

Endotracheal intubation skill acquisition by medical students

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Background: During the course of their training, medical students may receive introductory experience with advanced resuscitation skills. Endotracheal intubation (ETI – the insertion of a breathing tube into the trachea) is an example of an important advanced resuscitation intervention. Only limited data characterize clinical ETI skill acquisition by medical students. We sought to characterize medical student acquisition of ETI procedural skill.

Methods: The study included third-year medical students participating in a required anesthesiology clerkship. Students performed ETI on operating room patients under the supervision of attending anesthesiologists. Students reported clinical details of each ETI effort, including patient age, sex, Mallampati score, number of direct laryngoscopies and ETI success. Using mixed-effects regression, we characterized the adjusted association between ETI success and cumulative ETI experience.

Results: ETI was attempted by 178 students on 1,646 patients (range 1–23 patients per student; median 9 patients per student, IQR 6–12). Overall ETI success was 75.0% (95% CI 72.9–77.1%). Adjusted for patient age, sex, Mallampati score and number of laryngoscopies, the odds of ETI success improved with cumulative ETI encounters (odds ratio 1.09 per additional ETI encounter; 95% CI 1.04–1.14). Students required at least 17 ETI encounters to achieve 90% predicted ETI success.

Conclusions: In this series medical student ETI proficiency was associated with cumulative clinical procedural experience. Clinical experience may provide a viable strategy for fostering medical student procedural skills.

Keywords: *clinical skills; education environment; practical procedures; medical education research*

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Critically ill patients often require life-saving advanced interventions such as cardiopulmonary resuscitation, intravenous line insertion and cardiac defibrillation. Hunskaar and Seim recommended that all medical school graduates acquire skills in emergency life-saving procedures (1). During the course of their studies, medical students may receive informal introductory experience with advanced resuscitation procedures and techniques. Prior studies suggest that formal medical student instruction in emergency techniques is beneficial, resulting in improved student procedural competence and confidence, and reducing fatal errors (2, 3).

Endotracheal intubation (ETI) is a prominent example of a complex life-saving intervention performed on the

critically ill. Trainees in fields that provide critical care (for example paramedic students, emergency medicine residents and anesthesia residents) often acquire ETI skill through repetition in the controlled operating room setting under the guidance of attending anesthesiologists or nurse anesthetists (4–6). While medical students in the United States may have the opportunity to perform clinical ETI in the operating room, access to operating room airway training is often limited (7). Furthermore, only limited data characterize medical student acquisition of ETI skill from this experience. Assessing medical student ETI skill acquisition is important for validating the utility and effectiveness of this educational experience.

In this study, we characterized the association between clinical ETI procedural experience and ETI skill acquisition by medical students.

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Materials and methods

Study design, setting and population

We studied ETI performance by third-year allopathic MD and combined MD/graduate degree (PhD, MPH, etc.) students completing a required two-week anesthesiology clerkship at the University of Pittsburgh School of Medicine. At the time of this study, the existing clinical anesthesiology clerkship included 'hands-on' experience with ETI and other anesthesia procedures. This study evaluated results of the existing educational curriculum; there were no changes to the educational program, procedures or clinical interventions. Because of the observational nature of this study, the University of Pittsburgh Institutional Review Board approved the study without requiring informed consent from participating students or patients.

Components of the educational curriculum

The medical student anesthesiology clerkship was an existing component of a required eight-week combined surgery and anesthesiology clerkship. The structured clerkship curriculum consisted of assigned readings and human-simulator-based training exercises as well as participation in clinical anesthesia care.

On the first day of the rotation, all students received basic instruction in airway management procedures, including human-simulator-based training in mask ventilation, laryngeal mask airway insertion and ETI. Under the direction of five faculty instructors, four simulator-based ETI training sessions were held over the two-week clerkship at the university's simulation center. The first session occurred prior to any clinical exposure, and included a review of basic ETI technique, two to three simulated ETIs per student and simulated induction of general anesthesia. The other sessions took place throughout the clerkship at weekly intervals. All students in each clerkship group attended the simulation sessions at the same time.

After the introductory session, students participated in the clinical care of operating room patients under the direct supervision of attending anesthesiologists, including performing clinical ETI. Institutional policy required attending anesthesiologists to be physically present during all ETI. Students received ETI opportunities strictly at the discretion of the attending anesthesiologist. Students rotated with anesthesiology departments at one of seven hospitals, including university, community and pediatric centers.

Methods of measurement and outcomes

As a clerkship requirement, students recorded all attempted clinical procedures (endotracheal intubation,

mask ventilation and other procedures) in a structured logbook. We informed students of the research study on the first day of the clerkship. Although logbook completion was a requirement for the clerkship, student submission of the logbook for the research study was voluntary. An independent third party de-identified all logbooks prior to analysis by the study team. The University Institutional Review Board approved this approach.

For each attempted ETI, students reported pertinent data, including the date of procedure, patient age in years, gender, Mallampati score, the number of direct laryngoscopies and their procedural success.

The Mallampati score (classes I–IV) characterizes anticipated ETI difficulty based upon the oropharyngeal structures visible on pre-operative evaluation (8). For example, an individual in whom the tonsillar pillars and uvula are fully visible would be considered Mallampati class I (anticipated easy intubation). In contrast, an individual in whom none of the oropharyngeal structures can be seen would be considered a Mallampati class IV (anticipated very difficult intubation). Anesthesiologists use the Mallampati score to predict the difficulty of ETI efforts. Students reported Mallampati scores based upon pre-operative assessment by themselves or attending anesthesiologists (9).

Conventional oral ETI involves direct laryngoscopy (insertion of the metal laryngoscope into the mouth to expose the vocal cords) and intubation (placement of tube through vocal cords). We defined an ETI attempt as one direct laryngoscopy with intent to place an endotracheal tube, regardless of the success of endotracheal tube placement. We defined a successful ETI attempt as the combination of successful direct laryngoscopy and successful placement of an endotracheal tube into the trachea by the student. If the student's ETI attempts failed but another individual subsequently performed successful ETI, the student recorded the encounter as a failed student ETI. We excluded cases where the student performed only laryngoscopy or only endotracheal tube insertion but did not attempt to perform both. We excluded laryngeal mask airway insertions or instances with mask ventilation only. We did not include data from simulated mannequin or human-simulator ETI in the analysis.

Supervising attending anesthesiologists verified all logbook entries. As this was an observational study, we did not control the types of patients, ETI techniques used (for example, blade size or type), number or duration of direct laryngoscopies, number of clinical encounters, nor number of supervising attending physicians. We did not have information on the characteristics of participating students or attending anesthesiologist preceptors.

We studied ETIs performed by medical students during the period 1 January 2006 to 30 June 2007.

Data analysis

We analyzed the data using descriptive statistics, identifying the median, interquartile range (IQR) and overall range of procedures attempted by each student. We examined overall ETI success rate as well as the success rate for each sequential ETI encounter.

To assess the effect of procedural experience on ETI skill acquisition, we examined the 'learning curve' for ETI success. A learning curve describes the relationship between repeated efforts and operator proficiency (10). In this case the learning curve characterized the improvement in student ETI success with successive clinical ETI efforts. We modeled the relationship between ETI success and cumulative ETI encounters using mixed-effects logistic regression, using ETI success as the dependent variable, cumulative ETI experience as the primary fixed effect and each individual student as a random (clustering) effect. Under this approach, each patient served as the unit of analysis, and the random effect accounted for multiple observations per student.

Because of their potential influence on ETI success, we adjusted the models for patient age, sex, Mallampati score and number of laryngoscopies. We defined ETI success on a per-patient basis, not on a per-laryngoscopy basis. In a separate model, we also controlled for hospital location differences. The general form of the regression model was:

[Intubation success (yes/no)]

= fn[cumulative ETI encounters, patient age, patient sex, Mallampati score, number of direct laryngoscopies]

Prior studies defined ETI proficiency as 90% predicted ETI success (4, 5, 10, 11). We similarly attempted to identify the region of the learning curve approximating 90% predicted ETI success. While applied in prior studies, we elected not to use cumulative sum techniques, which describe performance trends for individual subjects only (4, 11, 12). We conducted all analyses using Stata v.10.0 (Stata Corporation).

Results

Data were available on 178 of 201 medical students (88.6%) during the 18-month study period; 23 students (11.4%) declined to provide data for the study. The 178 students attempted ETI on 1,646 patients. Student ETIs occurred at nine hospital locations, four of which accounted for >10% of attempts, ranging from 10.4% to 36.8% of ETI encounters. The patients were mostly female (52.1%) with a mean age of 47 years (SD 21 years). Mallampati scores were class I 49.9%, class II 38.4%, class III 10.4% and class IV 1.2%.

Data were evaluable for 1,627 ETI attempts; 19 ETIs could not be evaluated due to missing or incomplete data. Students attempted a median of nine ETIs (IQR 6–12; range 1–23). Of these students, 35 (19.7%) attempted one to five ETIs, 75 (42.7%) attempted six to ten, 54 (30.3%) attempted 11–15 and 14 (7.9%) attempted >15 ETIs.

Students attempt a median of one laryngoscopy per patient encounter (IQR 1–1; range 1–3). Medical students successfully completed ETI on 1,220 of 1,627 patients, reflecting an overall success rate of 75.0% (95% CI 72.9–77.1%).

Adjusting for patient age, sex, Mallampati score and the number of laryngoscopies, student ETI success was associated with cumulative ETI encounters (odds ratio 1.08 per additional encounter; 95% CI 1.03–1.13); see Table 1 and Fig. 1. Predicted ETI success increased from 73.6% on the first patient encounter to 90.4% on the 17th and 93.7% on the 23rd encounter. A Hosmer-Lemeshow test applied to an ordinary logistic regression model indicated good model fit ($p=0.43$) with parameter estimates similar to the mixed-effects model.

When fitting a mixed model using hospital as an additional categorical variable, there was no difference in odds of success. Of 178 students, 157 (88.2%) performed ≥ 5 ETI. There were no major differences in the regression model when excluding students with <5 ETIs.

Discussion

This study describes medical student ETI performance over time and across a continuum of training encounters, providing important perspectives regarding student acquisition of basic ETI skill. These results build upon prior studies of trainees in fields where ETI is a core skill, for example paramedic students and anesthesia residents (4–6). While our contrasting study evaluated a large heterogeneous group of third-year medical students, we were still able to detect improvements in ETI skill acquisition, supporting the value of the experience to all students – not just those motivated to learn ETI.

Table 1. Results of multivariable mixed-effects model: odds ratio for cumulative ETI encounter reflects odds of success for each additional ETI patient encounter

Variable	Odds ratio (95% CI)
Cumulative ETI encounter (odds of success for each successive ETI encounter)	1.08 (1.03–1.13)
Patient age (years)	1.01 (1.00–1.02)
Patient sex (male vs female)	0.67 (0.49–0.90)
Patient Mallampati score (I–IV)	0.41 (0.33–0.51)
Number of laryngoscopies	0.42 (0.28–0.63)

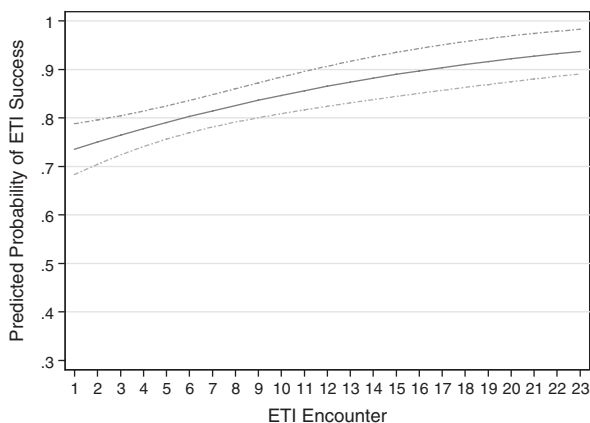


Fig. 1. 'Learning curve' for medical student ETI.

Ericsson's 'deliberate practice' model provides a theoretical framework for understanding the ETI skill acquisition observed in this study (13). While experience may improve performance in an activity, repetition alone may not lead to superior or expert skill levels. Deliberate practice posits that students must engage in intense goal-directed learning to achieve higher levels of proficiency. Learning activities pursued by the student must correct weaknesses and improve performance, and must be coupled with immediate feedback, correction, remediation and repetition. To engage in deliberate practice, students must first perform tasks outside their current realm of reliable performance. In the spectrum of ETI expertise acquisition, our study illustrates the latter point, depicting acquisition of basic ETI skill by novice medical students without prior specialized airway management skills. Attainment of expert-level ETI likely requires additional specialized goal-directed learning beyond the scope of our basic anesthesia curriculum.

The complementary use of human-simulator training in this series may have contributed to ETI skill acquisition. Hall et al. postulated that paramedic students could acquire ETI proficiency using human-simulator-based training only, without live operating room ETI (14). Mulcaster et al. and Harrison et al. included simulated ETI training prior to clinical experience (15, 16). Simulator/mannequin-based training theoretically facilitates intensive teaching without the distractions of ongoing clinical care, allowing for concentration on isolated aspects of a process or skill. Unfortunately, the design of this study did not permit evaluation of the independent or interactive effect of simulation upon clinical ETI performance.

Prior efforts defined ETI proficiency as a predicted ETI success of 90% (5, 6, 17). While the medical students in our series reached this threshold after 17 encounters, we hesitate to conclude that students achieved ETI proficiency after this quantity of experience. Beyond ETI success, performance nuances (for example, the manner

or speed of direct laryngoscopy) may distinguish expert from novice intubators. As alluded to previously, ETI is a complex skill, and students must likely engage in specialized strategies to achieve expert skill levels. Because of the absence of validated ETI rating scales, we were unable to characterize other dimensions of airway performance.

This study could not evaluate the safety of student ETI efforts in the operating room. However, we believe that the educational program is safe given the guidelines and culture of our institution. For example, the institution has a strict policy requiring attending anesthesiologist presence during anesthesia induction and ETI. The majority of student ETIs occurred on patients rated Mallampati class I or II, suggesting that students preferentially intubated easier cases. Furthermore, most patient encounters involved only one medical student laryngoscopy attempt, signaling potential limitation of student ETI efforts. We believe that early medical student exposure to ETI training is appropriate as long as the experience is appropriately supervised. Institutions without appropriate supervisory resources or culture may not be able to attain the same balance between education and patient safety.

Limitations

We were unable to quantify or adjust for prior airway experience. While supervising anesthesiology staff verified all logbook entries, self-reporting bias may have resulted in over-reporting of student ETI success. As discussed previously, students in this series may have preferentially performed easier intubations. There was wide variation in the number of ETI opportunities afforded to each student (range 1–23). We did not evaluate other airway management procedures, such as bag-valve-mask ventilation or laryngeal mask airway insertion.

We did not have information about the characteristics of students or instructors. We could not control for patient selection, ETI techniques used or other aspects of clinical care or education. We could not control for differences in instructors or instructional technique, or changes in clinical skill over time. Performance may have differed with longer or additional clerkship experience.

Our study only evaluates psychomotor skills; we did not assess decision-making skills, which are important in airway management. Our series depicts intubation performance by medical students under controlled, supervised operating room conditions and cannot be interpreted outside of this clinical practice setting.

Other factors may have influenced skill acquisition. For example, the nature and quality of instructor-trainee interaction would be expected to influence the learning process. Students planning to pursue critical care-oriented fields may have been more motivated to learn

ETI, performing larger numbers of ETIs and attaining higher rates of early ETI success.

We applied the best available analytic strategies given the inherent limits of the available data. More sophisticated modeling may be possible with a larger, more detailed dataset. Our study also did not evaluate skill decay, which is possible after initial periods of training and practice (13).

Conclusions

In this series medical student ETI proficiency was associated with cumulative clinical procedural experience. Clinical experience may provide a viable strategy for fostering medical student procedural skills.

Authors' contributions

HEW and MPM conceived and designed the study. PGT carried out the study and collected data. HEW, PGT and MPM analyzed the data. All authors contributed to drafting and critically revising the manuscript.

Conflict of interest and funding

The authors declare no competing interests. Dr Wang was supported by Clinical Scientist Training Award K08-HS013628 from the Agency for Healthcare Research and Quality. Dr Tarasi received support from the University of Pittsburgh Anesthesiology Summer Preceptorship Program.

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