Anesthesiology 2003; 98:349–53

What Is the Minimum Training Required for Successful Cricothyroidotomy?

A Study in Mannequins

David T. Wong, M.D., Atul J. Prabhu, F.R.C.A.,† Margarita Coloma, M.D.,‡ Ngozi Imasogie, F.R.C.A.,† Frances F. Chung, F.R.C.P.C.§*

Background: **A correctly performed cricothyroidotomy may be lifesaving in a cannot-ventilate, cannot-intubate situation. However, many practicing anesthesiologists do not have experience with cricothyroidotomy. The purpose of this study was to determine the minimum training required to perform cricothyroidotomy in 40 s or less in mannequins.**

Methods: **After informed consent, participants were shown a demonstration video and asked to perform 10 consecutive cricothyroidotomy procedures on a mannequin using a preassembled percutaneous dilational cricothyroidotomy set. Each attempt was timed from skin palpation to lung insufflation. Cricothyroidotomy was considered successful if it was performed in 40 s or less, and the cricothyroidotomy time was considered to have plateaued when there were no significant reductions in cricothyroidotomy times in three consecutive attempts.**

Results: **One hundred two anesthesiologists participated in the study. There was a significant reduction of cricothyroidotomy times over the 10 attempts ($P < 0.0001$) and between three consecutive attempts until the fourth attempt ($P < 0.03$). The cricothyroidotomy times plateaued by the fourth attempt, while the success rate plateaued at the fifth attempt (94, 96, 96, and 96% at the fourth, fifth, sixth, and seventh attempts, respectively).**

Conclusion: **Practice on mannequins leads to reductions in cricothyroidotomy times and improvement in success rates. By the fifth attempt, 96% of participants were able to successfully perform the cricothyroidotomy in 40 s or less. While clinical correlates are not known, the authors recommend that providers of emergency airway management be trained on mannequins for at least five attempts or until their cricothyroidotomy time is 40 s or less. The most appropriate retraining intervals have yet to be determined for optimal cricothyroidotomy skill retention.**

CORRECTLY performed cricothyroidotomy may be lifesaving in a cannot-ventilate, cannot-intubate situation.[1] However, emergent cricothyroidotomy is performed infrequently and can be difficult because of the lack of training and skill retention.[2,3] Thus, many physicians might not possess the necessary skills to perform a cricothyroidotomy correctly or expediently.

Recent advancement in residency training programs and improvements in airway management of patients with potential spine injuries have resulted in a decrease in the number of emergency cricothyroidotomy.[4,5] Given the rarity of this procedure, it is likely that many anesthesiologists will not acquire clinical experience with this technique during training[5] or may no longer have the skills to perform this procedure.[2] In light of this situation, many different techniques of cricothyroidotomy have been developed to simplify the procedure and increase retention.[2,6,7]

During the past 15 yr, there has been increasing interest in newer technologies to enhance the education and training of medical personnel.[8,9] However, individual and institutional learning process are complex and depend on a variety of factors, such as institutional preferences, the learning and teaching situation, and the number of cases over time.[10–12] To develop a rational training program for a new procedure, the necessary number of cases per procedure should be determined to achieve an optimal rate of success.[10–12] Few studies have investigated this topic in anesthesia. To date, no prospective study has established the minimum number of cricothyroidotomies required to be performed to acquire enough skills to achieve them in 40 s or less.

The purpose of this study was to determine the minimum number of training cricothyroidotomy attempts required to perform the procedure in 40 s or less in mannequins and also to determine the effect of training on cricothyroidotomy success rate and cricothyroidotomy times.

This article is featured in "This Month in Anesthesiology." Please see this issue of ANESTHESIOLOGY, page 5A.

Materials and Methods

The study was approved by the University Health Network Research Ethics Board (University of Toronto, Toronto, Ontario, Canada). Written informed consent was obtained from participants. They included staff anesthesiologists, fellows, and residents from the Department of Anesthesiology, University of Toronto. The participants' ages, years of practice, and previous cricothyroidotomy experience were recorded.

The participants were shown the steps of the procedure in a 3-min demonstration video (Cook Inc., Bloomington, IN) on the Seldinger technique cricothyrotomy

* Assistant Professor, † Clinical Fellow, ‡ Clinical Research Fellow, § Professor.

Received from the Department of Anesthesiology, Toronto Western Hospital, University of Toronto, Toronto, Ontario, Canada. Submitted for publication June 3, 2002. Accepted for publication October 7, 2002. Supported by the Department of Anesthesiology, Toronto Western Hospital, University of Toronto, Toronto, Ontario, Canada. Presented in part at the meeting of the Society for Ambulatory Anesthesia, Orlando, Florida, May 4, 2002.

Address reprint requests to Dr. Wong: Department of Anesthesiology, Toronto Western Hospital, University of Toronto, 399 Bathurst Street, EC 2-046, Toronto, Ontario M5T 2S8, Canada. Address electronic mail to: david.wong@uhn.on.ca. Individual article reprints may be purchased through the Journal Web site, www.anesthesiology.org.

Table 1. Participants' Demographics

Category	n (%)
Status	
Staff	62 (61)
Fellow	19 (18)
Resident	21 (21)
Age, yr	
25–34	33 (32)
35–44	37 (36)
45–54	17 (17)
≥55	15 (15)
Years in practice	
0–4	39 (38)
5–9	20 (20)
10–19	25 (24)
≥20	18 (18)
Previous cricothyroidotomy experience	
Mannequin	42 (41)
Patient	10 (10)
None	50 (49)

and were allowed to ask questions. The instrument used to perform cricothyroidotomy was a preassembled Melker emergency percutaneous dilational set (C-TCCS-400; Cook Inc.) that consisted of a needle, a syringe, a guide wire, a scalpel, a dilator, and an airway. According to the Seldinger technique, after the location of the cricothyroid membrane, it was punctured with an 18-gauge needle, and air was aspirated into an empty syringe. The 0.38-in guide wire was inserted *via* the needle into the airway. The needle was removed over the wire, the puncture site was enlarged by a stab with a No. 15 scalpel blade, and the uncuffed tracheostomy tube (4 mm ID) with the dilator (12-French) was inserted into the trachea over the wire. The dilator and the wire were removed from the tracheostomy tube, ventilation was performed, and placement was evaluated.[7]

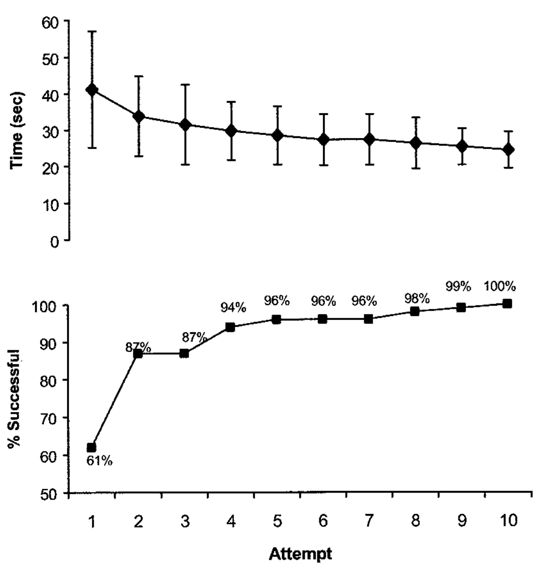

Fig. 1. (*Top*) Cricothyroidotomy times (mean ± SD; s) over the 10 attempts. (*Bottom*) Percentage of participants successful at thresholds of 40 s or less over the 10 attempts.

Participants then performed 10 consecutive cricothyroidotomies on a standard cricothyroidotomy mannequin with an anatomically correct airway that can be manipulated and intubated (Nasco, Fort Atkinson, WI). All attempts were timed with a stopwatch and recorded by a research assistant from the start of skin palpation to tracheal insufflation. The procedure was considered successful if the cricothyroidotomy airway was correctly placed in the trachea and was performed in 40 s or less. This arbitrary 40-s threshold was determined by consensus of the investigators after a review of the literature[2,3,7,13] and our own pilot study data.[14] The cricothyroidotomy times ranged from 40 ± 12 to 103 ± 62 s in the literature.[3,13] The pilot study investigated cricothyroidotomy times of 34 subjects on mannequins and the plateau effect.[14] A 40-s threshold was utilized for determining cricothyroidotomy success.[14] The cricothyroidotomy time was considered to have plateaued when there were no significant reductions in cricothyroidotomy time in three consecutive attempts by analysis of variance. The cricothyroidotomy success rate was considered to have plateaued when there were no significant changes in success rates in three consecutive attempts by 3 × 2 chi-square analysis.

Data were analyzed by four different categories: status (staff, resident, or fellow); age (25–34, 35–44, 45–54, or ≥55 yr); practitioner's years of practice 0–4; 5–9; 10–19; ≥20 yr); and previous cricothyroidotomy experience (with a mannequin, in a patient, or none).

Statistical Analysis

Data were analyzed by using the Number Cruncher Statistical System, version 6.0 (NCSS, Kaysville, UT). Continuous data were analyzed by using repeated-measures analysis of variance and the Student *t* test. Categorical variables were analyzed using chi-square analysis. Data were presented as mean value ± SD, numbers or percentages, with *P* values less than 0.05 considered statistically significant.

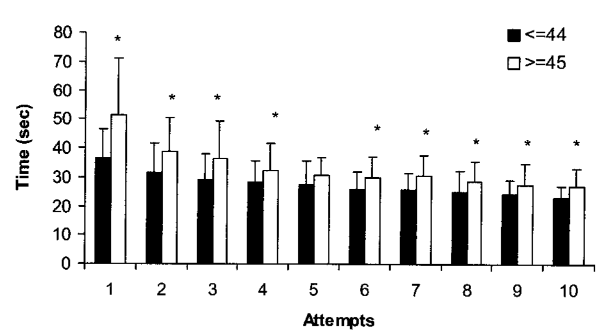

Fig. 2. Cricothyroidotomy times (mean ± SD; s) over the 10 attempts for the two age groups: participants aged 45 yr or older (white box) *versus* 44 yr or younger (black box). *$P < 0.05$ between the two age groups.

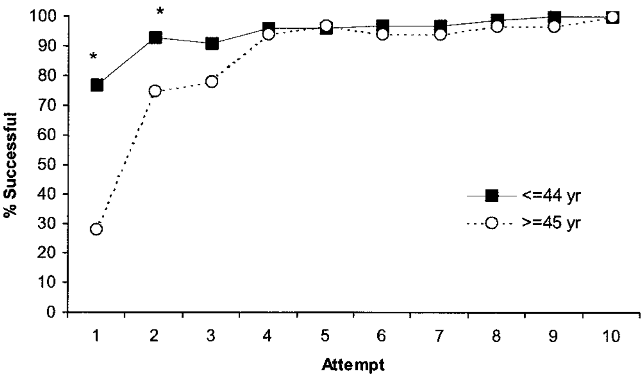

Fig. 3. Percentage of participants successful at thresholds of 40 s or less over the 10 attempts for the two age groups: participants aged 45 yr or older (white circle) *versus* 44 yr or younger (black box). *$P < 0.05$ between the two age groups for the first and second attempts.

Table 2. Cricothyroidotomy Times (Mean ± SD in s) for the First (T1) to the Tenth (T10) Attempt according to the Number of Years in Practice

	Number of Years in Practice			
Attempt	0–4 n = 39	5–9 n = 20	10–19 n = 25	≥20 n = 18
T1	37 ± 11	35 ± 7	42 ±12	55 ± 25*†‡
T2	31 ± 10	33 ± 11	34 ± 10	41 ± 14*
T3	28 ± 6	29 ± 13	32 ± 10	40 ± 14*†
T4	28 ± 7	28 ± 7	31 ± 6	34 ± 10*†
T5	28 ± 9	27 ± 9	28 ± 5	32 ± 7†
T6	26 ± 5	25 ± 7	28 ± 8	30 ± 6*†‡
T7	26 ± 7	24 ± 5	28 ± 6	33 ± 8*†‡
T8	26 ± 9	24 ± 5	26 ± 5	31 ± 7*†‡
T9	24 ± 5	24 ± 4	24 ± 5	30 ± 7*†‡
T10	23 ± 4	23 ± 5	24 ± 4	29 ± 4*†‡

*$P < 0.05$ *versus* 0–4 yr in practice group. †$P < 0.05$ *versus* 5–9 yr in practice group. ‡$P < 0.05$ *versus* 10–19 yr in practice group.

Results

A total of 102 anesthesiologists or anesthesiology trainees participated in the study. The demographic characteristics are shown in table 1. There was a significant difference in cricothyroidotomy times among the 10 attempts (1st to 10th) according to analysis of variance ($P < 0.0001$; fig. 1, top). When comparing among three consecutive attempts, there were differences among first to third and second to fourth attempts but not among other attempts. Based on our definition of plateauing, if there were no differences in cricothyroidotomy times in three consecutive attempts, cricothyroidotomy times had plateaued after the fourth attempt.

There was a significant difference in success rate among the 10 attempts (1st to 10th) according to 10 × 2 chi-square analysis ($P < 0.0001$; fig. 1, bottom). When comparing success rates among three consecutive attempts, there were differences among first to third and third to fifth attempts but not among other attempts. Based on our definition of plateauing, if there were no differences in success rates in three consecutive attempts, the success rate had plateaued after the fifth attempt. By the fifth attempt, 96% of the participants were able to perform the cricothyroidotomy in 40 s or less. The cricothyroidotomy success rates were 94, 96, 96, and 96% at the fourth, fifth, sixth, and seventh attempts, respectively.

When cricothyroidotomy times were analyzed according to the participant's age, cricothyroidotomy times for the group of participants aged 45 yr or older were consistently longer than those for the group of participants aged 44 yr or younger throughout the 10 attempts, with one exception at the fifth attempt ($P = 0.06$; fig. 2). When percent success was compared between the group aged 44 yr or younger and the group aged 45 yr or older across the 10 attempts, the group aged 44 yr or younger achieved a significantly higher degree of success only during the first and second attempts compared to the group aged 45 yr or older. Further attempts did not show a significant difference (fig. 3).

When cricothyroidotomy times were analyzed according to the number of years of practice, there was no significant difference in the times achieved by the first three groups (0–4, 5–9, and 10–19 yr). However, the group with 20 yr of practice or more had consistently higher cricothyroidotomy times compared to the other three groups (table 2). Participants aged 45 yr or older with 20 yr of experience or more had consistently higher cricothyroidotomy times compared to their respective counterparts.

When cricothyroidotomy times and success rates were analyzed according to participants' previous experience (mannequin, patient, or none) or status (staff, resident, or fellow), there were no significant differences noted.

Discussion

This study demonstrates that cricothyroidotomy times plateaued by the fourth attempt, while success rates plateaued by the fifth attempt. By the fifth attempt, 96% of the participants were able to perform the cricothyroidotomy successfully in 40 s or less. Therefore, the minimum number of cricothyroidotomy procedures needed to obtain enough skills to perform the procedure in 40 s or less in a mannequin is five.

Effect of Training on Skill Acquisition

Cricothyroidotomy is a life saving skill in cannot-intubate, cannot-ventilate situations. However, improvements in airway management have reduced the incidence of emergency cricothyroidotomies.[2–5] Koppel *et al.*[15] found that although 80% of American anesthesiology residency training programs taught cricothyroidotomy, 60% consisted of lectures only, without any practical experience. Many physicians have never performed a cricothyroidotomy during their residency training or clinical practice.

To acquire proficiency in manual skills, such as epidural catheter insertion, instructions using video or life demonstrations and repeated practice are both important.[8–12] In our study, participants were trained initially by a demonstration video and verbal instructions and performed 10 consecutive practice cricothyroidotomies on mannequins. The learning curve for success rates shows a steep upstroke followed by a plateau of a success rate greater than 95% by the fifth attempt. There were no comparable studies to assess the effect of learning on cricothyroidotomy success rates in the literature. Konrad *et al.*[11] generated learning curves for first-year anesthesia residents learning to perform five procedures on patients. He found that 57 and 71 cases were required to achieve 90% success rates for tracheal intubation and spinal anesthesia, respectively. In contrast, 90 cases of epidural anesthesia were required before an 80% success rate was achieved. Kopacz *et al.*[10] reported that 45 spinal and 60 epidural anesthetics were required before 90% success rates were reached. We believe it is important to determine the minimum number of cricothyroidotomy practice that one must perform to achieve proficiency, and we found the answer to be five. The small number required for cricothyroidotomy proficiency may be related to the large caliber of the airway *versus* the cannulating device, the utilization of practicing anesthesiologists already familiar with the Seldinger technique, compression of the learning experience into a single time setting, and performance of skill in a nonlive, mannequin situation.

Effect of Previous Cricothyroidotomy Experience and Age on Cricothyroidotomy Performance

Fifty-one percent of our subjects had previous experience with cricothyroidotomy. It was not documented when and how many times the subjects had performed cricothyroidotomy. Our results showed that there were no differences in cricothyroidotomy times and success rates between those with and without prior cricothyroidotomy experience. We believe that proficiency in cricothyroidotomy performance requires repeated practice and a clear mental algorithm of the cricothyroidotomy steps, not just sporadic past experience.

The effect of age of the subjects and cricothyroidotomy performance was assessed. We found those who were younger (≤44 *vs.* ≥45 yr) and with fewer years in practice (≤19 *vs.* ≥20 yr) were substantially faster in performing cricothyroidotomy over the 10 attempts. Previous studies on cricothyroidotomy did not investigate the effect of age on performance.[2–7,13] Our findings were consistent with investigations that showed that acquisition of sensorimotor skill and cognitive skill were slower in older adults than in younger adults.[16,17] Although not measured scientifically, we observed that poor vision and hand tremor were present in a number of older subjects, thereby adversely affecting their cricothyroidotomy performance. Further studies are needed to investigate the effect of age in cricothyroidotomy performance.

Percutaneous versus *Surgical Cricothyroidotomy Techniques*

The original cricothyroidotomies were performed using an open surgical technique.[6,18–20] More recently, percutaneous dilational cricothyroidotomies were introduced, and a number of studies have compared the two techniques.[2,3,7,13] Eisenburger *et al.*[7] compared the performance of percutaneous and surgical single cricothyroidotomy attempts by intensive care trainees on cadavers. The cricothyroidotomy times were 100 and 102 s, respectively. The slow times may be explained by the lack of video instructions and inexperience of trainees. Chan *et al.*[2] did a similar comparative study for emergency attending physicians and residents. He also found similar times (75 *vs.* 73 s) for the percutaneous and surgical cricothyroidotomy groups. Bainton[3] assessed 23 physicians using the percutaneous cricothyroidotomy technique on dogs. All completed the cricothyroidotomy successfully with a mean time of 40 s. In our study, we elected to use a Melker percutaneous cricothyroidotomy kit. This kit was used in a manner analogous to the Seldinger technique for vascular cannulation, which may be advantageous for anesthesiologists in terms of familiarity and recall.[2,3] This cricothyroidotomy kit is preassembled and commercially available, while the surgical cricothyroidotomy set must be assembled. Many anesthesiologists are not familiar with the surgical cricothyroidotomy approach and equipment and may be more reluctant in resorting to it. As most studies have shown similar or better times for the percutaneous compared to the surgical technique, we felt justified in choosing to assess the percutaneous technique only.

Limitations

First, this study was performed on a mannequin model, not human subjects or cadavers. Human controlled trials are difficult to perform given the emergent nature and relative rarity of the procedure. We acknowledge that performance of cricothyroidotomy on mannequins is artificial and different from real-life situations. Manipulation of human tissue, threat of an emergency situation, and complications, such as bleeding and edema, are not replicated in a mannequin model. Human cadavers may offer more realistic simulation of live patients. However, logistic limitations and the vast number of attempts required for the study prevent us from using cadavers. We also acknowledge that performance of cricothyroidotomy in real-life situations may take longer compared to on mannequins. Therefore, the suggested minimum training of five attempts on mannequins would be considered a bare minimum. Second, although we have shown that training at a single time point on mannequins improved cricothyroidotomy times and success rates, as cricothyroidotomy is rarely performed in clinical medicine, we do not know what the optimal retraining interval is. A previous study had demonstrated that a 1-month retraining interval may be superior to a 3-month interval for maintenance of cricothyroidotomy skills.[14]

Conclusion

In conclusion, training on mannequins leads to improvements in cricothyroidotomy times and success rates. By the fifth attempt, 96% of participants were able to perform the cricothyroidotomy successfully in 40 s or less. We recommend that providers of emergency airway management be trained on mannequins for five attempts or until their cricothyroidotomy time is 40 s or less. The most appropriate retraining intervals have yet to be determined for optimal cricothyroidotomy skill retention.

References

1. Benumof JL: Airway Management Principles and Practice, 1st edition. St. Louis, Mosby-Year Book, 1996, pp 513–30
2. Chan TC, Vilke GM, Bramwell KJ, Davis DP, Hamilton RS, Rosen P: Comparison of wire-guided cricothyrotomy versus standard surgical cricothyrotomy technique. J Emerg Med 1999; 17:957–62
3. Bainton CR: Cricothyrotomy. Int Anesthesiol Clin 1994; 32:95–108
4. Erlandson MJ, Clinton JE, Ruiz E, Cohen J: Cricothyrotomy in the emergency department revisited. J Emerg Med 1989; 7:115–8
5. 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; 5:247–51
6. Brofeldt BT, Panacek EA, Richards JR: An easy cricothyrotomy approach: The rapid four-step technique. Acad Emerg Med 1996; 3:1060–3
7. Eisenburger P, Laczika K, List M, Wilfing A, Losert H, Hofbauer R, Burgmann H, Bankl H, Pikula B, Benumof JL, Frass M: Comparison of conventional surgical *versus* Seldinger technique emergency cricothyrotomy performed by inexperienced clinicians. Anesthesiology 2000; 92:687–90
8. Gaba DM: Two examples of how to evaluate the impact of new approaches to teaching (editorial). Anesthesiology 2002; 96:1–2
9. Birnbach DJ, Santos A, Bourlier R, Meadows W, Datta S, Stein D, Kuroda M, Thys D: The effectiveness of video technology as an adjunct to teach and evaluate epidural anesthesia performance skills. Anesthesiology 2002; 96:5–9
10. Kopacz D, Neal J, Pollock J: The regional anesthesia "learning curve": What is the minimum number of epidural and spinal blocks to reach consistency? Reg Anesth 1996; 21:182–90
11. Konrad C, Schupfer G, Wietlisbach M, Gerber H: Learning manual skills in anesthesiology: Is there a recommended number of cases for anesthetic procedures? Anesth Analg 1998; 86:635–9
12. Schuepfer G, Konrad C, Schmeck J, Poortmans G, Staffelbach B, Johr M: Generating a learning curve for pediatric caudal epidural blocks: An empirical evaluation of technical skills in novice and experienced anesthetists. Reg Anesth Pain Med 2000; 25:385–8
13. Johnson DR, Dunlap A, McFeeley P, Gaffney J, Busick B: Cricothyrotomy performed by prehospital personnel: A comparison of two techniques in a human cadaver model. Am J Emerg Med 1993; 11:207–9
14. Prabhu AJ, Correa R, Wong DT, McGuire G, Chung F: What is the optimal training interval for a cricothyroidotomy? Can J Anesth 2001; 48:A59
15. Koppel J, Reed A: Formal instruction in difficult airway management. Anesthesiology 1995; 83:1343–6
16. Bock O, Schneider W: Acquisition of a sensorimotor skill in younger and older adults. Acta Physiol Pharmacol Bulg 2001; 26:89–92
17. Touron DR, Hoyer WJ, Cerella J: Cognitive skill acquisition and transfer in younger and older adults. Psychol Aging 2001; 16:555–63
18. Holmes JF, Panacek EA, Sakles JC, Brofeldt BT: Comparison of 2 cricothyrotomy techniques: Standard method versus rapid 4-step technique. Ann Emerg Med 1998; 32:442–7
19. Davis D, Bramwell K: Cricothyrotomy technique: Standard versus the rapid four step technique (letter). J Emerg Med 1999; 17:1072–3
20. Davis DP, Bramwell KJ, Vilke GM, Cardall TY, Yoshida E, Rosen P: Cricothyrotomy technique: Standard versus the rapid four step technique. J Emerg Med 1999; 17:17–21