cricothyrotomy, demonstrating a statistically significant difference in procedure completion time between at least two attempt groups ($F(11,225)=11.43$, $p<0.0001$). Significant post hoc pairwise comparisons between specific individual attempts are included in Table 2.

Preprocedure survey results demonstrated that our R1s had previously performed an average of 1.5 cricothyrotomies, which may have included cricothyrotomies performed in simulation, on cadavers, or in the clinical setting. R1s self-reported an average confidence level of 1.7 (range 0 [least] to 10 [most]) and comfort level of 1.3 (range 0 [least] to 10 [most]). Although correlation analysis suggested a possible weak inverse relationship between the time to complete Attempt 1 and R1 prior experience ($r=-0.22$, $p=0.07$), confidence ($r=-0.20$, $p=0.11$), and comfort ($r=-0.14$, $p=0.27$), none of these findings reached statistical significance.

Next, we compared the three R1 classes of resident participants (i.e., 2020 R1s vs. 2021 R1s vs. 2022 R1s). R1s in 2020 reported significantly higher numbers of prior cricothyrotomy experience than the 2021 and 2022 R1s (2.7 vs. 0.6 vs. 1.2, $p=0.04$) as well as greater levels of confidence (2.7 vs. 1.2 vs. 1.2, $p<0.01$) and comfort (1.9 vs. 1.1 vs. 0.8, $p=0.06$). Mean R1 attempt times, stratified by class year, are shown below in Table 3. We were only able to include the first four attempts due to limited numbers of continued attempts performed by participants in 2021 and 2022. Repeated-measures ANOVA was performed to compare the effect of attempt number on time to complete cricothyrotomy, with the between-groups factor of R1 class year. There was a statistically significant difference in completion time between at least two attempts across all classes ($F(3,49.3)=13.36$, $p<0.0001$). The interaction term between participant class year and attempt time was also significant ($F(6,57.7)=2.66$, $p=0.02$), with 2021 R1 participants having significantly slower completion times than other years.

As a subgroup analysis, we also examined a group of participants longitudinally across the 3 years (i.e., as R1 residents in 2020 vs. as R2s in 2021 vs. as R3s in 2022). The number of residents from this group who participated declined in each subsequent year, starting with $n=23$ in 2020, then $n=12$ in 2021, and only $n=7$ in 2022. Reported prior cricothyrotomy experience (2.7 vs. 12.5 vs. 17.3, $p<0.01$), confidence level (2.7 vs. 4.8 vs. 6.5, $p<0.01$), and comfort level (1.9 vs. 4.4 vs. 6.0, $p<0.01$) all increased significantly in this group with each year. In general, resident attempt times were faster with each additional year of experience (Table 4). However, the initial first attempts as R2s in 2021 were slower than their associated R1 times. This trend was no longer present in 2022, as R3s recorded the fastest times overall. Repeated-measures ANOVA was performed to compare the effect of attempt number on time to complete cricothyrotomy, with the between-groups factor of class year (2020 R1s vs. 2021 R2s vs. 2022 R3s). There was a statistically significant difference in completion time between at least two attempts across all class years ($F(6,29.4)=9.39$, $p<0.0001$). However, the interaction term between participant class year and attempt time was not significant ($F(12,41.3)=1.56$, $p=0.14$).

Finally, we then collated participants across all years to compare all R1s ($n=69$ participants across 3 years) versus all R2s ($n=21$ participants across 2 years) versus all R3s ($n=7$ participants across 1 year). With each additional year of residency, there was a significant increase in reported cricothyrotomy experience (1.5 vs. 11 vs. 17.3, $p<0.01$), confidence level (1.7 vs. 5.1 vs. 6.5, $p<0.01$), and comfort level (1.3 vs. 4.4 vs. 6.0, $p<0.01$). Resident mean attempt times were consistently faster with each additional year of experience, displayed below in Table 5, as well as graphically in Figure 1,

TABLE 1 Resident demographics.

Year	Total interns	Male	Female	Total second-year residents	Total third-year residents
2020	23	12	11	N/A	N/A
2021	23	13	10	12	N/A
2022	23	14	9	9	7

TABLE 2 Mean attempt times (sec) with repeated-measures ANOVA comparing the effect of attempt number on time to complete cricothyrotomy for combined R1 participants.

	Attempt											
	1	2	3	4	5	6	7	8	9	10	11	12
Time (sec), mean ± SD	75 ± 31	61 ± 27	51 ± 18	49 ± 19	48 ± 16	41 ± 9	41 ± 11	41 ± 11	41 ± 9	35 ± 7	35 ± 8	29 ± 0
N	69	58	43	34	25	20	20	17	14	5	3	1
p-value for time*	<0.0001											

Abbreviation: ANOVA, analysis of variance.

*Represents the effect of time across all 12 attempts; $p < 0.0001$ indicates that at least two of the 12 attempts were significantly different. Significant post-hoc pairwise comparisons at $p = 0.05$ using a Bonferroni adjustment between the following: attempts 1&2, 1&3, 1&4, 1&5, 1&6, 1&7, 1&8, 1&9, 1&10, 2&6, 2&7, 2&8, 2&9.

TABLE 3 Mean attempt times (seconds) with repeated measures ANOVA comparing the effect of attempt number on time to complete cricothyrotomy, with the between-groups factor of participant class year (2020 R1s vs. 2021 R1s vs. 2022 R1s).

	Attempt #			
Participant year	**1**	**2**	**3**	**4**
2020 R1s	71 ± 26 s *N* = 23	58 ± 19 s *N* = 23	55 ± 18 s *N* = 23	52 ± 15 s *N* = 23
2021 R1s	92 ± 30s *N* = 23	89 ± 38 s *N* = 12	55 ± 9 s *N* = 5	80 ± 43 s *N* = 2
2022 R1s	63 ± 31 s *N* = 23	49 ± 15 s *N* = 23	44 ± 19 s *N* = 15	36 ± 15 s *N* = 9
p-Value for time*	<0.0001			
p-Value for year × time interaction**	*p* = 0.02			

Abbreviation: ANOVA, analysis of variance.

*Represents the effect of time across all 3 participant years. **Represents the change in magnitude across the 4 attempts based on participant year. Significant post hoc pairwise comparisons at $p = 0.05$ using a Bonferroni adjustment between the following: Attempts 1 and 3, 1 and 4, and 2 and 3; interaction of year × time 2020 versus 2021—Attempt 2, 2021 versus 2022—Attempt 2, 2021 versus 2022—Attempt 4.

TABLE 4 Mean attempt times (sec) with repeated-measures ANOVA comparing the effect of attempt number on time to complete cricothyrotomy, with the between-groups factor of participant class year (2020 R1s vs. 2021 R2s vs. 2022 R3s).

	Attempt						
Participant year	**1**	**2**	**3**	**4**	**5**	**6**	**7**
2020 R1s	71 ± 26 *n* = 23	58 ± 19 *n* = 23	55 ± 18 *n* = 23	52 ± 15 *n* = 23	49 ± 16 *n* = 23	41 ± 9 *n* = 20	41 ± 11 *n* = 20
2021 R2s	96 ± 45 *n* = 12	77 ± 43 *n* = 12	60 ± 37 *n* = 12	55 ± 28 *n* = 11	38 ± 17 *n* = 8	31 *n* = 1	22 *n* = 1
2022 R3s	44 ± 12 *n* = 7	41 ± 16 *n* = 7	29 ± 8 *n* = 7	25 ± 10 *n* = 7	24 ± 7 *n* = 6	33 ± 17 *n* = 2	17 *n* = 1
p-Value for time*	<0.0001						
p-Value for year × time interaction**	*p* = 0.14						

Abbreviation: ANOVA, analysis of variance.

*Represents the effect of time across all 3 participant years. **Represents the change in magnitude across the seven attempts based on participant year. Significant post hoc pairwise comparisons at $p = 0.05$ using a Bonferroni adjustment between the following: Attempts 1 and 3, 1 and 4, 1 and 5, 1 and 6, 1 and 7, 2 and 4, 2 and 5, 2 and 6, and 2 and 7.

with R3s also appearing to more quickly reach a level after which no additional improvement with subsequent attempt was found. Repeated-measures ANOVA was again performed to compare the effect of attempt number on time to complete cricothyrotomy, with the between-groups factor of class year (all R1s vs. all R2s vs. all R3s). There was a statistically significant difference in completion time

TABLE 5 Mean attempt times (sec) with repeated-measures ANOVA comparing the effect of attempt number on time to complete cricothyrotomy, with the between-groups factor of participant class year (all R1s vs. all R2s vs. all R3s).

Participant year	Attempt 1	2	3	4	5	6	7
All R1s	75 ± 31 n = 69	61 ± 27 n = 58	51 ± 18 n = 43	49 ± 19 n = 34	48 ± 16 n = 25	41 ± 9 n = 20	41 ± 11 n = 20
All R2s	72 ± 45 n = 21	57 ± 41 n = 21	48 ± 31 n = 21	40 ± 30 n = 17	30 ± 13 n = 17	21 ± 9 n = 5	16 ± 4 n = 4
All R3s	44 ± 12 n = 7	41 ± 16 n = 7	29 ± 8 n = 7	25 ± 10 n = 7	24 ± 7 n = 6	33 ± 17 n = 2	17 n = 1
p-value for time*	<0.0001						
p-value for year × time interaction**	*p* = 0.62						

Abbreviation: ANOVA, analysis of variance.

*Represents the effect of time across all 3 participant years. **Represents the change in magnitude across the seven attempts based on participant year. Significant post hoc pairwise comparisons at $p = 0.05$ using a Bonferroni adjustment between the following: Attempts 1 and 3, 1 and 4, 1 and 5, 1 and 6, 1 and 7, 2 and 4, 2 and 5, 2 and 6, and 2 and 7.

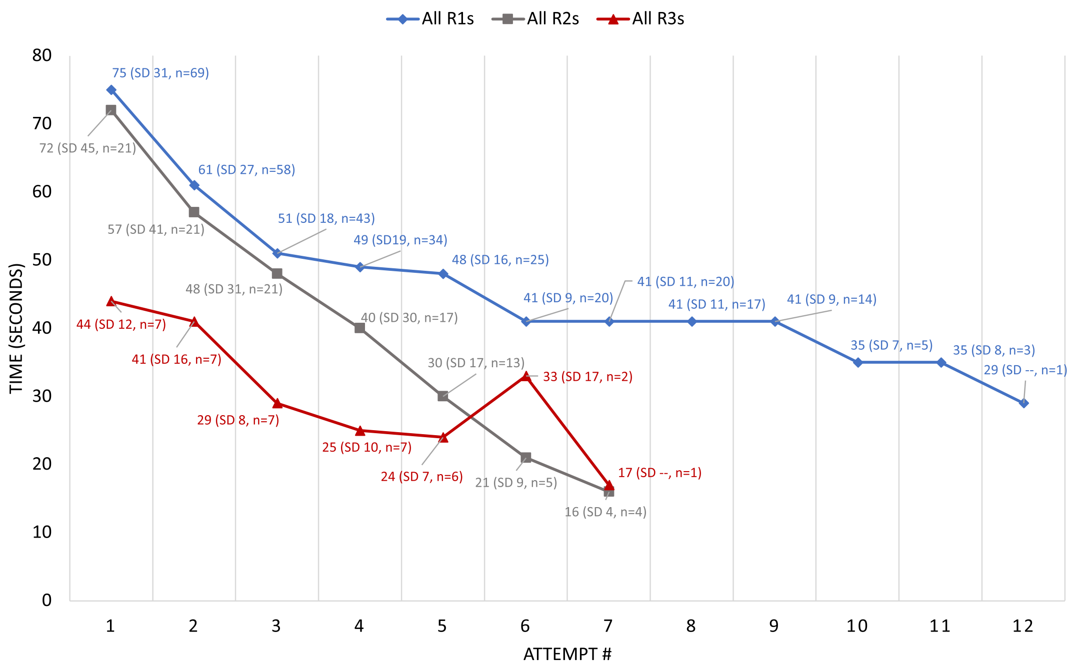

FIGURE 1 Mean time to completion for each attempt for all participants, stratified by resident class year.

between at least two attempts across all class years ($F(6,40.6) = 9.16$, $p < 0.0001$). However, the interaction term between participant class year and attempt time was not significant ($F(12\ 59.5) = 0.83$, $p = 0.62$).

DISCUSSION

Our study is the first, to our knowledge, to report EM resident performance on cricothyrotomy across multiple sequential attempts in a short time frame. Other studies that have attempted to quantify the number of attempts for cricothyrotomy proficiency enrolled intensive care unit physicians or anesthesiologists,[14–16] and with the exception of Clark et al.[16] they exclusively used a percutaneous technique as opposed to our open cricothyrotomy technique.[14,15]

Despite the differences in methodology and approach, our main results are similar to those of Shetty et al.[15] and Wong et al.[14] In our study resident time to completion improved through six attempts, after which no further significant improvement was found. Wong et al. reported improvement in procedure time through four attempts and overall success through five attempts. Subjects in the study by Shetty et al. were limited to five attempts and demonstrated statistically significant improvement through each of the five attempts. Clark et al.[16] used a mastery-based learning curriculum to train attending anesthesiologists in both percutaneous and open techniques, reporting increased speed with each attempt, though not providing average completion time by attempt number.

We chose time to procedure completion as our primary outcome because it is easy to measure with a high degree of accuracy and it has been used as an outcome of interest in multiple previous cricothyrotomy studies.[14,15,18–23] Several authors have noted this as an important outcome for this procedure given the clinical importance of time in the emergent situation in which the procedure is invariably performed.[15,19,22,24] Unlike some studies, we did not set a threshold time for successful performance because variability in model, technique, equipment used, and definition of time preclude direct comparisons from study to study. Similarly, variability in clinical status means that no single time is applicable to all real-life patients. Nevertheless, with a mean time of approximately 41 sec at attempt number six, completion times in our study were similar to that of multiple other studies[14,15,21] and below the maximum procedure times recommended by other authors.[19,24]

Unlike Wong and Shetty, our study measured retention 1 year after initial training. Some studies have shown a significant deterioration in resuscitative skills with time.[25–27] Boet et al.[23] measured retention of cricothyrotomy skills at 6 and 12 months following training and found that retention was similar at those two points in time and that skills were superior to pretraining baseline. However, they did not report the relationship between immediate posttraining proficiency and retention proficiency. Hubert et al.[20] also showed similar skill retention at 12 months compared with 3 and 6 months posttraining. Importantly, for both Boet and Hubert their study subjects included only anesthesiologists and they used a percutaneous technique. It is unknown if this is generalizable to open cricothyrotomy among emergency physicians. Both studies also incorporated their training and testing into high-fidelity simulation cases rather than using our static model, which could affect retention. Clark et al.[16] all measured retention performance at 15 month and reported significantly longer completion times compared with fastest testing time. Finally, in a recent study Nielsen et al.[27] identified a statistically significant deterioration of skills at 6 months compared to 1 month posttraining, though this was done with medical students rather than residents.

While our study primarily addressed the correlation between number of previous cricothyrotomy attempts and proficiency, other elements of training are also important. Our study demonstrated effective training using a 3D-printed cricothyrotomy model. It is unknown whether different models or high-fidelity clinical scenarios would result in more effective training or better retention, but high-fidelity training has been successful in previous studies.[20,23] A more structured training paradigm using deliberate practice may also be beneficial as this has been demonstrated to be superior to traditional procedural training[9] and has been recommended for procedural training by experts in this domain.[8] Under such a paradigm, a competency-based assessment model could be used to ensure mastery rather than using an arbitrary number of attempts. Further research would be needed to assess time to completion as a sufficient outcome compared to a validated assessment tool.

Surprisingly our R2s who had undergone training and testing the prior year had a slower first attempt than R1s. This is likely because our R1s underwent testing after one practice attempt, whereas our R2s did not have a practice attempt. After this first attempt, our R2s improved more rapidly than our R1s. As R3s, the first attempt was faster than the R2 first attempt and final completion times were even faster than R2 attempts. This suggests that there may be some deterioration in skills after 1 year and intermittent practice is required, but that once a baseline skill is achieved, refresher training can quickly restore proficiency.

There was no significant correlation between resident confidence and actual performance in our study, although our results do suggest a possible weak inverse relationship with faster time to completion of initial attempt in those reporting higher levels of confidence. While other studies have reported increased confidence with increased experience,[6] the relationship between confidence and proficiency has not been widely measured.

LIMITATIONS

There are several limitations to our study. It was conducted at a single simulation center with residents from one program, and it is unknown how generalizable it is to other settings. Because the number of residents per class is fixed there was limited opportunity to alter the number of enrolled participants and consequently we did not perform a power calculation prior to our data collection. Further, we did not specify a minimum number of attempts that residents were required to perform, as this was left to their discretion, which limited statistical analysis of later attempts. Because our R1 session is mandatory while our R2 and R3 sessions are not, we lost many of our subjects for retention testing. Our limited data suggest that periodic retraining for retention purposes is beneficial, but additional research could help better quantify the number of attempts that are needed for periodic refresher training. Given that attendance was optional, it may be that those residents attending felt more or less confident about airway procedures compared to the class as a whole. Finally, it is unclear how simulated performance translates to actual clinical care of real patients.

CONCLUSIONS

Our study, which is the first of its kind to measure the effect of sequential repetition for cricothyrotomy training in emergency medicine residents, strongly suggests that greater than three procedure attempts during residency leads to improved proficiency. This strengthens existing anesthesia literature, which indicates the same thing. In view of this, it appears that the three attempts currently required for emergency medicine residents is not sufficient. A competency-based assessment model may be ideal, but at a minimum we recommend the Residency Review Committee for Emergency Medicine consider increasing this number when revising minimum number of procedure requirements. Further research pertaining to training modalities, such as deliberate practice, and retention is warranted. In the meantime, with the increasing prevalence of low-cost and high-quality cricothyrotomy models, emergency medicine residency programs should take steps to increase the number of procedure attempts residents perform throughout their training.

AUTHOR CONTRIBUTIONS

Study concept and design: Joseph S. Turner, Timothy J. Ellender, Tyler M. Stepsis, Edward A. Bartkus, Paul Garverick II, Dylan D. Cooper. Acquisition of the data: Andrew C. Hybarger, Timothy J. Ellender, Paul Garverick II, Dylan D. Cooper. Analysis and interpretation of the data: Joseph S. Turner, Lauren K. Stewart, Andrew C. Hybarger, Paul Garverick II, Dylan D. Cooper. Drafting of the manuscript: Joseph S. Turner, Lauren K. Stewart, Andrew C. Hybarger, Timothy J. Ellender, Tyler M. Stepsis, Edward A. Bartkus, Paul Garverick II, Dylan D. Cooper. Critical revision of the manuscript for important intellectual content: Joseph S. Turner, Lauren K. Stewart, Dylan D. Cooper.

ACKNOWLEDGMENTS

The authors acknowledge the following volunteer study personnel who facilitated data collection and entry: Eric Chen and Alexandra LaShell. In addition, we thank The Simulation Center at Fairbanks Hall for space and equipment as well as the following staff for facilitating the study: Chassity Mays, Ryan Stambro, and Rachell Laughlin.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

ORCID

Joseph S. Turner https://orcid.org/0000-0001-6791-4489
Dylan D. Cooper https://orcid.org/0000-0001-7008-2046

REFERENCES

1. Falcon-Chevere JL, Mercado J, Mathew D, Uzcategui-Corder M, Almodovar A, Richards E. Critical trauma skills and procedures in the emergency department. *Emerg Med Clin North Am*. 2013;31:291-334.
2. Apfelbaum JL, Hagberg CA, Caplan RA, et al. Practice guidelines for management of the difficult airway: an updated report by the American Society of Anesthesiologists Task Force on Management of the Difficult Airway. *Anesthesiology*. 2013;118:251-270.
3. Asai T. Surgical cricothyrotomy, rather than percutaneous cricothyrotomy, in "cannot intubate, cannot oxygenate" situation. *Anesthesiology*. 2016;125:269-271.
4. Chang RS, Hamilton RJ, Carter WA. Declining rate of cricothyrotomy in trauma patients with an emergency medicine residency: implications for skills training. *Acad Emerg Med*. 1998;5:247-251.
5. Kwon YS, Lee CA, Park S, Ha SO, Sim YS, Baek MS. Incidence and outcomes of cricothyrotomy in the "cannot intubate, cannot oxygenate" situation. *Medicine (Baltimore)*. 2019;98:e17713.
6. Makowski AL. A survey of graduating emergency medicine residents' experience with cricothyrotomy. *West J Emerg Med*. 2013;14:654-661.
7. Cassara M, Schertzer K, Falk MJ, et al. Applying educational theory and best practices to solve common challenges of simulation-based procedural training in emergency medicine. *AEM Educ Train*. 2020;4:S22-S39.
8. Quinn A, Falvo L, Ford T, Kennedy S, Kaminsky J, Messman A. Curated collections for educators: six key papers on teaching procedural skills. *AEM Educ Train*. 2021;5:e10692.
9. McGaghie WC, Issenberg SB, Cohen ER, Barsuk JH, Wayne DB. Does simulation-based medical education with deliberate practice yield better results than traditional clinical education? A meta-analytic comparative review of the evidence. *Acad Med*. 2011;86:706-711.
10. Petrosoniak A, Sherbino J, Beardsley T, et al. Are we talking about practice? A randomized study comparing simulation-based deliberate practice and mastery learning to self-guided practice. *CJEM*. 2023;25:667-675.
11. Review Committee for Emergency Medicine. Emergency Medicine Defined Key Index Procedure Minimums. Accreditation Council for Graduate Emergency Medicine (ACGME). 2017.
12. NEJM Knowledge+ Team. Exploring the ACGME Core Competencies: Patient Care and Procedural Skills (Part 3 of 7). NEJM Knowledge+; 2016.
13. Barsuk JH, Cohen ER, Feinglass J, McGaghie WC, Wayne DB. Residents' procedural experience does not ensure competence: a research synthesis. *J Grad Med Educ*. 2017;9:201-208.
14. Wong DT, Prabhu AJ, Coloma M, Imasogie N, Chung FF. What is the minimum training required for successful cricothyroidotomy? A study in mannequins. *Anesthesiology*. 2003;98:349-353.
15. Shetty K, Nayyar V, Stachowski E, Byth K. Training for cricothyroidotomy. *Anaesth Intensive Care*. 2013;41:623-630.
16. Clark CA, Mester RA, Redding AT, et al. Emergency subglottic airway training and assessment of skills retention of attending anesthesiologists with simulation mastery-based learning. *Anesth Analg*. 2022;135:143-151.
17. Turner JS, Ellender TJ, Okonkwo ER, et al. Cross-over study of novice intubators performing endotracheal intubation in an upright versus supine position. *Intern Emerg Med*. 2017;12:513-518.
18. Siu LW, Boet S, Borges BC, et al. High-fidelity simulation demonstrates the influence of anesthesiologists' age and years from residency on emergency cricothyroidotomy skills. *Anesth Analg*. 2010;111:955-960.
19. Heymans F, Feigl G, Graber S, Courvoisier DS, Weber KM, Dulguerov P. Emergency cricothyrotomy performed by surgical airway-naive medical personnel: a randomized crossover study in cadavers comparing three commonly used techniques. *Anesthesiology*. 2016;125:295-303.
20. Hubert V, Duwat A, Deransy R, Mahjoub Y, Dupont H. Effect of simulation training on compliance with difficult airway management algorithms, technical ability, and skills retention for emergency cricothyrotomy. *Anesthesiology*. 2014;120:999-1008.
21. Muller KL, Facciolla CA, Monti J, Cronin A. Impact of succinct training on open cricothyrotomy performance: a randomized, prospective, observational study of U.S. Army first responders. *Mil Med*. 2020;185:e1779-e1786.
22. Wray A, Khan F, Ray J, et al. Comparison of the bleeding cricothyrotomy model to SimMan for training students and residents emergency cricothyrotomy. *J Adv Med Educ Prof*. 2019;7:144-148.
23. Boet S, Borges BC, Naik VN, et al. Complex procedural skills are retained for a minimum of 1 yr after a single high-fidelity simulation training session. *Br J Anaesth*. 2011;107:533-539.
24. Hock SM, Martin JJ, Stanfield SC, Alcorn TR, Binstadt ES. Novel cricothyrotomy assessment tool for attending physicians: a multicenter study of an error avoidance checklist. *AEM Educ Train*. 2021;5:e10687.
25. Borovnik Lesjak V, Sorgo A, Strnad M. Retention of knowledge and skills after a basic life support course for schoolchildren: a prospective study. *Inquiry*. 2022;59:469580221098755.
26. Semeraro F, Signore L, Cerchiari EL. Retention of CPR performance in anaesthetists. *Resuscitation*. 2006;68:101-108.

27. Nielsen MS, Raben-Levetzau FN, Andersen SAW, Wennervaldt K, Konge L, Nielsen AB. Retention of emergency cricothyroidotomy skills: a multicenter randomized controlled trial. *AEM Educ Train*. 2023;7:e10900.

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Turner JS, Stewart LK, Hybarger AC, et al. An investigation into emergency medicine resident cricothyrotomy competency: Is three the magic number? *AEM Educ Train*. 2023;7:e10917. doi:10.1002/aet2.10917