PARAMEDIC TRAINING FOR PROFICIENT PREHOSPITAL ENDOTRACHEAL INTUBATION

Keir J. Warner, BS, David Carlbom, MD, Colin R. Cooke, MD, MSc, Eileen M. Bulger, MD, Michael K. Copass, MD, Sam R. Sharar, MD

ABSTRACT

Background. Emergency airway management is an important component of resuscitation of critically ill patients. Multiple studies demonstrate variable endotracheal intubation (ETI) success by prehospital providers. Data describing how many ETI training experiences are required to achieve high success rates are sparse. **Objectives.** To describe the relationship between the number of prehospital ETI experiences and the likelihood of success on subsequent ETI and to specifically look at uncomplicated first-pass ETI in a university-based training program with substantial resources. **Methods.** We conducted a secondary analysis of a prospectively collected cohort of paramedic student prehospital intubation attempts. Data collected on prehospital ETIs included indication, induction agents, number of direct laryngoscopy attempts, and advanced airway procedures performed. We used multivariable generalized estimating equations (GEE) analysis to determine the effect of cumulative ETI experience on first-pass and overall ETI success rates. **Results.** Over a period of three years, 56 paramedic students attempted 576 prehospital ETIs. The odds of overall ETI success were associated with cumulative ETI experience (odds ratio [OR] 1.097 per encounter, 95% confidence interval [CI] = 1.026–1.173, p = 0.006). The odds of first-pass ETI success were associated with cumulative ETI experience (OR 1.061 per encounter, 95% CI = 1.014–1.109, p = 0.009). **Conclusion.** In a training program with substantial clinical opportunities and resources, increased ETI success rates were associated with increasing clinical exposure. However, first-pass placement of the ETT with a high success rate requires high numbers of ETI training experiences that may exceed the number available in many training programs. **Key words:** paramedic; student; endotracheal intubation; rapid-sequence induction; training

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INTRODUCTION

Emergency airway management is a central and important component of resuscitation of critically ill patients. Prehospital endotracheal intubation (ETI) success rates range from 69% to 98.4%.[1–6] Factors contributing to this variability in success may be divided into several categories: system factors, patient factors, and paramedic experience.[7] Paramedics face a constant challenge in obtaining adequate exposure to opportunities to perform this critical procedure and maintain this demanding manual and cognitive skill.

There are sparse data describing how many ETI training experiences are required to achieve appropriately high success rates with advanced airway management.[8] The most complete survey of paramedic training programs describes a median number of total ETIs per student of seven, with recommendations that 20–25 total ETIs are necessary to achieve an overall ETI success rate of 90%.[8] The goal of this study is to describe the relationship between the number of ETI experiences during initial paramedic student training and the likelihood of success on subsequent ETI attempts in the prehospital setting, in a university-based paramedic training program with substantial resources and clinical opportunities.

Because ETI with multiple attempts may increase potential complications, we wanted to specifically evaluate the training of paramedic students to perform uncomplicated first-pass ETI successfully. Additionally, we sought to determine a minimum threshold number of ETIs that should be performed by paramedic students to achieve a prehospital ETI success rate of 90% prior to graduation. We hypothesized that the number of ETI attempts by paramedic students early in their training would be associated with a greater ETI success rate prior to graduation.

MATERIALS AND METHODS

Study Design

We conducted a secondary analysis of a prospectively collected cohort of paramedic student prehospital intubation attempts. The protocol was reviewed and approved by the University of Washington Human Subjects Division (institutional review board). Because this investigation was retrospective, the requirement to obtain consent from either patients or students was

waived. Paramedic students (approximately 20 per year) acquire didactic knowledge and experience in prehospital medical care during a nine-month, full-time curriculum in the Seattle Fire Department's Medic One program prior to obtaining paramedic certification. All paramedics in the program are trained in the student curriculum of the University of Washington Paramedic Training Program and follow uniform patient management protocols. Data on ETIs performed by students were collected in the Paramedic Training Quality Assurance Program by a single coordinator, who was not blinded to the purpose of the study.

EMS System and Training Hospital

The Seattle Fire Department employs a tiered prehospital emergency medical services (EMS) response triaged by dispatchers based on severity of illness or injury. The average response time for basic life support (BLS) units is 3 minutes, and that for advanced life support (ALS) units is 5 minutes.[9] At any time, seven medic units and one medical services officer are available within the city; each medic unit is staffed by two paramedics. Physician medical control is provided by radio or phone from the emergency department at Harborview Medical Center (HMC). Two medic units are stationed at HMC and paramedic students rotate on these units to gain prehospital clinical experience when not in didactic or laboratory classes. Two students work with two experienced medics on each unit and rotate on a 12-hour shift schedule.

Paramedic Training Overview

The University of Washington Paramedic Training Program is based at HMC. Students in the paramedic training program are trained over a nine-month period and receive 2,200 hours of training divided between 400 hours of lectures, 100 hours of laboratory work, 600 hours of hands-on clinical work (e.g., emergency department, operating room), 800 hours of field internship, and 300 hours of formal evaluation.

Airway management education begins in the first week of training. Initial exposure to BLS and ALS airway techniques begins early to allow maximum time to accumulate procedural experience. Students' initial experience with ETI begins with intensive manikin training supervised by paramedic instructors and emphasizing laryngoscopy skills and coincides with lectures on airway management and skill laboratories. This translates to practical clinical experience in the HMC operating room where students are taught airway assessment, bag–mask ventilation, direct laryngoscopy, and rescue techniques by faculty from the University of Washington School of Medicine Department of Anesthesiology. After completing a minimum of five successful ETIs in adults in the operating room,

students are allowed to perform airway management in the field under the direct supervision of senior paramedics, but continue to acquire additional airway management experience in the operating room.

Prehospital airway management experience extends for approximately eight months. Students may attempt ETI in the emergency department with permission and direct supervision from attending physicians. Additional education in pediatric airway management is provided in the operating room of Seattle Children's Hospital under direction of faculty from the University of Washington School of Medicine Department of Anesthesiology. Advanced training in surgical airway management is provided by the Director of Paramedic Training and the University of Washington Department of Surgery in simulation laboratories.

Data Collection

ETI data were collected by the Paramedic Training Quality Assurance Program from standardized, self-report procedure forms completed by the students after each patient contact involving airway management in the operating rooms, in the emergency department, and in the field. An *ETI attempt* was defined as any placement of the laryngoscope in the mouth, and *subsequent attempts* were defined as any further laryngoscope placements that followed an unsuccessful ETI attempt. *Success* was defined as any placement of an endotracheal tube (ETT) that was confirmed to be within the trachea regardless of number of attempts, and *first-pass success* was defined as placement of an ETT within the trachea on the first ETI attempt.

Data collected from the operating room and emergency department included only the numbers of successful ETIs performed. Data collected on prehospital ETIs included indication, paralytic drug use, sedation use, pulse oximetry use, capnography use, number of direct laryngoscopy attempts, and advanced airway procedures performed (if needed, because of unsuccessful oral ETI). Data were collected on each intubation and entered into a Microsoft Access Database (Microsoft Access 2002 SP3, Microsoft Corp., Redmond, WA).

The primary outcome variable was successful placement of an ETT in the trachea by the student, regardless of number of attempts. Previous studies of ETI skill acquisition have defined successful placement as any placement of the ETT regardless of number of laryngoscopy attempts.[8] Since first-pass ETI success minimizes potential patient complications, including hypoxemia, hypercarbia, aspiration, and intubation-related trauma due to multiple attempts, we considered uncomplicated first-pass placement of the ETT as the benchmark for ETI training success. First-pass success rates for student ETI attempts in the prehos-

pital setting are presented as the secondary outcome variable.

Statistical Analysis

Data on each student's experience in ETI were described using measures of central tendency for continuous data and percentages for categorical data. Multivariable logistic regression, using generalized estimating equations (GEE) with robust variance estimators, was used to assess the effect of cumulative experience on paramedic student prehospital ETI success rates while adjusting for confounding variables. GEE offers a simple regression-based method to account for the within-student correlation of each ETI success or failure. We considered cervical spine precautions in trauma, cardiac arrest, and rapid-sequence induction (RSI) as potential confounders in the analysis. We summarized the relationship between prehospital ETI success rate and total number of ETI attempts by plotting the predicted success rate and 95% prediction intervals from the regression equation as a function of cumulative number of ETIs. All tests for significance were two-tailed and utilized an α of 0.05. Statistical analyses were conducted using Stata 9.2 (StataCorp LP, College Station, TX).

RESULTS

Over a period of three years, 56 paramedic students in three consecutive classes completed training. The students attempted 1,616 intubations, with each student attempting a median of 29 intubations (Table 1). Operating room experience in adults accounted for 706 (44%) of all ETIs. Students performed 71 successful ETIs in the emergency department (4% of all ETIs). Pediatric experience in the operating room comprised 263 (16%) of successful student ETIs, with each student achieving a median of five pediatric ETIs. The remaining 576 (36%) ETIs were done in the prehospital setting under the supervision of senior paramedics. Each paramedic student attempted a median of 10 prehospital ETIs, with a range of 3–19.

Of the 576 prehospital ETI attempts, 175 (30%) were made while the patient was in cardiac arrest

TABLE 1. Location and Number of Endotracheal Intubations Attempted by the Paramedic Students ($n = 56$ Students)

ETI Location	n	No. ETIs per Student, Median (IQR)
Operation room (adults)	706	13 (11–14)
Emergency department	71	1 (0–2)
Operating room (children)	263	5 (3–6)
Prehospital setting	576	10 (7–13)
TOTAL INTUBATIONS	1,616	29 (25–33)

ETI = endotracheal intubation; IQR = interquartile range.

TABLE 2. Special Patient Physiology: Paramedic Students' Attempts at Prehospital Endotracheal Intubation ($N = 576$ Attempts)

ETI Type	n	Percentage of Prehospital ETIs	No. ETIs per Student, Median (IQR)	Total Success Rate	First-Pass Success Rate
Cardiac arrests	175	30.4%	3 (2–4)	88.6%	63.4%
Trauma	148	25.7%	3 (1–4)	87.8%	63.5%
RSI	375	65.1%	6 (5–9)	88.3%	67.7%

Because some patients may have fit into several of these categories, the total does not sum to 576.
ETI = endotracheal intubation; IQR = interquartile range; RSI = rapid-sequence induction.

(Table 2). ETI attempts in trauma patients with cervical spine precautions accounted for 148 (26%) of prehospital attempts. RSI using succinylcholine for paralysis and benzodiazepines for sedation accounted for 375 (65%) of student prehospital attempts. Thirty (5%) attempted ETIs were classified as *difficult airway*, defined as a failed ETI by a paramedic student and one or more missed attempts by an experienced laryngoscopist (e.g., senior paramedic or anesthesiologist). Three pediatric patients (age ≤14 years) were intubated in the prehospital setting by students during the three-year period.

Paramedic student success at prehospital ETI, regardless of number of laryngoscopic attempts, averaged 88% for all students, whereas the average rate of first-pass ETI success was 66%. However, these success rates are cumulative for the entire training period and fail to account for the learning curve of ETI. Multivariable GEE analysis described the effect of increasing prehospital ETI experience on prehospital ETI success rates (Figure 1, Table 3 and 4). To account for potential confounding variables, we included variables known to contribute to the difficult airway, including cervical spine precautions, cardiac arrest with cardiopulmonary resuscitation (CPR), and RSI. Regardless of number of ETI attempts, the odds of ETI success were 1.097 times higher for each successive patient, demonstrating the positive effect of cumulative experience on overall intubation success (odds ratio [OR] 1.097, 95% confidence interval [CI] = 1.026–1.173, p = 0.006). For first-pass ETI success, the odds of ETI success were 1.061 times higher for each consecutive prehospital ETI experience (OR 1.061, 95% CI = 1.014–1.109, p = 0.009).

DISCUSSION

After adjusting for potential confounding variables, we demonstrated that the most important factor in prehospital ETI success among paramedic students was cumulative exposure to prehospital ETI. However, gaining adequate clinical training and exposure to ETI is challenging for many programs. In our system, we
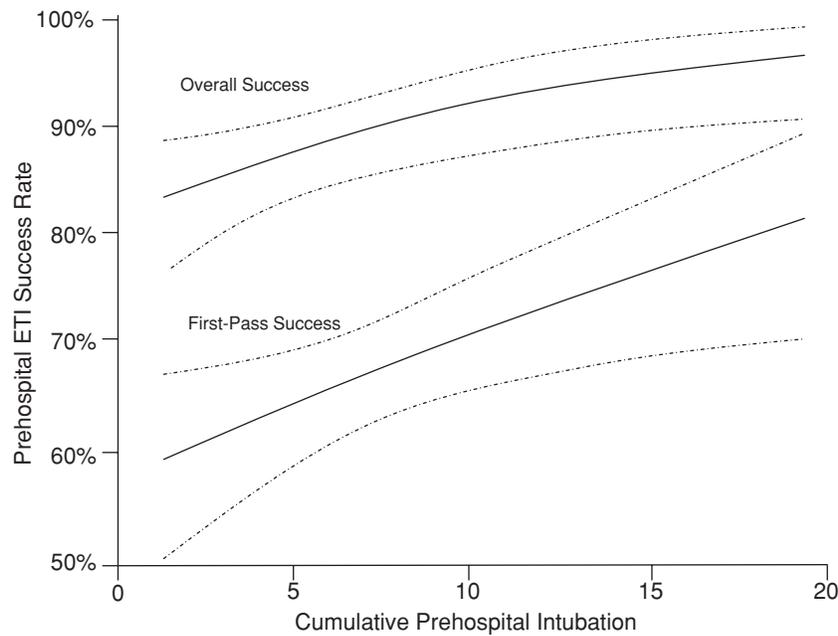
FIGURE 1. Mean prehospital endotracheal intubation (ETI) success rates are graphed (*solid line*) with 95% confidence intervals (*dashed lines*) for overall ETI success rates (regardless of number of attempts) and first-pass ETT placement. Whereas data for mean student overall ETI success begin to plateau between 10 and 15 prehospital ETIs, there is no plateau for first-pass success up to 20 prehospital ETIs, suggesting that more than 20 prehospital ETIs are required to achieve appropriate first-pass ETI success. Note that this figure is constructed only from data collected in the prehospital ETI setting and does not include ETIs performed in other settings (e.g., operating room, emergency department).

have access to a university-affiliated surgical facility, support from the anesthesia faculty, a rigorous quality assessment program providing real-time monitoring of student progress, and ample clinical opportunity for ETI training.

Despite our findings, prehospital ETI by paramedics is still controversial. Several authors, including an expert panel, attribute the lack of efficacy of prehospital ETI in preventing mortality to low ETI success rates, complicating factors such as hypoxia and hyperventilation, and system issues that may impair adequate paramedic training and skills maintenance.[7,10] Many systems capture only placement of the ETT, without accounting for other factors such as hypoxia, hyper- and hypoventilation, aspiration, and multiple laryngoscopic attempts. The need to reduce these important complications suggests that training goals

should focus on first-pass ETI success. Currently, few prehospital systems have reported first-pass success rates for ETI, but those reported range from 62% to 75%.[3,11]

The minimum educational standards established for prehospital ETI by the National Highway Traffic Safety Administration (NHTSA) *Emergency Medical Technician Paramedic: National Standard Curriculum* may not be adequate to guarantee subsequent success in ETI. The NHTSA document specifies that students should achieve a minimum of five successful ETIs prior to graduation,[12] a number that is discordant with minimums established for other intubating providers. This level is well below the recommended level of 35 ETIs for emergency medicine residents.[13] Anesthesiology residents reportedly must perform between 45 and 60 ETIs to achieve at least a 90% success rate in

TABLE 3. Factors Contributing to Increasing Odds of Overall Success in Paramedic Intubations

Adjusted GEE All-Pass Success	Odds Ratio	95% Confidence Interval
ETI number	1.097	1.026–1.173
Cardiac arrests	1.045	0.454–2.405
Trauma	0.904	0.482–1.697
RSI	0.949	0.432–2.081

Odds of overall intubation success were higher for each successive patient, demonstrating the effect of cumulative experience on overall intubation success.

ETI number = cumulative number of ETIs by student; GEE = generalized estimating equations; RSI = rapid-sequence induction.

TABLE 4. Factors Contributing to Increasing Odds of First-Pass Success in Paramedic Intubations

Adjusted GEE First-Pass Success	Odds Ratio	95% Confidence Interval
ETI number	1.061	1.014–1.109
Cardiac arrests	1.263	0.698–2.286
Trauma	0.836	0.552–1.266
RSI	1.575	0.831–2.985

Odds of first-pass intubation success were higher for each successive patient, demonstrating the effect of cumulative experience on first-pass intubation success.

ETI number = cumulative number of ETIs by student; GEE = generalized estimating equations; RSI = rapid-sequence induction.

the controlled operating room setting.[14–17] Wang et al. previously demonstrated paramedic student learning curves for ETI suggesting that at least 20–25 live ETIs need to be performed to achieve success rates of at least 90%.[8] In our training program, students had a median of 29 total laryngoscopy experiences across all locations. These numbers far exceed the experiences reported in similar studies.[8] This increased exposure during the training period may help to explain the high success rates observed in our cohort. However, the learning curve may not be significantly different in a program with fewer ETI opportunities; rather, the curve would be shorter and achieved success rates would be lower in proportion to the student's position on the curve at graduation.

Paramedic students performing ETI in the operating room are subject to selection bias, as patients with more stable physiology and less challenging anatomy often may be selected by the anesthesia faculty for paramedic student learning. This may also occur in the prehospital environment as senior paramedics select patients with more manageable conditions and in less austere environments for student ETI attempts. Previous anesthesiology research employed trained observers to document ETI attempts and successes that reflect accurate and objective results.[15] However, other similar prehospital research utilized self-reports of ETI attempts and successes that might have introduced bias into the data collection.[1,3,8,11] Figure 1 demonstrates our findings for ETI success in the prehospital setting; it must be considered that paramedic students in our training program acquire important, yet variable, ETI experience in other settings (e.g., operating room) prior to attempting ETI in the prehospital setting.

Our data demonstrate that while the learning curve for overall ETI success in the prehospital setting begins to plateau above 15 prehospital ETIs, the learning curve for first-pass success shows no evidence of a plateau. Thus, the actual number of prehospital ETIs required to achieve first-pass ETI proficiency may extend beyond 20 prehospital attempts. Many paramedic programs do not have the opportunities available for each paramedic student to perform more than 20 total ETIs (including the operating room, emergency department, and prehospital setting) during training.[8,18]

In our prehospital system, ETI is performed only when indicated as an emergent, lifesaving procedure. We have established that a 95% success rate is a minimum standard in this system. In systems where alternative airway techniques are more commonly utilized, one might tolerate a slightly lower success rate for ETI; however, ETI remains the standard in our system for providing a secure airway that has the highest likelihood of providing 1) oxygenation, 2) ventilation, and 3) prevention of aspiration.

Although the use of a threshold level for ETI proficiency based on mean student performance is an attractive benchmark, our data suggest that ETI proficiency may be achieved only by careful real-time monitoring of paramedic student ETI success. This allows for direct remediation of students who require more exposure to achieve proficiency. Our program accomplishes this task by using an online data-collection system maintained by the paramedic training quality coordinator to contemporaneously monitor performance.

LIMITATIONS

This study has several noteworthy limitations. First, we relied on self-reported data for number of attempts and overall success rates, which may bias results in the direction of higher success (i.e., if failed ETI attempts were not reported). However, since students were supervised for all ETIs, our data are more likely to be accurate. Second, we have limited data on numbers of ETI attempts for procedures performed in the operating room, thereby limiting our ability to thoroughly evaluate the contribution of operating room training. The relationship between cumulative intubation attempt and intubation success may be subject to residual confounding. We adjusted for CPR, RSI, and cervical precautions in the regression model, yet there are known predictors of intubation success such as patient body mass index (BMI) and oropharyngeal anatomy that may confound the relationship between intubation attempt and intubation success that were not collected in the quality assurance database and were therefore not included in the regression analysis.

CONCLUSIONS

In a paramedic training program with substantial resources and clinical opportunities, the learning curve for prehospital ETI success rates demonstrates an increase in the odds of successful ETI with each cumulative training exposure to ETI. First-pass placement of the ETT with high success rates requires high numbers of previously performed ETIs that may exceed the number available in many training programs.

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