Quality Improvement Program Outcomes for Endotracheal Intubation in the Emergency Department

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Objectives: We describe our 3-year experience with endotracheal intubation (ETI) outcomes during a multidisciplinary emergency department (ED)-based quality improvement (QI) program.

Methods: This was a single-center, observational study taking place during a QI program. We used a registry for airway management performed in the ED from April 2014 to February 2017. The QI program focused on procedural standardization, airway management education, and comprehensive preparation of airway equipment. The primary outcome was first-pass success (FPS) rate. The secondary outcomes were multiple-attempts rate and overall rate of complications.

Results: A total of 1087 emergent ETIs were included. The FPS rate significantly increased from 68% in the first year to 74% in the second year and 79% in the third year (*P* for trend <0.01). The multiple-attempts rate in the first year was 12%, followed by 7% and 6% in the second and third years, respectively (*P* for trend <0.01). The overall complication rate was 16% in the first year, 8% in the second year, and 8% in the third year (*P* for trend <0.01).

Conclusions: We observed improved ETI outcomes in the ED, including increased FPS rate and decrease in multiple-attempt rate and overall complication rate during the multidisciplinary QI program to enhance patient safety.

Key Words: intubation, airway management, quality improvement, patient safety

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Endotracheal intubation (ETI) is a life-saving procedure for critically ill patients in the emergency department (ED). However, several obstacles, including an uncontrolled environment, lack of skilled workforce and advanced equipment, and unstable patients with limited physiologic reserve are challenges associated with ETI in the ED. Difficult intubations during emergent ETI can occur up to twice as often compared with in the operating room.[1] In addition, a number of life-threatening complications including failed intubation, severe hypoxemia, and severe hypotension are associated with emergent ETI.[1,2]

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LOCAL PROBLEMS

After experiencing several sentinel events during ETI attempts in the ED, we determined that the quality of airway management should be improved. We reviewed every sentinel event that occurred in the ED to define underlying causes and identified potentially modifiable factors that might be associated with adverse outcomes. First, the ETI process was highly variable according to the operator, which led to long preparation times. Second, difficult airway characteristics were not uniformly assessed. Third, alternative devices were rarely prepared in case of attempt failure, and ETI was frequently performed without the presence of an expert. Fourth, ETI was frequently attempted without sufficient effort to achieve optimal preoxygenation. Fifth, the concept of a team approach, including information sharing and constructive interventions, was not incorporated into the ETI process. Finally, airway devices were scattered throughout the ED, and some important devices such as an end-tidal CO_2 monitor and video laryngoscope (VL) were not available.

The authors perceived these issues as urgent and made deliberate plans to improve quality of airway management. We initiated a quality improvement (QI) project in March 2014 in the ED. In this study, we described our 3-year experience and ETI outcomes during this multidisciplinary ED-based QI program.

METHODS

Study Design and Setting

This was an observational study taking place during a QI project. We used an institutional registry of airway management performed in the ED from April 1, 2014, to February 28, 2017. The study was approved by the institutional review board, and informed consent was waived because it was a retrospective study and no interventions were performed.

The study was conducted in the ED of Samsung Medical Center, a university-affiliated teaching hospital with approximately 70,000 patient visits a year. All ETI performed on adult patients (18 years or older) during the study period were analyzed. This institution has an accredited 4-year emergency medicine (EM) residency program. Approximately 400 cases of ETI per year are performed on adult patients in the ED. An EM physician performed most of the ETIs.

Quality Improvement Project for Emergency Airway Management

The Airway QI Team, consisted of EM physicians, emergency nurses, and emergency medical technicians (EMTs),

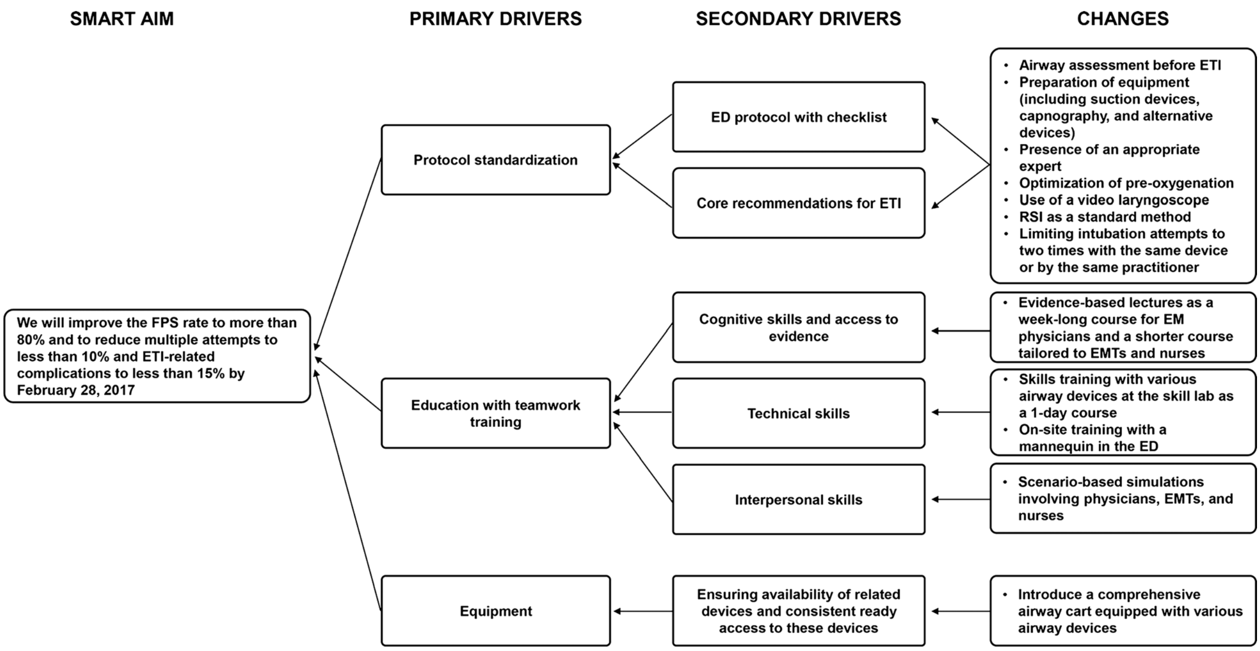

FIGURE 1. Driver diagram for improvement in airway management. RSI, rapid sequence intubation.

was organized in March 2014 as a part of continuous QI project for emergency airway management. Representatives from every professional area relevant to airway management in the ED were involved in the program. A multidisciplinary approach was taken to increase the likelihood of program success because change is essential to improving quality and is often difficult, especially in the context of changing established cultures prevalent throughout the ED.

Aims, Drivers, and Change Ideas

The QI team developed a "SMART aim" (Specific, Measurable, Actionable, Relevant, and Time-bound) and a "driver diagram" with specific action plans to achieve goals (Fig. 1).[3] The QI team aimed to improve the first-pass success (FPS) rate to more than 80% and to reduce multiple attempts to less than 10% and ETI-related complications to less than 15% by February 28, 2017. The primary drivers were procedure standardization, education with teamwork training, and equipment.

Procedure Standardization

It is unrealistic to approach treatment of all patients in the same way because of the anatomical and pathophysiological heterogeneity of ED patients. However, standardizing best practices would be beneficial in the ED environment because the time available for detailed planning is often limited, and standardization provides predictability, consistency, and reliability to professionals participating in the procedure.[4] After evidence review processes by EM physicians, core recommendations and an ED protocol with a checklist were developed for bedside workflow from preparation to post-intubation management (Box 1, and see Appendix, Fig. E1 http://links.lww.com/JPS/A177).[5] These recommendations were not intended to introduce or test new concepts, but rather to apply those that have been established on the basis of published data in this field.

BOX 1. Core Recommendations for Endotracheal Intubation

Preparation	1. Assess risk factors for difficult airway before intubation 2. Prepare equipment including suction devices and quantitative capnography before intubation 3. Prepare secondary plans and devices before the first intubation attempt 4. Ensure the presence of two operators including more than one experienced physician 5. Perform adequate preoxygenation that targets more than 90% SpO_2
Intubation	6. Use a video laryngoscope as the first method of intubation. To educate inexperienced physicians, use C-MAC for direct laryngoscopy under video monitoring 7. Use rapid sequence intubation as a standard method 8. Use ketamine and etomidate as sedatives (with dose reduction in patients with unstable hemodymic status or advanced age). Use of rocuronium or succinylcholine as paralytics depending on contraindications 9. Consider awake intubation in patients with anticipated difficult airway and when SpO_2 cannot be manitained at more than 90% (e.g., tracheal stenosis, upper airway obstruction, dystorted airway anatomy) 10. Limit intubation attempts to two attempts with a failed device or by the same operator
Postintubation	11. Use quantitative capnography for tube verificaiton 12. Monitor for postintubation complications 13. Review and give feedback in cases with multiple attempts or severe complications after the procedure

NIV, noninvasive ventilation.

During the preparation period, particular attention was paid to patient assessment. In addition, the recommendations emphasized an established backup plan for every ETI procedure including collaboration with an anesthesiologist and otolaryngologist as well as availability of alternative devices in the case of a failed attempt. At least one experienced EM physician should be on site to supervise all processes.[6,7] When ETI was the selected treatment course for a patient in the ED, the charge nurse broadcast an announcement in the ED to inform the airway team.

The intubation plan was divided into the following five options: (1) Plan A1, VL; (2) Plan A2, direct laryngoscope (DL); (3) Plan B, intubation with bougie; (4) Plan C, extraglottic device (EGD) or intubation through EGD or reattempt with another method; or (5) Plan D, surgical cricothyroidotomy with/without EGD. No matter which plan was used on the first attempt, at least one alternative method had to be prepared for unexpected situations.

Preoxygenation has been demonstrated to be less effective in critically ill patients, especially among patients intubated for reasons other than airway protection.[8] For preoxygenation, patients were categorized according to peripheral oxygen saturation (SpO_2) at the time of decision to intubate: (1) low risk, $SpO_2 > 95\%$; (2) high risk, SpO_2 91%–95%; and (3) hypoxemic, $SpO_2 < 91\%$. Positive pressure ventilation and apneic oxygenation were considered in high-risk patients according to the situation. Positive pressure ventilation and apneic oxygenation were mandatory for hypoxemic patients.[9] For this protocol, a nurse would set up the mechanical ventilator and nasal cannula at the beginning of the preparation period.

For ease of drug preparation during rapid sequence intubation, we limited the available sedatives (ketamine and etomidate) and neuromuscular blocking agents (succinylcholine and rocuronium). To prevent postintubation hypotension, sedatives were titrated in patients at high risk (age ≧ 70 years, hemodynamically unstable defined as systolic blood pressure of 90 mm Hg or less, mean arterial pressure of 65 mm Hg or less, or shock index 0.8 or less).

The use of quantitative capnography was emphasized after placement of an endotracheal tube. One designated EMT was assigned to measure end-tidal CO_2 after tube placement.

Education and Teamwork Training

An airway management course that consisted of evidence-based lectures, hands-on training with devices, and scenario-based simulations was developed for education.[10] Two-hour lectures for EM physicians given by EM attending physicians were conducted daily for 1 week. A shorter course tailored to EMTs and nurses was also provided. A 1-day workshop consisting of hands-on sessions and scenario-based simulations was designed for technical and interpersonal skills training. Hands-on sessions covered various techniques from bag-mask ventilation to flexible fiberoptic bronchoscopy. A cricothyroidotomy session using a pig tracheal model was also included. During the simulation, the participants practiced how to respond to commonly encountered clinical situations using the airway checklist. Elements of effective resuscitation team dynamics used in advanced cardiopulmonary resuscitation were incorporated into our simulation program.[11] These included closed-loop communication, clear messages, clear roles and responsibilities, knowledge sharing, constructive intervention, re-evaluation and summarizing, and mutual respect. We assigned airway team roles as follows: supervising physician, operator, medication and device assistants, and process monitoring member. The participants changed roles according to scenario to ensure that they understood not only their own role but also the roles of other team members. This training method had certain advantages. First, it ensured appropriate preparation including devices and drugs. Second, all team members were aware of the next actions. Third, it enabled the team members to communicate well and clarify their roles. These courses were conducted annually, and all EM physicians and EMTs and approximately half of ED nurses participated in this workshop. In the second year of the project, an airway mannequin was placed in the ED to facilitate skills practice during duty hours.

Equipment

After identifying equipment problems, we decided to develop a comprehensive airway cart prepared for complex situations. The design of the cart was focused on ensuring the consistent availability of necessary devices. This concept was supported by Mort,[12] in that immediate availability of advanced airway devices during emergent intubation was associated with reduced ETI-related complications and attempts. The design of the cart corresponded to the proposed intubation plan and checklist for airway management (see Appendix, Fig. E1, http://links.lww.com/JPS/A177). One of our team members designed a preliminary form of the cart, which was manufactured by a professional medical company during the first year of the QI project (see Appendix, Fig. E2, http://links.lww.com/JPS/A178). The devices in the cart are listed elsewhere (see Appendix, Table E1, http://links.lww.com/JPS/A179).

The cart was managed by the designated nurse and EMT. They checked the availability and cleanliness of the devices and refilled missing items during every duty period. They also checked the battery charge status for portable devices.

Outcome Measures and Data Collection

The primary outcome was FPS rate. The secondary outcomes were multiple attempts rate and overall rate of ETI-related complications. All intubation processes were monitored by an independent EMT who did not participate in the procedure. The EMT checked each step of the ETI process using the checklist. After the intubation procedure, an airway management registry was completed by the operator and the EMT, and the president of this program confirmed the data. A meeting was held monthly to review the current airway management status and outcomes. In multiple-attempt or complicated cases, the QI team conducted a detailed review of the entire procedure to see whether there were any modifiable factors. The data were retrieved from an airway registry and electronic medical records by a single abstractor and included general patient characteristics of age, sex, height, and weight; vital signs and SpO_2 at the time of the decision to intubate; SpO_2 immediately before the first intubation attempt; reasons for intubation; number of intubation attempts; intubating devices; Cormack-Lehane grade and percentage of glottic opening score reported by the operator; presence of difficult airway characteristics; ETI-associated complications; operator experience and training level; and medications used to facilitate ETI.

Definitions

An intubation attempt was defined as placement of a laryngoscope blade into the mouth, regardless of an endotracheal tube insertion attempt. Multiple attempts were defined as three or more intubation attempts. The FPS was defined as successful ETI on the first intubation attempt. An anticipated difficult airway was defined as the presence of the following characteristics: external features such as short neck, facial trauma, and small mandible; obesity; Mallampati class of greater than 3; airway obstruction including airway edema or a history of tracheal stenosis; distorted airway due to tuberculosis or surgery; cervical immobilization; and lung stiffness including pulmonary edema and limited mouth opening (<3 cm). A difficult airway was defined as Cormack-Lehane grade III or more. Postintubation hypotension was defined as systolic blood pressure of less than 90 mm Hg at any time within 30 minutes after intubation. Postintubation hypoxemia was defined as SpO_2 of less than 80% at any time within 30 minutes after intubation. Cardiac arrest and preexisting hypotension and hypoxemia before ETI were not considered as postintubation complications.

Statistical Analysis

Data are presented as median with interquartile range for numeric data and number with percentage for categorical data. The Kruskal-Wallis test was used for nonnormally distributed variables, and the χ^2 test was used for categorical variables. We used nonparametric testing for trends in outcomes and core recommendation adherence across 3 years. A multiple logistic regression model was developed to assess variables related to FPS. Variables with a P value of less than 0.2 on univariate logistic regression were included in multiple logistic regression. The following variables were included in the final model: study period, patient age and sex, anticipated difficult airway, operator training level, indication for intubation (cardiac arrest versus noncardiac arrest), device used to facilitate intubation (DL versus VL) on the first attempt, and quantitative capnography use for tube verification. The results were described as adjusted odds ratio (OR) with a 95% confidence interval (CI). We used the Hosmer-Lemeshow test to assess goodness of fit. A P value of less than 0.05 was considered significant. STATA 13.0 (STATA Corporation, College Station, Tex) was used for statistical analysis.

RESULTS

A total of 1087 emergent ETIs were included during the study period. The baseline characteristics of all cases are presented elsewhere (see Appendix, Table E2 http://links.lww.com/JPS/A179). The median (interquartile range) age of patients was 67 (54–76), and 62% were male. The most common indication for ETI was respiratory distress (35%), followed by cardiac arrest (33%), airway protection for altered mentation (25%), and shock (6%).

In cases without cardiac arrest, etomidate was the most frequently used induction agent (49%), followed by ketamine (34%) and midazolam (5%) (see Appendix, Table E3, http://links.lww.com/JPS/A179). Neuromuscular blocking agents were used in 636 cases (87%), and succinylcholine was the most commonly used drug (62%).

Adherence to Core Recommendations

Adherence by core recommendation is shown in Table 1. Adherence to use of quantitative capnography for tube verification was only 36% in the first year but significantly increased to 96% by the third year (P for trend <0.01). Alternative device preparation for first attempt failure was performed in 35% of cases in the first year and increased to 69% and 78% in the second and third years, respectively (P for trend <0.01). Most ETIs were performed in the presence of two or more physicians during the study period. Video laryngoscope was selected as the first device in 9% of cases in the first year, and this increased to 44% and 60% of cases in the second and third years, respectively (P for trend <0.01). Among cases without cardiac arrest, 83% achieved a SpO_2 of 90% or more before first intubation attempt in the first year, which increased to 91% in the third year (P for trend = 0.01).

Outcomes

Figure 2 shows the quarterly changes in FPS rates, multiple-attempt rates, and ETI-related complication rates. The overall FPS rate was 74% (n = 806/1087) (see Appendix, Table E4, http://links.lww.com/JPS/A179). The FPS rate significantly increased from 68% in the first year to 74% in the second year and 79% in the third year (P for trend <0.01). The multiple-attempts rate in the first year was 12%, followed by 7% and 6% in the second and third years, respectively (P for trend <0.01). The overall complication rate was 16% in the first year, 8% in the second year, and 8% in the third year (P for trend <0.01).

Multivariable Analysis

Male sex (adjusted OR = 0.61, 95% CI = 0.45–0.83, $P < 0.01$), difficult airway (adjusted OR = 0.28, 95% CI = 0.18–0.42, $P < 0.01$), and cardiac arrest (adjusted OR = 0.67, 95% CI =0.49–0.91, $P = 0.01$) were associated with lower FPS rate

TABLE 1. Adherence to the Core Recommendations

Overall cases	Total (n = 1,087)	First year (n = 318)	Second year (n = 312)	Third year (n = 457)	*P*	*P* for trend
Quantitative capnography for tube verification	791 (73)	114 (36)	239 (77)	438 (96)	<0.01	<0.01
Alternative device preparation	680 (63)	111 (35)	214 (69)	355 (78)	<0.01	<0.01
Presence of ≥2 physicians	1,043 (96)	304 (96)	298 (96)	441 (97)	0.74	0.50
Presence of an attending physician	935 (86)	267 (84)	270 (87)	398 (87)	0.44	0.23
Preparation of suction device	1,075 (99)	314 (99)	304 (97)	457 (100)	<0.01	0.05
Use of VL*	441 (41)	28 (9)	137 (44)	276 (60)	<0.01	<0.01
In cases without cardiac arrest	**Total (n = 727)**	**First year (n = 224)**	**Second year (n = 209)**	**Third year (n = 294)**		
SpO_2 > 90% immediately before intubation†	595/688 (86)	178/214 (83)	162/194 (84)	255/280 (91)	0.01	0.01
Rapid sequence intubation on first attempt	609 (84)	186 (83)	183 (88)	240 (82)	0.19	0.58

Data are presented as n (%).

First year: April 2014–February 2015; second year: March 2015–February 2016; third year: March 2016–February 2017.

*C-MAC for direct laryngoscopy was included.

†In 39 cases, SpO_2 was uncheckable immediately before intubation.

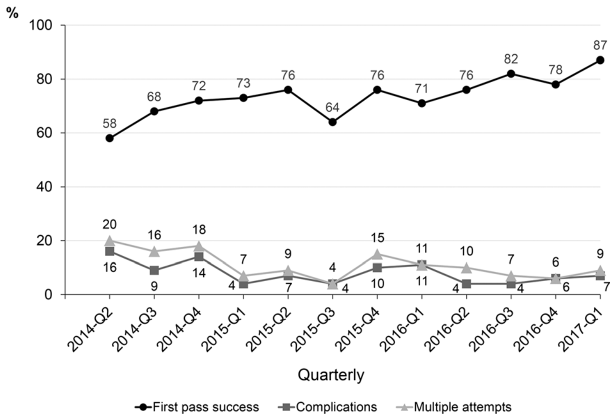

FIGURE 2. Run chart showing outcomes per quarter. Data for March were not included in the first quarter of 2017.

(see Appendix, Table E5, http://links.lww.com/JPS/A179). Third year compared with the first year (adjusted OR = 1.54, 95% CI = 1.01–2.35, P = 0.04), intubation by a senior physician (adjusted OR = 1.81, 95% CI = 1.34–2.43, P < 0.01), and use of VL (adjusted OR = 1.51, 95% CI = 1.08–2.13, P = 0.02) were associated with higher FPS rates.

DISCUSSION

This study used a QI methodology to incorporate ED-based multidisciplinary airway training to improve practice. We observed that the FPS rate increased, whereas the overall complication rate and multiple-attempts rate decreased during the study period. These results might be useful for future studies or activities to improve patient safety during ETI in the ED.

Several factors could have impacted airway management quality and improvement in this study. First, an evidence-based protocol with core recommendations and a checklist tailored for our ED was used. Process standardization using protocols, checklists, and bundles has been well described in the area of critical care,[13] and this approach provides consistency, completeness, efficiency, and overall awareness of the procedure process. Second, preparation for intubation improved. Specifically, preparing alternative devices increased from 35% in the first year to 78% in the final year. In addition, there were no cases in which suction devices were not appropriately prepared in the final year. Appropriate preparation can save time during urgent intubation situations. Third, use of VL increased during the study period. Video laryngoscope can enhance glottis views and increase the FPS rate.[14] In this study, the use of VL was significantly associated with FPS. Fourth, quantitative waveform capnography was used in only 36% of cases at the beginning of the QI program; however, use increased to 77% and 96% in the second and final year, respectively. Quantitative waveform capnography can reduce unnecessary extubation due to ambiguous verification or facilitate early identification of esophageal intubation. Mort[15] showed that esophageal intubation, when detected by clinical assessments based on physical exam, was associated with significant increase in hypoxemia, regurgitation, aspiration, bradycardia, cardiac dysrhythmia, and cardiac arrest in critically ill patients that required emergent ETI outside the operating room. Quantitative waveform capnography has been widely accepted as the most reliable way to confirm correct tube placement even in patients with cardiac arrest.

Our study showed that some complications during ETI could be prevented. Complication rates, including postintubation hypotension, hypoxemia, vomiting, dental injury, and cardiac arrest, were relatively low in the final year. These results might be due to the increased FPS rate and decrease in multiple attempts.[16] In addition, we included some strategies for preoxygenation using bag-valve-mask, noninvasive positive pressure ventilation or apneic oxygenation, and dose reduction of sedatives in specific situations. However, further studies will be needed to evaluate the causality of specific components.

Teamwork is essential for improving patient care and safety, especially in an environment with high-risk patients. One prospective study of adult and pediatric ICUs in the United States reported that teamwork failures accounted for 32% of all incidents that could or did lead to patient harm.[17] Morey et al[18] showed that clinical error significantly decreased from 30.9% to 4.4% through implementation of a teamwork-training curriculum in the ED. Emergency airway management is carried out by ad hoc teams composed of staff with varying levels of educational and occupational training, which highlights the need for team collaboration and preparedness. Although we did not objectively measure the impact of the team approach on patient safety, we believe that our multidisciplinary activities and education led to improved communication and airway management.

The FPS rate was relatively low in our study compared with previously reported data, although it improved during QI program implementation.[4,19] There are several possible explanations for these results. First, we counted any insertion of a laryngoscopic blade into the mouth, whether or not the operator intended to insert a tube into the trachea, because even brief manipulation by the blade could lead to patient harm through nervous system stimulation. Second, every ETI procedure in our study was independently monitored by an EMT, and data were collected in real time to eliminate recall and reporting bias. Kerrey et al[20] analyzed ETI data collected by video review in a pediatric ED. The authors found that first attempt failure was much more common than previously reported and raised concerns about underestimation of this issue in previous studies. Third, we did not implement a policy to exclude young physicians to increase FPS rate. As an academic hospital, we should provide training to less experienced residents. Approximately half of all ETI attempts were performed by a first- or second-year resident. Operator training level was associated with FPS rate in multivariate logistic analysis, and this result was consistent with previous studies.[6,7] Because patient safety should always take precedence over training, various efforts were made to resolve this dilemma. The attending physician was obliged to supervise every ETI procedure. In some cases, C-MAC was used as a DL to teach the DL technique whereas the supervising EM physician was able to see the monitor and provide instructions in real time to assist the operator in finding the glottis and verifying tube placement through the vocal cords.

There were several limitations to this study. First, it was conducted as a single-center study in an academic ED, so generalization of our findings may be limited for other institutions. Second, although registry data were collected prospectively, some were abstracted from medical records. Third, many elements were involved in this project; however, we could not determine which specific elements contributed significantly to the outcomes. Fourth, approximately 15% of first intubation attempts were performed by non-EM physicians (internal medicine physician: 10%; others such as anesthesiologists and critical care physicians: 5%) who did not complete the QI project education programs. Even in these situations, however, the attending EM physician supervised the whole procedure to ensure adherence to the standardized protocols. Fifth, the Hawthorne effect, which is the possibility of enhanced performance or preparation secondary to being observed by an independent EMT, could have affected the results.[21]

Finally, because data were not collected before program initiation, we did not have a control group and could not compare outcomes before and after our program.

In conclusion, we observed an increased FPS rate and decreases in multiple attempts and overall ETI-related complication rates through implementation of a QI methodology including protocol standardization, education with teamwork training, and improved equipment availability and organization. It is important that all professionals in the ED participate in QI programs to improve success rates.

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