ORIGINAL RESEARCH

Assessment of an Airway Curriculum in a Pulmonary and Critical Care Fellowship Program

Ikuyo Imayama[1], Kevin P. Haas[1], Ashley Binder[1], Tanja Barac[2], John Holanday[4], Xia Zhou[3], Ping-Shou Zhong[3], Steven M. Dudek[1], and Tirsa M. Ferrer Marrero[1]

[1]Division of Pulmonary, Critical Care, Sleep and Allergy, Department of Medicine, [2]Department of Medical Education, and [3]Department of Mathematics, Statistics and Computer Science, University of Illinois Chicago, Chicago, Illinois; and [4]Simulation Center, Jesse Brown Veterans Affairs Medical Center, Chicago, Illinois

ORCID ID: 0000-0003-0301-7871 (T.M.F.)

ABSTRACT

Background: Endotracheal intubations (EIs) in the intensive care unit are high-risk procedures often performed by pulmonary and critical care medicine (PCCM) providers. The Accreditation Council for Graduate Medical Education mandates PCCM fellows' competency in this procedure; however, the learning experiences vary across programs. After conducting a needs assessment, we developed a curriculum unique to our institution to supplement our fellows' existing EI experiences in the operating room and the intensive care unit.

Objective: To assess the curriculum's short-term objectives: knowledge acquisition, maintenance, and practical skills 1 year after participation.

Methods: We administered a survey to the graduating PCCM fellows for two consecutive years. We designed the comprehensive airway curriculum to include didactic lectures and simulation-based education. The knowledge acquisition and maintenance were measured

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Correspondence and requests for reprints should be addressed to Tirsa M. Ferrer Marrero, M.D., Division of Pulmonary, Critical Care, Sleep and Allergy, Department of Medicine, University of Illinois Chicago, 840 South Wood Street (MC 719), Room 920N, Chicago, IL 60612. E-mail: tmferrer@uic.edu.

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by administering a 26-question knowledge survey before and after curriculum participation and after 1 year. The fellows also received a practical examination 1 year after participation. To compare knowledge survey scores, we used paired *t* tests and permutation tests.

Results: In the needs assessment, 56% of graduating fellows believed they were proficient in performing EI, whereas 33% were undecided and 11% believed they were unprepared. Most believed they would need more than two courses after graduation to be confident in independently performing EIs. Most will only occasionally have backup for EI from anesthesiology or emergency medicine in their future jobs. One identified barrier to learning EI was the lack of a formal curriculum. In the knowledge assessment, nine first-year fellows participated in the curriculum. The cohort's mean presurvey score was 13.0 (standard deviation [SD], 4.5) versus 18.6 (SD, 3.6) mean postsurvey score. One year after participation, the mean survey score was 17 (SD, 1.2). The postsurvey and 1-year postparticipation survey scores were significantly higher than the presurvey scores ($P < 0.05$). One year after participation, the practical examination showed most fellows retained skills in EI using ramped position, video and direct laryngoscopy, bag-mask ventilation, and oropharyngeal airway placement.

Conclusion: The airway curriculum enhances fellows' knowledge acquisition and maintenance 1 year after participation. The practical examination 1 year after participation highlighted the skills retained and those still needing improvement.

Keywords:
airway management; medical education; intubation; curriculum

Endotracheal intubation (EI) is a potentially lifesaving procedure, but it is high risk when performed nonelectively in a critically ill patient (1). The risks are related to the physiologically and anatomically difficult airway and the situational complexities of the intensive care unit (ICU) (2, 3). These challenging patients are often intubated by pulmonary and critical care medicine (PCCM) providers (4).

Although the Accreditation Council for Graduate Medical Education mandates PCCM trainees be competent in this procedure, there is no standardized curriculum, resulting in wide variation in airway management learning experiences across the United States (1). Therefore, it may be difficult for PCCM fellows to gain enough experience to become proficient upon graduation and remain skilled in airway management (5).

Many programs use rotations in the operating room (OR) for EI training (6). Although experiences in the OR contribute to the attainment of competency in this procedure, they may not offer the situational complexity of intubation experiences in the ICU (1).

Simulation-based education (SBE) in airway management training is widely used (6). Although literature supports using SBE as a tool to reduce the gap between the classroom and the practical application (7), sole use of SBE to teach competency is not advised (5). Knox and Wong showed that a higher number of successful attempts completed by graduation was associated with increased fellow procedural comfort, reinforcing the need for real-life EI experiences (8).

EI education with a comprehensive curriculum improves first-pass success

and decreases complications (4). A robust curriculum could improve the quality of intubation experiences and accelerate the attainment of competence and confidence (1). The lack of definitive standards for airway management training leads to variability in learning experiences and results in less confidence in performing this necessary skill.

After conducting a needs assessment in our PCCM fellowship program, we developed a comprehensive airway curriculum to supplement the fellows' already existing experiences (9). Before implementing this curriculum, the fellows would intubate in the OR, mainly using video laryngoscopy (VL). The number of intubations varied among fellows, ranging from 20 to 80 intubations over 3 years. In our institution, anesthesiologists predominantly perform EIs. Therefore, when fellows performed intubations in the ICU, it was mainly under the supervision of the anesthesiology attending or, on occasion, under one of the PCCM attendings who perform airway management. Before this curriculum, the fellows would have received one or two airway management lectures over the years without SBE. Here we present a preliminary analysis of this curriculum. We discuss its effectiveness in knowledge acquisition, knowledge maintenance, and practical skills 1 year after its establishment. Some of the data in this article were previously published as an abstract and presented at the American Thoracic Society International Conference in 2022 (9).

METHODS

We aim to report the process of our airway curriculum development and its preliminary evaluation. We developed the curriculum using the Analysis, Design, Development, Implementation, and Evaluation model (10), with the short-term goals of impacting fellows' knowledge acquisition, knowledge maintenance, and practical skills 1 year after participation. Figure 1 describes the timing of each

Activity	Curriculum Year	1					2				
	Months	June	July	August	September	October to June	June	July	August	September	October to June
3rd year fellows completed the exist survey as part of the needs assessment.											
1st year fellows take knowledge pre-survey.											
2nd year fellows take the knowledge survey.											
All fellows receive online access to recommended reading material.											
Airway curriculum core lecture series for all fellows (attendance is mandatory for 1st year fellows)											
1st year fellows participate in simulation-based education with Hand-On teaching sessions with the task trainer mannequins (one instructor - one fellow).											
1st year fellows participate in simulation-based education with high-fidelity scenarios.											
2nd year fellows take the practical skills exam.											
1st year fellows will evaluate the simulation-based education portion of the curriculum.											
1st year fellows take knowledge post-survey.											
All the fellows will continue the academic clinical rotations as per the PCCM fellowship training curriculum with rotations in the OR and ICU.											

Color legend:
Blue – 1st year fellows
Pink – 2nd year fellows
Green – 3rd year fellows
Purple – All fellows

Figure 1. Overall timeline of the study assessments. ICU = intensive care unit; PCCM = pulmonary and critical care medicine.

activity. The needs assessment was performed by surveying the graduating fellows over 2 years. After the airway curriculum was implemented, it was evaluated using knowledge assessments, practical skills tests, and postcurriculum surveys. This project was declared institutional review board exempt by the University of Illinois Chicago Institutional Review Board.

Needs Assessment

An exit survey was administered to the graduating fellows in June for two consecutive years to identify trainees' needs related to airway management training. The third-year graduating fellows received an e-mail with a link to the survey.

During the second year of the exit survey, the curriculum was already being implemented for the first-year fellows. The survey targeted third-year fellows, who indirectly participated in this curriculum, because they could listen to the lectures, had access to reading materials, and assisted the first-year fellows during the SBE. The survey was administered using a password-protected software platform. Other inputs, such as informal interviews, program evaluation committee, and quarterly meetings, were also used.

Curriculum Development

We assembled an airway curriculum team with four PCCM core faculty physicians who perform EIs in the ICU. The lead faculty had experience in SBE and had received training in conducting debriefings at the University of Illinois Simulation and Integrative Learning Center.

Didactic Education

Each fellow had online access to recommended reading materials and the intubation checklist. The fellows also attended six 1-hour didactic lectures on *1*) airway assessment and preparation for intubation; *2*) pharmacology and selecting the drugs for rapid sequence intubation; *3*) bag-mask ventilation, supraglottic airway (SGA), and VL; *4*) direct laryngoscopy (DL) and bougie; *5*) difficult airway: awake intubation and fiberoptic intubation; and *6*) can't intubate, can't ventilate, and surgical airway.

The lectures start in mid-July each year and are given by PCCM, anesthesiology, and pharmacology attendings. The lectures are incorporated into our noon conferences and offered once or twice per week up to the end of August. The specific day of each lecture is scheduled on the basis of the speaker's availability. These lectures are mandatory for the first-year fellows, and attendance is taken. The lectures are given via an online conferencing platform, recorded with the lecturers' authorization, and made available to all the fellows.

Hands-On and Simulation-based Education

First-year fellows participated in a one-to-one hands-on teaching session. The session was a one-time 1-hour session conducted in a large room at the simulation center. The room had multiple fully equipped tables with task trainer mannequins. Each fellow was paired mainly with faculty members from the core airway curriculum team and were assigned a table where the one-to-one teaching occurred. The fellows were taught to perform bag-mask ventilation, oral and nasal airway placement, SGA placement, DL with Miller and Macintosh blades, VL, and bougie intubation. This session was mandatory and the educational time was protected.

After the hands-on session, the fellows participated in two high-fidelity simulation

scenarios (*see* Supplemental Material E1 in the data supplement) created by the senior author and lead faculty. The scenarios were designed to require critical planning, communication, teamwork, use of the intubation checklist (Supplemental Material E2), and securing the airway by the intubating fellow. Each scenario lasted 15 minutes, and all first-year fellows (four or five) were expected to execute different and randomly assigned roles during the scenarios (intubating fellow, respiratory therapist, resident, and nurse[s]).

As a team, they were required to optimize the preintubation setting (patient's positioning, hemodynamic support, and preoxygenation), set up the equipment, select medications and devices, assist with bag-mask ventilation, discuss strategies in anticipation of a difficult airway, and execute immediate postintubation management. Each scenario was followed by a 45-minute debriefing session led by the attending physicians.

Equipment for SBE

The equipment used includes the Airway Management Trainer by Laerdal, and for the high-fidelity simulation case scenarios, we used SimMan Essential by Laerdal, the Gaumard mannequin, and the CAE Healthcare mannequin.

Evaluation: Learning Outcomes and Measures

Knowledge assessment. The primary outcome was fellows' knowledge acquisition, measured with a 26-question (1 point each) survey (Supplemental Material E3). The survey assessed knowledge in airway assessment, preparation for intubation, pharmacology, bag-mask ventilation, SGA placement, DL and VL, bougie intubations, and difficult airways. The survey included multiple-choice and true-or-false questions. The survey was drafted after an extensive literature review (11–14) and modified by the senior author and lead faculty. The knowledge examination was not pilot tested but was reviewed for face and content validity by another PCCM core faculty member, one anesthesiology attending, and one pharmacy resident.

The survey was administered to the first-year fellows before and after their curriculum participation and to the second-year fellows at the beginning of their second academic year (1 yr after participation in the curriculum). The fellows received a link to the survey via e-mail, and responses were collected using a cloud-based, password-protected software platform. The questions were scored as correct = 1 versus incorrect = 0.

Practical skills assessment after 1 year of participation in the curriculum. After 1 year postparticipation in the curriculum, all the second-year fellows performed different airway management tasks using mannequins. The skills were evaluated by an independent PCCM physician experienced in airway management but not involved in the curriculum teaching sessions. The independent physician met with the curriculum team a few days before the examination date to review the evaluation sheet and the scoring process. The independent physician completed an evaluation marking yes or no, based on the tasks the fellows completed correctly. We calculated the percentage of fellows who were able to complete each task.

The practical skills evaluation sheet (Supplemental Material E4) was modified by the curriculum team lead faculty from a previously published evaluation sheet (15) created and validated by a military program for its use in combat. It was modified to focus on the skills needed in

the medical ICU setting, adding SGA placement and bag-mask ventilation.

This practical examination evaluation differs from the intubation checklist. The former focuses on technical skills, whereas the checklist includes preparation, pharmacotherapy, safety, hemodynamic support and monitoring, team communication, and postintubation management.

The practical examination was administered on the same day the first-year fellows received SBE, but in a separate room with fully equipped tables and mannequins. The examination tested skills on positioning (ramp vs. sniffing), bag-mask ventilation, oropharyngeal airway (OPA) and nasopharyngeal airway (NPA) placement, SGA placement, DL and VL intubations, and bougie intubation.

Evaluation of the SBE Experience

First-year fellows' satisfaction was measured with a survey to rate the experience: excellent, very good, good, fair, poor, or very poor. Open-ended questions were used for recommendations and comments. The link to this survey was sent via e-mail upon completion of the SBE.

Statistical Analysis

Descriptive statistics for presurvey and postsurvey scores and the difference between presurvey and postsurvey scores were reported where appropriate, including mean, standard deviation (SD), median, and range. Paired *t* tests and permutation tests were applied to compare the presurvey and postsurvey scores, including overall and scores in the seven categories of the knowledge test. The differences in knowledge acquisition between the two different years were also compared. Because of the small sample size, the results based on permutation tests are more reliable (16). Permutation tests were obtained on the basis of 10,000 permutations. The statistical analyses were performed using R (www.r-project.org).

RESULTS

Needs Assessment

The exit survey was performed over 2 years, and 9 out of 11 graduating fellows completed the survey (81.8% response rate): 4 out of 6 graduating fellows responded the first year (66.7% response rate), and all 5 graduating fellows responded the second year (100% response rate). In the first year ($n = 4$), the graduating fellows who completed the survey had no exposure to this airway curriculum, whereas in the second year ($n = 5$), they were indirectly exposed to the curriculum by taking part in lectures and individual teaching sessions (Figure 1). Because there were no remarkable differences between the first- and second-year survey results, aggregated results are presented for the needs assessment.

Although 56% of the respondents agreed they believed they were proficient in performing EI, 33% were undecided, and 11% disagreed. Most (78%) believed they would still need two or more courses after graduation to be confident. After graduation, 56% would work in community-based hospitals or *locum tenens*, with 78% working >50% of the time in the ICU. In addition, 56% reported that backup for EI would only occasionally be available, whereas 11% said backup would be rare. The identified barriers to obtaining EI skills included the lack of a formal airway curriculum, the lack of protocols in the ICU, the absence of ICU faculty for supervision, and anesthesiology procedural dominance.

Table 1. Presurvey and postsurvey scores for overall and seven topic categories tested

	Pretest		Posttest		Post–Pre		
	Mean	SD	Mean	SD	Mean	SD	*P* Value
Airway assessment and preparation for intubation (0–7)	3.89	1.45	5.22	0.67	1.33	1.41	0.011
Pharmacology and drug selection for induction (0–5)	1.89	1.05	3.33	1.23	1.44	1.13	0.003
Bag-mask ventilation and supraglottic devices (0–3)	1.67	1.00	1.89	1.05	0.22	1.39	0.323
General knowledge (0–3)	1.78	0.97	2.11	0.93	0.33	1.12	0.199
Video and direct laryngoscopy (0–3)	0.78	0.67	1.89	0.93	1.11	1.17	0.011
Difficult airway (0–2)	1.11	0.60	1.44	0.53	0.33	0.50	0.040
Bougie Intubation (0–3)	1.89	0.78	2.67	0.50	0.78	0.83	0.012
Total (0–26)	13.0	4.50	18.56	3.64	5.56	3.94	0.001

Definition of abbreviation: SD = standard deviation.

Knowledge Assessments

A total of nine first-year PCCM fellows (five in Year 1 of the curriculum and four in Year 2) have participated in the curriculum. The mean presurvey score was 13.0 (SD, 4.5) versus the mean postsurvey score of 18.6 (SD, 3.6). The mean score change was 5.6 (effect size, 1.4). Table 1 reports the mean and SD of the presurvey, postsurvey, and differences between pre- and postsurvey scores. The postsurvey score is significantly greater than the presurvey score ($P = 0.001$).

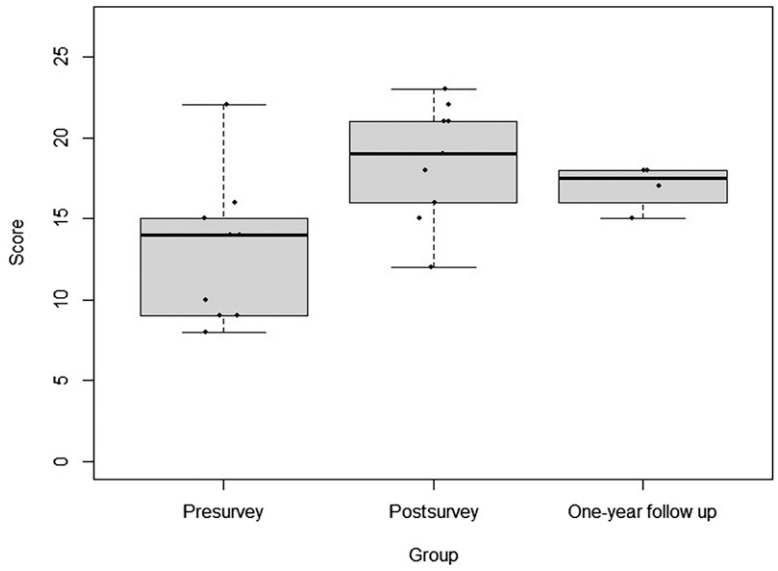

Figure 2. Changes in knowledge assessment scores.

Figure 2 shows the scores before, after, and 1 year after the airway curriculum. The postsurvey and 1-year follow-up scores were significantly higher than presurvey (both $P < 0.05$). There were no statistically significant differences in scores between curriculum Year 1 and curriculum Year 2 ($P > 0.05$).

We analyzed changes in scores by each topic category tested (Table 1). The mean postsurvey scores were statistically significantly higher than the mean presurvey scores in the following categories: airway assessment and preparation for intubation, pharmacology and drug selection for induction, video and direct laryngoscopy, difficult airway, and bougie intubation. The categories in which the fellows underperformed included bag-mask ventilation, supraglottic devices, and general knowledge. In these categories, the difference between the mean postsurvey score and the mean presurvey score failed to achieve statistically significant improvements.

Skills Assessment after 1 Year of Participation in the Curriculum

Four fellows took the practical examination 1 year after participating in the curriculum. Fifty percent were able to demonstrate ramped positioning versus only 25% who were able to demonstrate the sniffing positioning on the mannequin. More than 75% of the fellows were able to perform effective bag-mask ventilation with single-hand EC clamp, double-hand EC clamp, and double-hand jaw thrust. More than 75% mastered the following skills: correct measurement for placing NPA and OPA, OPA placement, and VL and DL intubation.

Areas in which fellows underperformed (<50%) were NPA placement, techniques of properly removing the rigid stylet during VL, placement of the endotracheal tube at the correct depth of 19–25 cm at the lips, identifying the grade view, elevating the tongue without rocking their wrists, intubation using SGA, bougie intubation with VL and DL, and pillow bend of the bougie.

Evaluation of SBE

All participating trainees in the SBE denied detecting bias during the teaching session. Thirty-three percent of the fellows rated the overall learning experience as excellent, 56% rated it very good, and 11% rated it as good. Of those who participated in Year 1, 60% considered it to be excellent and 40% very good.

Fifty-six percent considered the course content excellent, and 44% very good. Sixty-seven percent rated the instructors' effectiveness in the teaching as excellent versus 33% very good. Forty-four percent (44.5%) believed the knowledge obtained was excellent, 44.5% very good, and 11% good.

The fellows identified that the strengths of the course included the hands-on experience, the high-fidelity simulation scenarios, the one-to-one teaching, and how it highlighted the essential points for real-life application.

Other

In addition to the airway curriculum training, the fellows in our cohort have performed approximately 20 EIs per year (by review of the procedure logs). These intubations are mainly in the OR using VL and supervised by anesthesiologists. Our cohort also performed intubations in the ICU supervised by an anesthesiology attending or by one of the PCCM attendings who performs airway management. Currently, approximately 40% of the PCCM attending physicians perform EIs in the ICU.

DISCUSSION

In this study, we report the preliminary evaluation of our airway curriculum's short-term goals of knowledge acquisition and knowledge and skills maintenance. The curriculum significantly increased fellows' knowledge after their participation, and the improvement is statistically meaningful. Although there was a decrease in knowledge survey scores 1 year after participation, they remained significantly higher than the presurvey scores. Exposures to ICU and OR intubations during the first year of training may also influence knowledge retention 1 year after participation. However, our curriculum very likely contributed to the knowledge being maintained.

Kapoor and colleagues showed that an airway curriculum with SBE significantly improved the fellows' knowledge immediately after participation (17). After repeating the posttest 3 months later, the score dropped significantly compared with the posttest, but it was higher than the pretest score (17). In contrast, Walker and colleagues reported knowledge improvement and maintenance after 6 and 12 months in paramedics who participated in an airway course (18). However, paramedics apply these skills daily, which may be the critical factor for knowledge retention, highlighting the need for refresher courses to maintain knowledge and to account for procedural volume.

In our present study, the fellows significantly improved their knowledge in five of seven topic categories. These could be attributed to the curriculum comprehensiveness, with a systematic approach to building on knowledge using SBE and one-to-one teaching. General knowledge, bag-mask ventilation, and SGA were the categories that failed to achieve statistically significant improvement in the postsurvey. This could be attributed to the need for more dedicated time to these topics in one-to-one teaching and SBE.

One strength of this curriculum is SBE, which allows the fellows to train in a controlled environment and receive feedback (19). When SBE is used to teach airway management, learner skills and patient outcomes improve (20, 21), but these benefits are potentiated when integrated into a comprehensive curriculum (19, 22). Emergency EI requires clinical reasoning and time-sensitive interventions, and the cognitive demands are invariably high (23). Failure to follow recommended guidelines is often responsible for adverse outcomes (24). Therefore, building on knowledge and SBE must be considered when designing curriculums for this competency.

Although there is a correlation between procedural comfort and the number of successful attempts, no guidelines exist outlining the number needed for independent practice (8). Furthermore, the number of intubations needed during training varies widely between disciplines (25). Still, the literature shows that a comprehensive curriculum to supplement live practice could help trainees achieve proficiency and competency (1).

The practical examination 1 year after participation showed that despite hands-on training and SBE, several critical skills were not correctly demonstrated by most fellows, including NPA placement, SGA placement, and bougie intubation. These data could indicate that even after this type of intervention, most fellows may not yet be ready for independent intubations. However, using these techniques has clinical implications in managing difficult airways (26, 27). Although these techniques were taught in the one-to-one teaching, our findings could reflect the limited

exposure to securing difficult airways during the first year of fellowship.

Limitations

The skills assessment given 1 year after participation in the curriculum introduced the first potential limitation in our study. The lack of a prepractical examination makes it impossible to assess the real impact of the curriculum on second-year fellows' performance. We cannot conclude whether their performance at the beginning of their second year of fellowship reflected the existing skills or those gained during their first year of training. Our proposed solution involves administering a practical examination to all incoming fellows before and after curriculum participation and in subsequent years. This approach will enable us to effectively document the acquisition and retention of skills. However, we recognize the need to account for fellows' clinical rotations and EI procedural volume, because these factors also influence any changes in skills retention.

Another limitation is the practical examination scoring system of yes (pass) versus no (fail), and the evaluation sheet which did not capture which component of each skill was failed. For example, for VL intubation, the choosing of the appropriate size and type of blades, endotracheal tube size, type of stylet, and so forth could be tested. We plan to modify the sheet and use global rating scales to capture an overall evaluation of performance in the future.

The third potential limitation is administering the same knowledge survey pre- and postintervention, which could have introduced recall bias. Yet, the risks were attenuated by not discussing the answers with the fellows and by the substantial time elapsed between examinations. Having two high-fidelity scenarios introduced the fourth limitation because only two fellows could be the intubators. However, these roles were randomly assigned, and fellows learned how to delegate and what is expected from each role. Plans include adding more simulation contact time and multidisciplinary simulation scenarios so that all the first-year fellows could intubate and lead. Last, the small sample size limits generalizability.

Our future plans include implementing multiple refreshers per year to target the underperforming areas. Because the knowledge and skills assessment 1 year after participation occurred at the beginning of the second year of fellowship, these fellows will have two additional years of training. Therefore, we will explore knowledge and practical skills changes between the beginning of the second and third years of fellowship. We acknowledge the need to adjust for fellows' clinical rotations and procedural volume because these could influence knowledge and skill retention.

Eventually, the exit surveys will reflect the curriculum effects on fellows' self-reported confidence. Although we do not address the curriculum impact on fellows' proficiency in this article, we will modify the curriculum to make that assessment. Therefore, long-term plans include direct attending evaluations of the graduating fellows while performing real-time intubations and mega-airway simulation scenarios to assess their preparedness for independent practice.

Conclusions

We have successfully implemented a practical airway management curriculum that assures fellows' knowledge acquisition postparticipation. The survey administered to our fellows 1 year after their participation in the curriculum revealed knowledge

retention, and the practical examination highlighted the skills that still need improvement. Our initial curriculum enhanced some of the knowledge and procedure foundations necessary to build confidence and competency during the remaining years of training. These findings demonstrate the promising potential of this curriculum to provide a strong foundation for airway training that will guide future iterative enhancements to further impact our fellows' education in an even more positive way.

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