

# Effect of Simulation Training on Compliance with Difficult Airway Management Algorithms, Technical Ability, and Skills Retention for Emergency Cricothyrotomy

Vincent Hubert, M.D., Antoine Duwat, M.D., Romain Deransy, M.D., Yazine Mahjoub, M.D., Hervé Dupont, M.D., Ph.D.

## ABSTRACT

**Background:** The effectiveness of simulation is rarely evaluated. The aim of this study was to assess the impact of a short training course on the ability of anesthesiology residents to comply with current difficult airway management guidelines.

**Methods:** Twenty-seven third-year anesthesiology residents were assessed on a simulator in a “can’t intubate, can’t ventilate” scenario before the training (the pretest) and then randomly 3, 6, or 12 months after training (the posttest). The scenario was built so that the resident was prompted to perform a cricothyrotomy. Compliance with airway management guidelines and the cricothyrotomy’s duration and technical quality were assessed as a checklist score [0 to 10] and a global rating scale [7 to 35].

**Results:** After training, all 27 residents (100%) complied with the airway management guidelines, compared with 17 (63%) in the pretest ( $P < 0.005$ ). In the pretest and the 3-, 6-, and 12-month posttests, the median [range] duration of cricothyrotomy was respectively 117 s [70 to 184], 69 s [43 to 97], 52 s [43 to 76], and 62 s [43 to 74] ( $P < 0.0001$  vs. in the pretest), the median [range] checklist score was 3 [0 to 7], 10 [8 to 10], 9 [6 to 10], and 9 [4 to 10] ( $P < 0.0001$  vs. in the pretest) and the median [range] global rating scale was 12 [7 to 22], 30 [20 to 35], 33 [23 to 35], and 31 [18 to 33] ( $P < 0.0001$  vs. in the pretest). There were no significant differences between performance levels achieved in the 3-, 6-, and 12-month posttests.

**Conclusion:** The training session significantly improved the residents’ compliance with guidelines and their performance of cricothyrotomy. (**ANESTHESIOLOGY 2014; 120:999-1008**)

**D**ESPITE the publication and dissemination of guidelines and algorithms in France,<sup>1</sup> Europe,<sup>2</sup> and the United States,<sup>3</sup> complications of difficult airway management occur and can have serious consequences.<sup>4</sup> Airway management is essential for ensuring the safety of anesthetic practice in the operating theater,<sup>5</sup> in intensive care units<sup>6</sup> and in emergency departments.<sup>6-8</sup> A recent study showed that 6.2% of intubations in the operating theater are difficult.<sup>9</sup> Difficult intubation with difficult ventilation occurs in 1.5% of procedures, with impossible intubation and difficult ventilation in 0.3% of procedures, and a “can’t intubate, can’t ventilate” (CICV) situation in 0.07% of procedures.<sup>10</sup> In intensive care units, the difficult intubation rate is even higher (at approximately 11%)<sup>11,12</sup> and is associated with complications (including aspiration pneumonia, esophageal intubation, pneumothorax and dental injuries).<sup>6,11,13</sup> Similarly, a higher rate is reported in prehospital medical care—even when the provider is trained in

### What We Already Know about This Topic

- Introduction of simulation in medical field serves to improve and maintain technical as well as nontechnical skill
- High-fidelity simulation of cricothyrotomy increased its skill and maintained it for at least for 1 yr, but no study has examined possible effects on algorithm compliance or nontechnical skill

### What This Article Tells Us That Is New

- Using a prestudy–poststudy design with randomized follow-up, this study demonstrated cricothyrotomy high-fidelity simulation increases and serves to maintain compliance of difficult airway management algorithm during “cannot intubate cannot ventilate” scenarios in addition to retention of the improved skill for 1 yr in the third-year anesthesia residents

alternative intubation techniques.<sup>14</sup> Transtracheal oxygenation and cricothyrotomy are the final options in all CICV airway management algorithms.<sup>1-3</sup> These techniques are rarely performed by physicians but are of vital importance

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when needed.<sup>15</sup> Given that this procedure is performed in crisis situations, it is crucial to optimize teaching and training methods in this field. These complex procedural skills must be effectively assimilated and then retained for a long time; indeed, skills decay has been shown to be problematic in this context and degrades patient safety.<sup>16</sup> Retention of skills is poor only a few months after lectures, workshops, or courses.<sup>17</sup> Nevertheless, the 1-yr retention of complex, rarely performed, and urgent procedural skills in cricothyrotomy after a single session of simulation training has been recently described.<sup>18</sup> Simulation involves the use of simulators (notably in the aeronautics, aerospace, or nuclear power industries) or patient simulators and manikins (in the field of medicine) to reproduce common situations (or, on the contrary, rare and critical situations) in the daily professional simulated setting of the trainees and in the absence of risk for passengers (in aeronautic or aerospace fields), patients (in medicine fields), equipment, and the environment.<sup>19</sup> Indeed, simulation is now a well-established method for teaching guidelines, algorithms, complex procedural skills, and decision-making in common and critical situations. In addition to these technical aspects, simulation can be useful for addressing nontechnical skills for crisis resource management, ethics, or end-of-life care.<sup>19,20</sup>

The aim of the current study was to assess whether a single 2-day simulation training session may improve compliance with difficult airway management algorithm and technical ability to perform cricothyrotomy in a population of third-year residents in anesthesiology. Hence, the primary endpoint was improvement of compliance with the difficult airway management algorithms issued after the French Anesthesiology and Critical Care Society's latest consensus conference (2006, Société Française d'Anesthésie et de Réanimation, Paris, France).<sup>1</sup> The secondary endpoint was improvement of duration and technical quality of the cricothyrotomy. Assessments were performed before and at either 3, 6, or 12 months after the simulation training session.

## Materials and Methods

### Ethics

The study's objectives and procedures were approved by the local institutional research board (Amiens University Medical Center, Amiens, France). All participants provided written, informed consent to being video-recorded and signed confidentiality agreements to prevent details pertaining to the clinical scenario from being disseminated before the end of the study.

### Population

All 27 third-year residents in anesthesiology at Amiens, Caen, and Rouen University Medical Centers were included in the study. All had received some training in difficult airway management through lectures and clinical practice on patients during internships. Before the study, none of the

residents had been trained on task trainers or high-fidelity simulators and none had experience of cricothyrotomy in a real-life CICV situation.

### Seminar

In March 2011, a 2-day seminar was delivered by expert physicians with experience of difficult airway management and simulation. *Via* an interactive video produced by the trainers, the first half of day 1 dealt with the difficult airway management algorithms issued by the French Anesthesiology and Critical Care Society's latest consensus conference.<sup>1</sup> In the second half of day 1, task trainers were used to present and practice all alternative airway management techniques: Frova Intubating Introducers (Cook Medical Inc., Bloomington, IN), *LMA Fastrach*<sup>™</sup> (LMA North America Inc., San Diego, CA), fiberoptic intubation (KARL STORZ GmbH & Co. KG, Tuttlingen, Germany and Ambu Inc., Glen Burnie, MD), transtracheal oxygenation with a Ravussin cannula plus Manujet<sup>®</sup> (VBM Medical Inc., Noblesville, IN) and ENK Oxygen Flow Modulator Sets (Cook Medical Inc.), cricothyrotomy with Melker kits (Cook Medical Inc.), Quicktrach (VBM Medical Inc.), and Portex (Smiths Medical ASD Inc., Norwell, MA). The second day was devoted to seven training scenarios (table 1) using two Advanced Life Support Patient Simulators and two SimMan manikins (Laerdal Medical, Stavanger, Norway). Each of the residents took the role of the leader in at least one scenario.

### Study Design

A pre–postdesign with randomized follow-up was planned.

### The Pretest

One month before the training seminar, all the residents were assessed in a CICV scenario. In each of the three simulation centers (Amiens, Caen, and Rouen university medical centers), a SimMan manikin with standard monitoring (electrocardiogram, noninvasive blood pressure monitoring, peripheral capillary oxygen saturation [SpO<sub>2</sub>] measured with a pulse oximeter, end-tidal oxygen and end-tidal carbon dioxide) was placed in an operating-theater setting. The residents were briefed before the start of the scenario. In the scenario itself, the resident was called to help with a CICV situation by an anesthesiologist and an anesthesiology nurse (both playing the roles of facilitators). The simulation began after the induction of general anesthesia for laparoscopic cholecystectomy of a 59-yr-old patient: the anesthesiologist had performed two laryngoscopies (including one with a Frova Intubating Introducer) and *LMA Fastrach*<sup>™</sup> insertion—none of which were successful. The simulator was programmed to immediately present a CICV situation, with an SpO<sub>2</sub> of 92% and a 10% drop per minute. After being called to help, the resident received a brief explanation of the situation by the anesthesiologist (who then acted as a facilitator): if the resident had not independently chosen

**Table 1.** Pretest, Posttest, and Training Scenarios

	Difficult Airway Criteria	Description of the Scenario	Exit of the Scenario
Pretest	Mallampati class 2.	Nonpredictable difficult ventilation. Nonpredictable difficult intubation. Can't ventilate/Can't intubate. 59-yr-old patient. Laparoscopic cholecystectomy.	Cricothyrotomy
TS 1	Interincisor distance <3 cm. Mallampati class 4. Thyromental distance less than three finger breadths.	Predictable difficult intubation. 30-yr-old patient. Laparoscopic cholecystectomy.	Fiberoptic intubation.
TS 2	Ballistic facial trauma.	Can't ventilate/Can't intubate. 45-yr-old patient. Ballistic facial trauma.	Cricothyrotomy.
TS 3	BMI >40. Beard. Toothless.	Predictable difficult ventilation. Nonpredictable difficult intubation. Can't ventilate/Can't intubate. 68-yr-old patient. Laparotomy left colectomy.	<i>LMA Fastrach</i> <sup>TM</sup> . Intubation.
TS 4	Preeclampsia. Mallampati class 3.	Nonpredictable difficult ventilation. Predictable difficult intubation. Can't ventilate/Can't intubate. 30-yr-old patient. Emergency caesarian.	<i>LMA Fastrach</i> <sup>TM</sup> . Intubation.
TS 5	Prominent overbite and relatively long length of upper incisors. Mallampati class 3.	Nonpredictable difficult ventilation. Nonpredictable difficult intubation. Can ventilate/Can't intubate. 40-yr-old patient. Thyroidectomy.	<i>LMA Fastrach</i> <sup>TM</sup> . Intubation.
TS 6	BMI >40 Short and thick neck. Cannot touch tip of chin to chest. Cannot extend neck. Mallampati class 3.	Nonpredictable difficult ventilation. Predictable difficult intubation. Can't ventilate/Can't intubate. 55-yr-old patient. Peritonitis/laparotomy.	Transtacheal oxygenation with Ravussin cannula and Manujet <sup>®</sup> .
TS 7	Retropharyngeal abscess. Neck cellulitis.	Can't ventilate/Can't intubate. 20-yr-old patient in ICU. Postoperative refractory acute lung injury. Self-extubation during nursing.	Cricothyrotomy.
Posttest	Mallampati class 2.	Nonpredictable difficult ventilation. Nonpredictable difficult intubation. Can't ventilate/Can't intubate. 37-yr-old patient. Peritonitis/laparotomy.	Cricothyrotomy.

*LMA Fastrach*<sup>TM</sup> (LMA North America Inc., San Diego, CA); Ravussin cannula and Manujet<sup>®</sup> (VBM Medical Inc., Noblesville, IN).  
BMI = body mass index; ICU = intensive care unit; TS = training scenario.

to initiate cricothyrotomy within 3 min, the facilitator asked the resident whether cricothyrotomy might be an option. A difficult airway cart was available in the operating theater. A fiberscope and jet ventilation equipment were not available; the goal was to prompt the resident to perform a cricothyrotomy (with a Melker kit). The scenario ended when the cricothyrotomy had been performed and the manikin was being ventilated *via* the cricothyrotomy cannula, with SpO<sub>2</sub> increasing by 20% per minute.

To avoid retraining bias, none of the residents was given the opportunity to train on a manikin or simulator between the pretest and the posttest.

**Randomization**

After the pretest and the seminar, the residents were randomized for a posttraining assessment at either 3, 6, or 12 months (fig. 1). The randomization was split according to center (*i.e.*,

at Amiens, Caen, and Rouen university medical centers). A number was given to each resident in the three centers and a computer-based randomization table was printed at each posttraining assessment. In each center, approximately one third of the residents were assessed in the 3-month posttest, with a second third assessed in the 6-month posttest, and the remaining third assessed in the 12-month posttest. To avoid any retraining bias, each resident was randomized for assessment at only one time point after training (*i.e.*, 3, 6, or 12 months). The randomization was performed just before the beginning of the scenario. Residents' distribution for the different test time points is shown in table 2.

**The Posttest**

In accordance with the per-center randomization, the residents were tested in a new CICV scenario at 3, 6, or 12 months after the training. The scenario involved the same

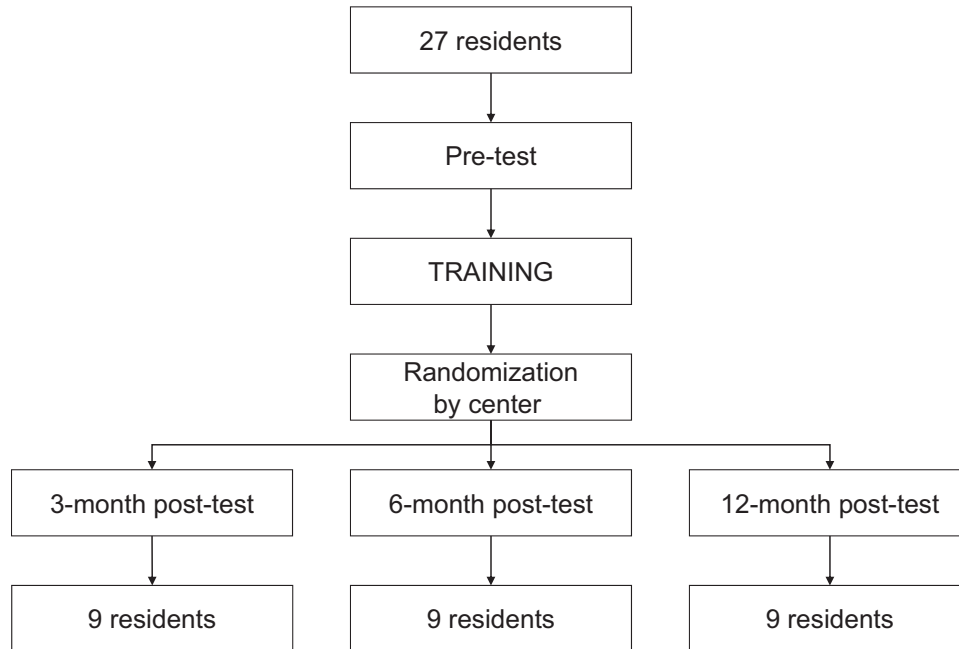


Fig. 1. Flow chart.

manikin and the same environment as in the pretest. The resident was again briefed before the start of the scenario. He/she played the role of anesthesiologist, taking care of a 37-yr-old patient with peritonitis. The patient did not meet any of the criteria for difficult airways during the preanesthesia consultation and general anesthesia was planned. One facilitator played the role of the anesthesiology nurse and a second facilitator played the role of a colleague whom the resident could call on for help. The resident was left to choose the anesthesia induction and airway management protocols. As in the pretest, a difficult airway cart was available in the operating theater. A fiberoptic and jet ventilation equipment were not available; the goal was again to prompt the resident to perform a cricothyrotomy (using a Melker kit). The simulator was programmed as “cannot intubate,” with possible face-mask ventilation. To ensure valid comparisons, the end of the posttest scenario was similar to that of the pretraining scenario: after the first attempt at *LMA Fastrach*<sup>™</sup> insertion, the simulator switched to “cannot ventilate,” with an SpO<sub>2</sub> of 92% and drop of 10% per minute. The scenario ended when cricothyrotomy was performed and the simulator was being ventilated *via* the cricothyrotomy cannula, with the SpO<sub>2</sub> increasing by 20% a minute.

Table 2. The Distribution of the Anesthesiology Residents

Medical Center	Pretest	Posttests		
		3-month	6-month	12-month
Amiens	11	3	4	4
Caen	8	3	2	3
Rouen	8	3	3	2
Total	27	9	9	9

### Briefing and Debriefing

Before the start of the scenario, the resident was briefed on the manikin and its characteristics, the materials provided, and the assistance available locally. To familiarize themselves with the available material, all the residents performed a direct laryngoscopy and an endotracheal intubation on the manikin. After the scenario, two expert physicians (with experience, respectively, in difficult airway management and simulation) performed a debriefing. It was focused on difficult airway management algorithms, decision-making times, the duration of cricothyrotomy, technical skills, and non-technical skills for crisis resource management.

### Measurements

All the simulations were video-recorded and rated on a blind basis: each video recording was anonymized through the attribution of a code number chosen by the resident and maintained throughout the study. The camera's field of view was centered on the technical procedures and the participants' faces were not filmed. Each video recorded before or after the training session was viewed once and rated (on the basis of a validated checklist) by three expert physicians with experience in difficult airway management. Individually and successively, each expert physician noted the level of compliance with algorithms, the duration of the cricothyrotomy (defined as the time between location of the cricothyroid membrane and the achievement of ventilation through the cricothyrotomy cannula), and technical skill and then awarded a checklist score [0 to 10] (table 3) and a global rating scale [7 to 35] (table 4).<sup>21</sup> In case of disagreements between the three experts about the level of compliance with algorithms, the video recording was reviewed simultaneously by the three experts, and an agreement was obtained.

**Table 3.** Task-specific Checklist for Cricothyrotomy<sup>21</sup>

Task	Score		
	0	1	2
Aspiration to identify trachea	Does not aspirate.	Performed inadequately.	Aspirates with air-filled or fluid-filled syringe.
Ventilation during cricothyrotomy	Does not ventilate during the cricothyrotomy.	Ventilates for part of the duration of the cricothyrotomy.	Ventilates for the entire duration of the cricothyrotomy.
Correct caudal angling during guidewire insertion (not during needle insertion)	Cephalad angle.	90° to trachea.	45° caudad.
Adequate skin and membrane incision	Does not use the scalpel for incision.	Performed inadequately.	Cuts skin and cricothyroid membrane with the scalpel.
Correct use of dilator and cricothyrotomy	Attempts to insert cricothyrotomy cannula without dilator in place.	Dilates separately and then railroad entire assembly.	Railroad entire assembly (dilator and cricothyrotomy cannula).

Concerning the duration of the cricothyrotomy, the checklist score, and the global rating scale, the means of the duration/scores noted by the three experts was considered as the final duration/scores of the resident.

**Statistics**

Results are quoted as the number of events (percentage) for qualitative variables and the median [min–max] for quantitative variables. Sample size was estimated based on McNemar test. The anticipated discordant pairs were 50% (residents who failed first and succeeded thereafter) and 5% (residents who succeeded first followed by a failure). On the basis of these proportions, a bilateral  $\alpha$  level of 5% and a power of 85%, 22 residents were needed. The SAS/STAT<sup>®</sup> Software version 9.2 (SAS Institute Inc., Cary, NC) proc POWER was used for sample size calculation. First, we conducted paired comparison between the pretest and the aggregated

posttest results (3-, 6-, and 12-month posttests results). Then, we compared pretest *versus* various posttest results for 3-month, 6-month, and 12-month posttest after controlling for multiple comparisons with Bonferonni–Holm adjustment method. McNemar test was used to compare pretest *versus* posttest compliance with difficult airway management algorithms. Wilcoxon signed-rank test was used for pretest *versus* posttest comparisons of paired, quantitative variables (the median cricothyrotomy duration, checklist score, and global rating scale score). For the comparison of quantitative variables in the 3-, 6-, and 12-month posttests, a Kruskal–Wallis one-way ANOVA was applied. All comparisons were two-sided and a *P* value less than 0.05 was considered statistically significant. Statistical analyses were performed with the SAS/STAT<sup>®</sup> Software version 9.2 (SAS Institute Inc.). Because of the limited sample size (nine residents in each posttest), we could not perform any equivalence test to assess

**Table 4.** Global Rating Scale for Cricothyrotomy<sup>21</sup>

	Score			
	1	2	3	4
Preparation for procedure	Did not organize equipment well. Had to stop procedure frequently to prepare equipment.	Equipment generally organized. Occasionally had to stop and prepare items.		All equipment neatly organized, prepared, and ready for use.
Respect for tissue	Frequently used unnecessary force on tissue or caused damage.	Careful handling of tissue but occasionally caused inadvertent damage.		Consistently handled tissues appropriately with minimal damage.
Time and motion	Many unnecessary moves.	Efficient time/motion but some unnecessary moves.		Clear economy of movement and maximum efficiency.
Instrument handling	Repeatedly made tentative or awkward moves with instruments.	Competent use of instruments but occasionally appeared stiff or awkward.		Fluid moves with instruments and no awkwardness.
Flow of procedure	Frequently stopped procedure and seemed unsure of next move.	Demonstrated some forward planning with reasonable progression of procedure.		Obviously planned course of procedure with effortless flow from one move to the next.
Knowledge of procedure	Deficient knowledge.	Knew all important steps of procedure.		Demonstrated familiarity with all aspects of procedure.
Overall performance	Very poor.	Competent.		Clearly superior.

whether there was any decay over time in cricothyrotomy performance.

## Results

The study population comprised all 27 third-year anesthesiology residents at Caen, Rouen, and Amiens university medical centers (12 men and 15 women; mean age: 27 years). As requested, none of the residents had trained on a manikin or simulator between the pretest and the posttest. Furthermore, none of the residents had experienced a cricothyrotomy in a real-life CICV situation between the pretest and the posttest.

All the residents complied with the difficult airway management algorithms in the posttest, whereas only 17 (63%) did so before training ( $P < 0.005$  when compared with posttests).

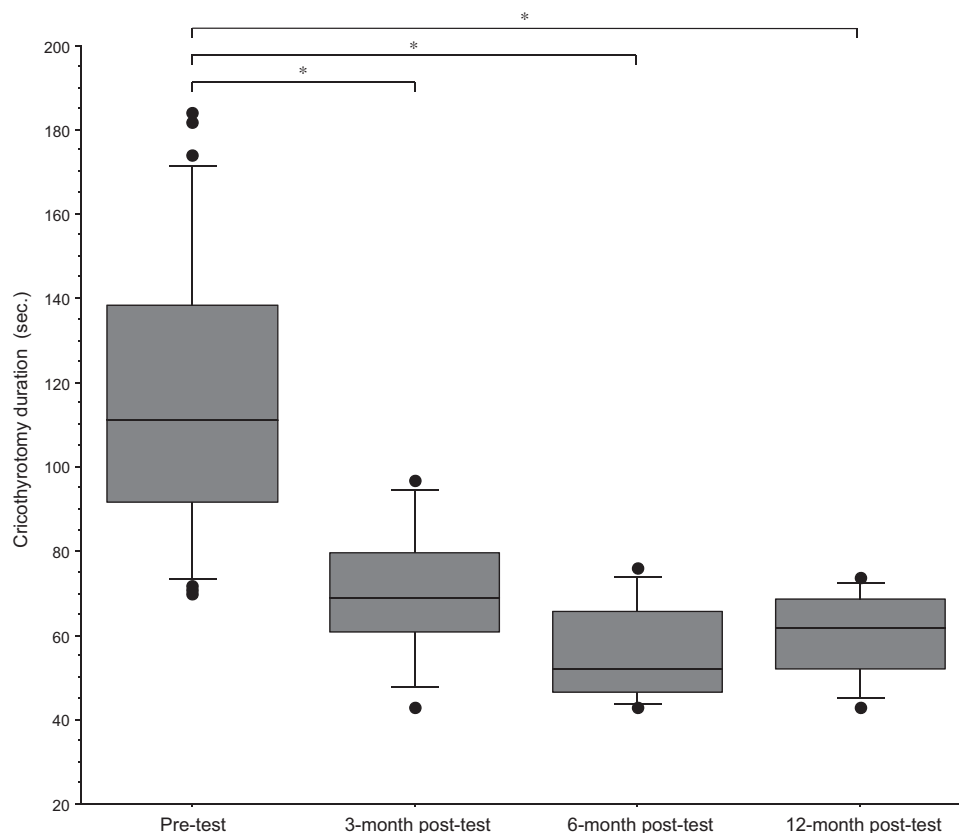
The median cricothyrotomy duration (fig. 2) was significantly shorter in the posttest than in the pretest ( $P < 0.0001$ ). It was 117 s [70 to 184] in the pretest, 69 s [43 to 97] in the 3-month posttest, 52 s [43 to 76] in the 6-month posttest, and 62 s [43 to 74] in the 12-month posttest ( $P < 0.05$  for each comparison between the various posttests with the pretest). The mean time gained between the pretest and the posttest was 42 s in the 3-month posttest, 55 s in the 6-month posttest, and 66 s in the 12-month posttest. There were no significant differences between the posttest results at 3, 6, and 12 months.

Regarding the performance in cricothyrotomy skills, the median checklist score (fig. 3) was significantly better in the posttest than in the pretest ( $P < 0.0001$ ). It was 3 [0 to 7] in the pretest, 10 [8 to 10] in the 3-month posttest, 9 [6 to 10] in the 6-month posttest, and 9 [4 to 10] in the 12-month posttest ( $P < 0.05$  for each comparison between the various posttests with the pretest). The mean gain in the checklist score between the pretest and the posttest was 6 in the 3-month posttest, 4 in the 6-month posttest, and 5 in the 12-month posttest. There were no significant differences between the posttest results at 3, 6, and 12 months.

The median global rating scale (fig. 4) was significantly better in the posttest than in the pretest ( $P < 0.0001$ ). It was 12 [7 to 22] in the pretest whereas it was 30 [20 to 35] in the 3-month posttest, 33 [23 to 35] in the 6-month posttest, and 31 [18 to 33] in the 12-month posttest ( $P < 0.05$  for each comparison between the various posttests with the pretest). The mean gain in the global rating scale between the pretest and the posttest was 15 in the 3-month posttest, 19 in the 6-month posttest, and 19 in the 12-month posttest. There were no significant differences between the posttest results at 3, 6, and 12 months.

## Discussion

Our results demonstrate that after a 2-day seminar with simulations, all our anesthesiology residents complied with



**Fig. 2.** Median duration of cricothyrotomy (\* $P < 0.05$  when compared with the pretest).

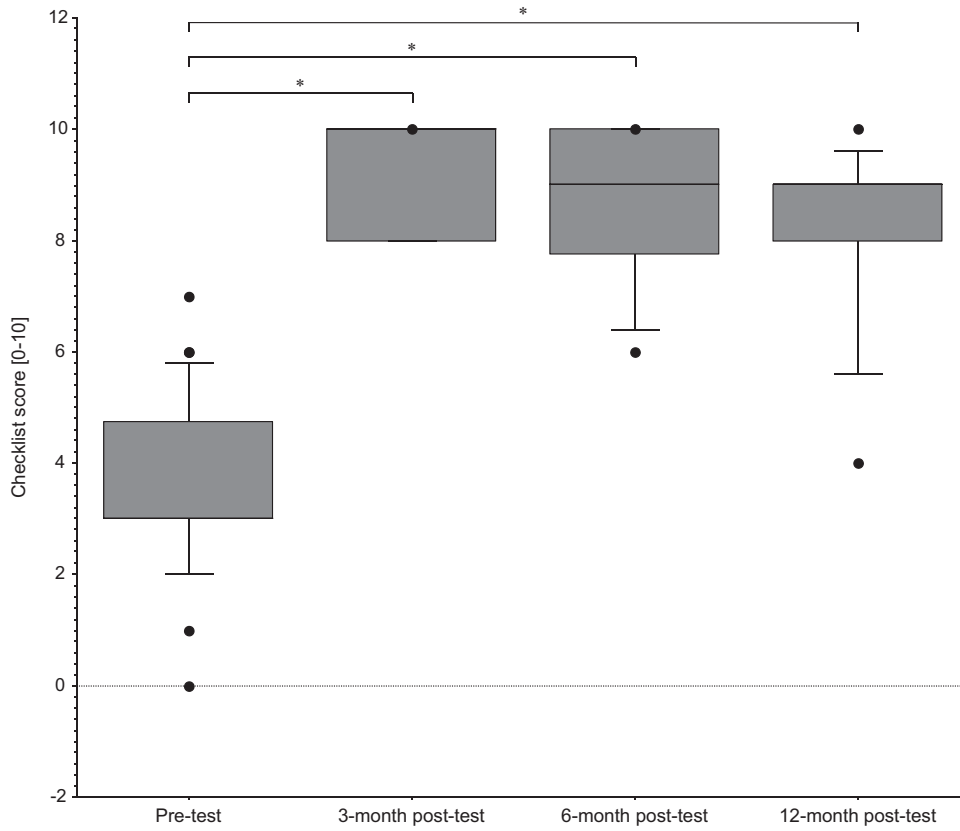


Fig. 3. Median checklist score for cricothyrotomy skills [range, 0–10] (\* $P < 0.05$  when compared with the pretest).

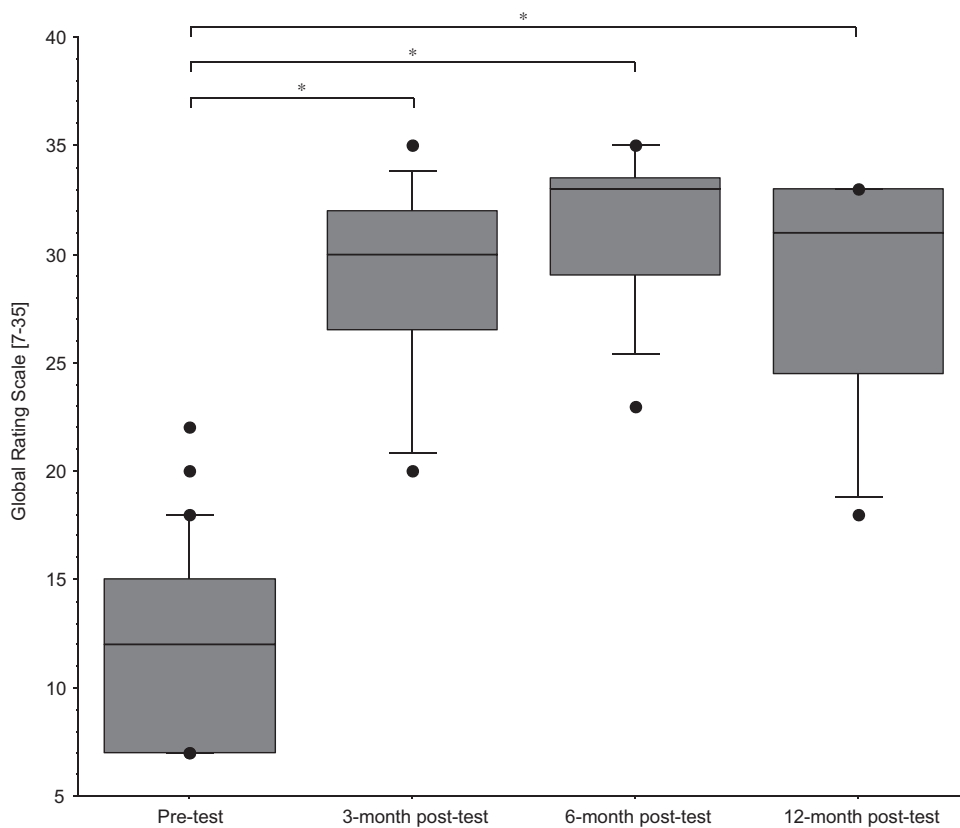


Fig. 4. Median global rating scale for cricothyrotomy skills [range, 7–35] (\* $P < 0.05$  when compared with the pretest).

the French Anesthesiology and Critical Care Society's difficult airway management algorithms<sup>1</sup> (whereas this was the case for only 63% of the group before training) and retained these difficult airway management skills for at least a year afterward. Furthermore, our results emphasize the value of simulation for training in general and for the acquisition of algorithms and complex procedural skills in particular. The cricothyrotomy duration was significantly shorter in the posttest than in the pretest and tended toward the time of 40 s (the time considered to correspond to proficient performance of a successful cricothyrotomy).<sup>22</sup> Furthermore, the technical quality of the cricothyrotomy (as measured by the checklist score and the global rating scale) was improved significantly after the training. There were no significant differences in skills between the 3-, 6- and 12-month posttests. Indeed, even though we did not observe any significant difference between the results of the three posttests, we cannot state that there was no decay in cricothyrotomy performance.

There are few data on the impact of simulation on the acquisition of airway management skills in general and cricothyrotomy in particular. A recent study by Boet *et al.*<sup>18</sup> reported that a single simulation cricothyrotomy training session improved the procedural skills of 28 attending anesthesiologists and that this improvement was retained for at least a year. In the latter study, the attending anesthesiologists were assessed in a simulated cricothyrotomy scenario in a pretest, immediately after a debriefing and structured teaching session on cricothyrotomy insertion and at either 6 or 12 months posttest. The same scenario was used in the pretest and in the posttests; the resident played the role of an anesthesiologist called on to help with an ongoing intubation attempt. On the simulated patient's arrival, the oxygen saturation was 89% and falling by 10% per minute. All intubation methods were destined to be unsuccessful, because the manikin was set up in the CICV configuration. Hence, the scenario was designed to prompt the anesthesiologist to perform a cricothyrotomy. The time needed to perform cricothyrotomy in Boet *et al.*'s study appears to be longer than that observed in the current study and those reported elsewhere.<sup>22,23</sup> Because the scenarios were the same in the pretest and the posttests, one can reasonably suppose that in posttests, the anesthesiologists recognized the scenario that they had already acted out in the pretest and were therefore able to choose the right actions more rapidly. In contrast, we used two different scenarios for the pretest and the posttest so that residents would not recognize them. Hence, the residents could not presume that the scenarios would end in the same way (*i.e.*, with identical  $SpO_2$  starting values and decreases). Furthermore, our population of 27 third-year residents in anesthesiology was randomized for assessment in a 3-, 6-, or 12-month posttest. Hence, each resident was assessed in the pretest and just one posttest (3, 6, or 12 months after training). This design avoided the training bias that would probably have been present if each resident had been assessed

3, 6, and 12 months after training because each posttest scenario would have served as training for the next one. This choice of study design also prevented us from assessing the decision-making time, which is nevertheless an important parameter.

In the current study, the randomization was split by center to mitigate a potential source of bias related to hypothetical differences in the residents' respective knowledge and skills. With a view to limiting bias, no other training on difficult airway management was provided during the study period; the only way of being "trained" corresponded to the (rare) occurrence of a difficult airway situation in the residents' clinical practice. We were unable to perform a comparison with a control group: it was impossible to exclude anesthesiology residents from the 2-day seminar because it was part of their third-year course.

In view of the unavailability of a fibroscope and transtracheal oxygenation materials in the scenarios used here, the residents were ultimately prompted to perform a cricothyrotomy. This choice was justified because it enabled a complete exploration of the difficult airway management algorithms and allowed us to assess all the associated steps and procedures. Furthermore, cricothyrotomy is the final option in all CICV airway management algorithms and is easily available and usable under all circumstances (from prehospital care to intensive care). Last, the technical aspects of cricothyrotomy can be assessed against published, objective criteria.<sup>21</sup> We chose to use a Melker cricothyrotomy kit because it requires more steps and uses the wire-guided (Seldinger) technique, with which our population of anesthesiology residents was very familiar (after regular use for arterial and central venous cannulation, percutaneous tracheostomy, and thoracic cavity drainage). Although other cricothyrotomy kits or techniques have been compared,<sup>24–32</sup> inexperience was always associated with a high failure rate and delayed the successful initiation of ventilation. Our pretest results were similar, with a high error rate for the wire-guide/dilator/catheter sequence of actions. In studies of the cricothyrotomy learning curve, task training reduced the duration of the procedure; by their fifth attempt, 96% of anesthesiologists were able to successfully perform a cricothyrotomy in 40 s or less.<sup>22</sup> During the seminar's task-training sessions, residents were allowed to perform more than five cricothyrotomy procedures within 40 s or less. Literature reports have shown a decay in performance after 6 months and have recommended that workshop training should be repeated every 6 months.<sup>22,33</sup>

We could compare our pretest and posttest scenarios because they ended in the same way despite having different pathways to the CICV scenario. Furthermore, we decided to avoid hypoxic cardiac arrests during the scenarios by ensuring that the  $SpO_2$  remained above 50%. This choice avoided the involvement of cardiac arrest management, which was not an efficacy criterion in the current study. If the  $SpO_2$  reached 50%, the facilitator recommended a cricothyrotomy but ensured that the resident performed the procedure on



his/her own. It is clear that many hypoxic cardiac arrests would have been observed in the pretest and would have called on the residents' knowledge of cardiac arrest algorithms as well as CICV management skills. Given the shorter decision-making time and duration of cricothyrotomy in the posttest, no hypoxic cardiac arrests were recorded and the facilitator did not have to step in.

The pretest and posttest scenarios were highly realistic and a total of seven other scenarios had been acted out during the seminar. We acknowledge that (1) the cricothyroid membrane is easier to identify in a manikin than on a patient<sup>34</sup> and (2) performance of a cricothyrotomy on a manikin is artificial and differs from real-life situations. However, controlled trials are difficult or even impossible to perform on humans because of the urgency and rarity of this procedure. Nevertheless, the literature seems to indicate that both non-technical and procedural surgical skills can indeed be transferred from simulators to patients,<sup>32,35</sup> and places high value on simulations in medical education.<sup>36</sup> Feedback is crucial to the learning process<sup>37</sup> and we always performed debriefings. These debriefings were led by an expert in difficult airway management and an expert in simulation, who always provided the resident with useful advice on main errors made during the scenario. The debriefings focused on the French Anesthesiology and Critical Care Society's difficult airway management algorithms,<sup>1</sup> decision-making times, the duration of cricothyrotomy, technical skills for cricothyrotomy,<sup>21,22</sup> and nontechnical skills for crisis resource management.<sup>38</sup> They were based on self-assessment by the resident, discussion of errors or points for improvement, and then constructive advice on how to perform better.<sup>20,39</sup>

On the basis of our direct costs over 5 yr (with two 2-day seminars a year and 12 participants per seminar), the estimated cost of our process is 600 euros (approximately 800 U.S. dollars) per trainee.

## Conclusion

Our seminar (based on simulation) was associated with an improvement in our anesthesiologist residents' knowledge of difficult airway management algorithms and cricothyrotomy skills with retention for at least 1 yr. After training, all the residents complied with the algorithms and were able to perform this lifesaving procedure quickly and accurately in a CICV scenario. This inherently stressful situation did not prevent the residents from achieving good performance levels. The posttest results testified to the participants' greater awareness and should, we hope, enable them to manage a true difficult airway situation with confidence in the future.

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## Competing Interests

The authors declare no competing interests.

## Correspondence

Address correspondence to Dr. Hubert: Department of Anesthesiology and Critical Care, CHU d'Amiens, Place Victor Pauchet, F-80054 Amiens Cedex, France. hubert.vincent@chu-amiens.fr. Information on purchasing reprints may be found at [www.anesthesiology.org](http://www.anesthesiology.org) or on the masthead page at the beginning of this issue. ANESTHESIOLOGY's articles are made freely accessible to all readers, for personal use only, 6 months from the cover date of the issue.

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