3,423 Emergency Tracheal Intubations at a University Hospital

Airway Outcomes and Complications

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ABSTRACT

Background: There are limited outcome data regarding emergent nonoperative intubation. The current study was undertaken with a large observational dataset to evaluate the incidence of difficult intubation and complication rates and to determine predictors of complications in this setting.

Methods: Adult nonoperating room emergent intubations at our tertiary care institution from December 5, 2001 to July 6, 2009 were reviewed. Prospectively defined data points included time of day, location, attending physician presence, number of attempts, direct laryngoscopy view, adjuvant use, medications, and complications. At our institution, a senior resident with at least 24 months of anesthesia training is the first responder for all emergent airway requests. The primary outcome was a composite airway complication variable that included aspiration, esophageal intubation, dental injury, or pneumothorax.

Results: A total of 3,423 emergent nonoperating room airway management cases were identified. The incidence of difficult intubation was 10.3%. Complications occurred in 4.2%: aspiration, 2.8%; esophageal intubation, 1.3%; dental injury, 0.2%; and pneumothorax, 0.1%. A bougie introducer was used in 12.4% of cases. Among 2,284 intubations performed by residents, independent predictors of the composite complication outcome were as follows: three or more intubation attempts (odds ratio, 6.7; 95% CI, 3.2–14.2), grade III or IV view (odds ratio, 1.9; 95% CI, 1.1–3.5), general care floor location (odds ratio, 1.9; 95% CI, 1.2–3.0), and emergency department location (odds ratio, 4.7; 95% CI, 1.1–20.4).

Conclusions: During emergent nonoperative intubation, specific clinical situations are associated with an increased risk of airway complication and may provide a starting point for allocation of experienced first responders.

What We Already Know about This Topic

- Emergent intubations outside the operating room are challenging
- There are limited data regarding their management and outcomes

What This Article Tells Us That Is New

- Based on 3,423 emergent intubations, this study reports a 10% rate of difficult intubations and a 4.2% rate of airway complications
- Difficult intubation or location outside the intensive care unit (ICU) is a predictor of airway complications

URGENT or emergent airway management is often required in hospitalized patients. Compared with elective intubation in the operating room, there are unique challenges inherent in airway management in the emergent nonoperating room setting.[1,2] Providers often must act quickly, are unfamiliar with the patient, and have limited time for assessment. Patients are frequently hypoxic or hemodynamically unstable, rarely fasted, and are often in locations lacking optimal resuscitation equipment.

Despite the fact that providers are frequently faced with these challenging critical airway scenarios, the literature on this topic is limited. Several small studies have documented an 8–12% incidence of difficult intubation in the emergent setting,[3–6] as opposed to 5.8% during elective intubation in the operating room.[7] Mort[5] observed a 7-fold higher complication rate when difficulty was encountered during emer-

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gent intubation (70 *vs.* 10.5%). Complication rates in the emergent setting have been described in several single-center trials: aspiration, 2–4%; esophageal intubation, 1.6–9%; and oropharyngeal trauma, 0.5–7%[3,4,6,8–10]; however, they are limited by variable definitions and small sample size.

Recently, a series of publications[11–14] has discussed the role of neuromuscular blockade (NMB) and the role of trainees in emergent airway management at teaching institutions. NMB to facilitate intubation in this setting remains an area of controversy, and previous investigations[3–6,9] document marked variability in NMB use across centers (5, 20, 28, 62, and 80%). In addition, there has been controversy regarding the role of anesthesiology residents-in-training in the emergent setting, which has implications for perioperative safety and cost in teaching hospitals. Complication rates associated with resident-in-training management of emergent scenarios have varied: aspiration, 4–5.8%; esophageal intubation, 3.4–9%; and oral trauma, 6.8–7%.[3,6,9] In contrast, a preliminary review[13] of 2,460 emergent airway management procedures for respiratory distress at our center, which uses senior anesthesia residents as first responders, demonstrated a complication rate of only 2.3%. Variation in the experience of the initial responder to emergent airway situations may be responsible for variations in outcome. The dilemma of informed consent makes randomized controlled investigations an impractical design to explore these questions further.[11] Large observational studies may be the most feasible way to advance our knowledge.

The current study was undertaken to review a large series of emergent nonoperating room airway procedures comprehensively in a teaching institution in which senior resident participation is the standard of care. We sought to confirm the incidence of difficult intubation and complication rates, describe airway adjuvant and NMB use, and determine whether process variables, including time of day[15] and patient location, affect complication rates. We hypothesized that, compared with previous literature based on a junior first responder, we would observe a decreased airway complication rate.

Materials and Methods

Adult patients requiring nonoperating room emergent intubation at our tertiary care institution from December 5, 2001 to July 6, 2009 were included in this observational study. Institutional review board (University of Michigan, Ann Arbor, Michigan) approval was obtained, and informed consent was waived. Exclusion criteria were age <18 yr, preexisting endotracheal tube exchanges, or location in the perioperative areas (*e.g.*, postanesthesia care unit, preoperative holding area, or operating room). Urgent nonoperative awake fiberoptic intubations were identified; however, these were excluded from the analysis to be consistent with previous literature.[4,6,9] Patients in the emergency department in whom induction was performed before the arrival of the anesthesia team were excluded. Emergent intubations performed by emergency department providers without anesthesiology involvement were also excluded.

Anesthesia providers recorded prospectively defined data points, including time of day, location, attending physician presence, number of attempts, laryngoscopic view, adjuvant use, medications, and complications using a perioperative clinical information system (Centricity; General Electric Healthcare, Waukesha, WI). Medicolegal documentation of emergent airway management using this system is a departmental standard of care. The perioperative clinical information system is available at bedside workstations throughout the facility, including floor and intensive care unit (ICU) beds. The emergent intubation documentation is typically completed by the anesthesia resident performing or supervising the intubation and is automatically forwarded to the attending physician for review. The attending physician reviews the documentation, modifies it as necessary, and cosigns the note, locking it from further editing. Within each airway management record, required fields are designed with a drop-down menu without default settings. Each element is required and allows selection of one or more options and a comment section for free text if the options provided are not adequately descriptive. Consistent with previous literature[15] evaluating the role of time of day on in-hospital resuscitation outcomes, we defined normal weekday staffing as Monday through Friday, from 7:00 AM to 11:00 PM.

At our institution, a senior clinical anesthesia (CA)-3 resident, completing his or her fourth and final year of residency, addresses emergent airway calls with the assistance of a junior CA-2 or CA-1 resident. All CA-3 residents have completed at least 24 months of anesthesiology training and have regularly assisted senior providers in emergent airway scenarios during this 24-month period. CA-3 residents attend a lecture series on nonoperating room emergent airway management with emphasis on the importance of preoxygenation, medication selection, techniques to minimize aspiration risk, methods to confirm endotracheal tube placement, and appropriate use of airway adjuvants. An attending anesthesiologist is physically present "in house" 24 h daily. The attending anesthesiologist may elect to participate in emergent airway management, or his or her presence may be requested if difficulty is anticipated or experienced by the senior resident. If the attending anesthesiologist was physically present for any key portion of the intubation process, his or her presence is documented in the emergent intubation note.

Our primary outcome was a composite variable that included aspiration, esophageal intubation, dental injury, and pneumothorax. Documentation for each intubation was hand reviewed. *Aspiration* was defined as immediate periinduction observation of gastric contents at the glottic opening or in the endotracheal tube. *Esophageal intubation* was defined as recognized or unrecognized esophageal endotracheal tube placement. Any cases for which comments required interpretation were reviewed by two investigators (L.D.M.

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Table 1. Characteristics of Patients With Airway-related Complications during Emergent Nonoperative Intubation

Characteristics	All Intubations			Resident-only Intubations		
	Complication (Composite) (n = 144)	No Complications (n = 3,279)	Univariate *P* Value	Complication (Composite) (n = 96)	No Complications (n = 2,188)	Univariate *P* Value
Age, yr*	57.8 ± 16.7	58.4 ± 16.3	0.78	58.6 ± 17.0	58.3 ± 16.1	0.61
Male sex	89 (62)	1,841 (56)	0.18	56 (58)	1,235 (56)	0.72
Medicine service†	92 (64)	2,050 (63)	0.74	60 (63)	1,470 (67)	0.34
Location						
Floor	77 (54)	1,245 (38)	<0.001	54 (56)	914 (42)	0.005
Intensive care unit	64 (44)	2,000 (61)	<0.001	39 (41)	1,263 (58)	0.001
Emergency department	3 (2.1)	34 (1.0)	0.20	3 (3.1)	11 (0.5)	0.02
Evening/weekend staffing hours‡	67 (47)	1,521 (46)	0.97	45 (47)	1,078 (49)	0.65
Attending physically present	48 (33)	1,091 (33)	0.99	NA	NA	NA
Indication						
Cardiac arrest	71 (49)	1,455 (44)	0.24	52 (54)	990 (45)	0.09
Respiratory arrest	67 (47)	1,701 (52)	0.21	42 (44)	1,137 (52)	0.12
Airway protection	3 (2.1)	70 (2.1)	1.00	1 (1.0)	34 (1.6)	1.00
Muscle relaxation						
Any	91 (63)	2,375 (73)	0.02	56 (58)	1,552 (71)	0.01
Succinylcholine	73 (51)	1,967 (60)	0.03	45 (47)	1,282 (59)	0.02
Nondepolarizer	18 (13)	408 (12)	0.99	11 (12)	270 (12)	0.80
Grade view: III or IV§	28 (20)	282 (8.7)	<0.001	18 (19)	167 (7.7)	<0.001
No. of attempts ≥3	23 (16)	64 (2.0)	<0.001	13 (14)	36 (1.6)	<0.001

Data are given as number (percentage) of each group unless otherwise indicated. Age is presented as mean ± SD.

* The *P* value was computed using the Mann–Whitney U test. † All inpatient general medicine services, including medical intensive care unit. ‡ Evening hours from 11:00 PM to 7:00 AM Monday through Friday or anytime on Saturday or Sunday. § Cormack and Lehane grade III or IV laryngoscopic view.

NA = not applicable.

and S.K.). Secondary outcomes were difficult intubation, defined as Cormack and Lehane grade III or IV laryngoscopic view[16]; or three or more attempts by an anesthesiology provider.

Statistical analysis was performed using SPSS (R) version 16 (SPSS Inc. Chicago, IL). Descriptive analyses were performed on all independent variables listed in table 1, and simple analyses of categorical variables were performed using a Pearson chi-square, Fisher exact, or Mann–Whitney U test. Because of reviewers' concerns regarding the variable interpretability of "attending presence" in this dataset, multivariate analysis and modeling of predictors of airway complications were limited to situations in which a resident performed the intubation without attending physician presence.

Before performing any modeling, colinearity diagnostics were performed to assess for the presence of two or more highly correlated independent variables. This is performed by evaluating the condition index of the entire group of independent variables.[17] If the condition index is greater than 30, it suggests that further investigation is required using a bivariate Pearson correlation coefficient matrix. A Pearson correlation coefficient of 0.70 or greater between two independent variables demonstrates a high level of correlation that must be addressed by variable selection or collapsing. The condition index of the independent variables in this dataset was less than 30. As a result, all variables were entered into a logistic regression full model fit with the composite variable of airway complications as the dependent outcome. Variables deemed to be significant in the full model fit ($P < 0.05$) were established as independent predictors. Each independent predictor was also assessed for effect size using an adjusted odds ratio. The predictive value of the resulting model was evaluated using a receiver operating characteristic area under the curve. A sensitivity analysis was performed to assess all emergent intubations meeting study criteria, including those cases with only residents and those with attending physician presence, in a logistic regression full model fit.

Results

During an 8-yr period, 3,923 emergent nonoperating room intubation documents were recorded, and 3,423 intubation events met inclusion criteria. A total of 500 cases were excluded for the following reasons: 132 pediatric intubations, 89 perioperative locations, 79 extubations, 53 endotracheal tube exchanges, 27 duplicate documents, 86 awake fiberoptic intubations, 12 preexisting airways, and 22 other. The average patient age was 58 yr, and 56.4% were male. Patients were most often located in the ICU (n = 2,064 [60.3%]), followed by the general care floor (n = 1,322 [38.6%]), and the emergency department (n = 37 [1.1%]). The most frequent indication for intubation was respiratory distress (n = 1,768 [51.7%]), followed by cardiac arrest (n = 1,526 [44.6%]), airway protection (n = 73 [2.1%]), and other

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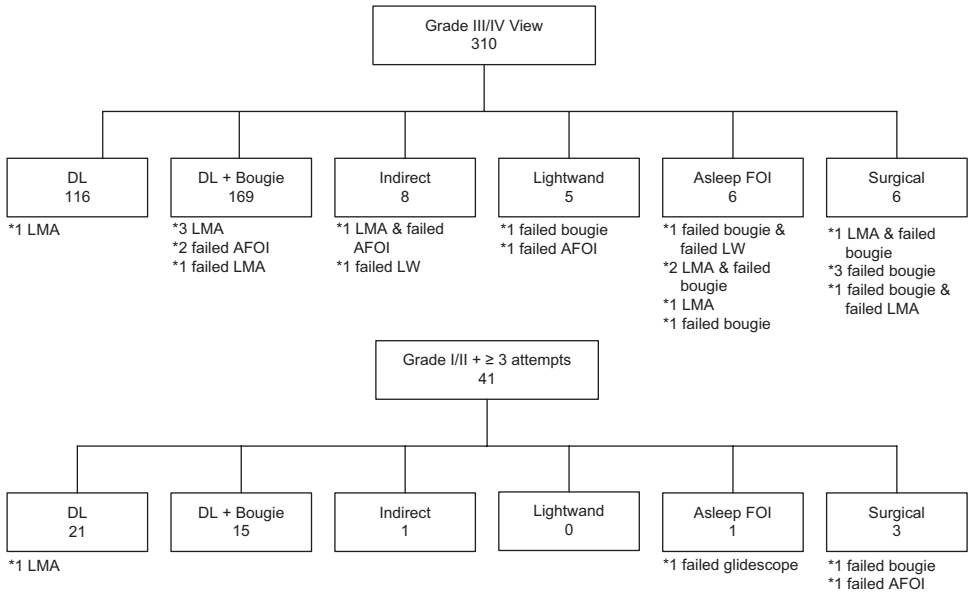

Fig. 1. Definitive airway management techniques for difficult intubations. *Boxes* include the total number of each definitive technique. All techniques attempted before the definitive technique are enumerated below each box. Laryngeal mask airways (LMAs) were used as a successful temporizing measure before the respective definitive technique unless otherwise described as failed. AFOI = asleep fiberoptic intubation; DL + bougie = direct laryngoscopy and bougie introducer; Indirect = indirect fiberoptic technique including bullard or glidescope; LW = lightwand.

(n = 56 [1.6%]). Etomidate was the most frequently used induction agent (57%), followed by propofol (18%). Muscle relaxation was used in 2,466 cases (72.0%), and succinylcholine was used most often (n = 2,040 [59.6%]).

Airway adjuvants were used in 15.6% of cases, and the bougie introducer was the most common technique (n = 426 [12.4%]). Difficult intubation occurred in 10.3% of patients. Muscle relaxation was used in 239 (68.1%) of 351 difficult intubations, and faculty were present for 140 (39.9%). Temporizing laryngeal mask airways were used successfully in 10 patients and failed in 2 patients. Bougie-guided intubation was the definitive airway management technique in 52% of difficult intubations (fig. 1). Nine surgical airways were obtained, and three of these patients developed anoxic brain injury leading to withdrawal of care. All three of these patients had arrested before arrival of the anesthesia team. Of the nine surgical airways, eight received NMB: six received succinylcholine, and two received nondepolarizing agents. Seven surgical airways were performed by a surgical service, one by the emergency department, and one by the anesthesia team. Six surgical airways were obtained as the result of failed laryngoscopy, two patients experienced uncontrolled bleeding in the airway, and one patient could not be intubated as the result of unanticipated tracheal stenosis. The figure describes the failed and definitive airway techniques for each of the difficult intubations.

Airway-related complications occurred in 144 patients (4.2%): aspiration in 95 (2.8%), esophageal intubation in 46 (1.3%), dental injury in 6 (0.2%), and pneumothorax in 4 (0.1%). Patients with complications had similar demographic characteristics, primary service, and indications for intubation compared to those without (table 1). Overall, 7- and 30-day all-cause in-hospital mortality rates were 25% and 37%, respectively.

Among the 2,284 patients managed by a senior anesthesiology resident without attending physical presence, airway-related complications occurred in 96 patients (4.2%): aspiration in 69 (3.0%), esophageal intubation in 26 (1.1%), dental injury in 4 (0.2%), and pneumothorax in 1 (0.04%). These rates were similar to those observed in the overall dataset (table 2). A logistic regression full-model fit, including the variables listed in table 1, demonstrated four independent predictors of the composite complication outcome ($P < 0.05$): three or more intubation attempts (adjusted odds ratio, 6.7; 95% CI, 3.2–14.2; $P < 0.001$), grade III or IV view (adjusted odds ratio, 1.9; 95% CI, 1.1–3.5; $P = 0.03$), general care floor location (adjusted odds ratio, 1.9; 95% CI, 1.2–3.0; $P = 0.004$), and emergency department location (adjusted odds ratio, 4.7; 95% CI, 1.1–20.4; $P = 0.037$). The model was evaluated using the omnibus tests of model coefficients, which demonstrated a chi-square value of 54.063 with 10 degrees of freedom and a $P < 0.001$. Receiver operating characteristic curve analysis demonstrated an area under the curve of 0.68 ± 0.03. Sensitivity analysis was performed by multivariate analysis of all 3,423 emergent intubations meeting inclusion criteria. This logistic regression full-model fit included all variables listed in table 1. It demonstrated only two independent predictors of an airway complication: three or more intubation attempts (adjusted odds ratio, 8.0; 95% CI, 4.5–14.3; $P < 0.001$) and location on the general care floor (adjusted odds ratio, 2.0; 95% CI, 1.4–2.8; $P < 0.001$).

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Table 2. Complications Overall Compared with Complications for Resident-only Intubations

Complication	All Intubations (n = 3,423)	Senior Residents Only (n = 2,284)	*P* Value*
Aspiration	95 (2.8)	69 (3.0)	0.57
Esophageal intubation	46 (1.3)	26 (1.1)	0.50
Dental injury	6 (0.2)	4 (0.2)	1.00
Pneumothorax	4 (0.1)	1 (0.04)	0.65
Composite complication†	144 (4.2)	96 (4.2)	1.00

Data are given as number (percentage) of each group.

* Calculated using the Pearson chi-square or Fisher exact test. † Denotes the total number of patients experiencing a complication. Some patients experienced more than one complication.

Discussion

By using a prospectively collected large clinical dataset of 3,423 emergent nonoperative intubations at a tertiary care center during an 8-yr period, we observed a difficult intubation rate of 10.3% and a composite airway complication rate of 4.2%. Logistic regression analysis of emergent intubations performed by residents-in-training without an attending anesthesiologist identified four independent predictors of the composite airway complication outcome: three or more intubation attempts, grade III or IV direct laryngoscopy view, and patient location on the general care floor or emergency department.

Our observed difficult intubation rate of 10.3% is similar to that in previous studies.[3,5,6] To our knowledge, this is the first study to categorize difficult intubation in emergent scenarios using the number of attempts and laryngoscopic grade view. Consistent with previous studies, our data suggest that patients who are difficult to intubate are at higher risk for airway-related complications.[5] Reported complication rates during emergent nonoperative intubations range from 4.1 to 28% (esophageal intubation, 1.6–9%; aspiration, 2–4%; and trauma, 0.5–7%), reflecting variations in practice patterns, outcome definitions, and data collection methods.[3,4,6,8–10] Our composite complication rate of 4.2% is consistent with the lower end of this spectrum. Some studies[4,5] included hemodynamic parameters, such as tachycardia, bradycardia, hypertension, hypotension, and hypoxia, in their reported complication rates. Consistent with recent literature, we elected not to include hemodynamic outcome data because it is difficult to distinguish airway-related hemodynamic perturbations from underlying pathophysiologic states given the clinical situation being evaluated.[9]

Compared with studies using similar nonhemodynamic outcome measures, we hypothesize that the decreased complication rates observed for esophageal intubation, aspiration, and oral trauma may be because of the relative increased experience of the first responder at our institution. Our practice pattern ensures that a CA-3 resident with at least 24 months of perioperative intubation experience is present at each emergent nonoperative airway management situation. Schmidt *et al.*[9] observed an overall complication rate across all providers of 16.1% (52 of 322 patients experienced a complication). However, 202 of the 322 patients underwent unsupervised intubations by junior anesthesiology residents: 67 by CA-1 residents and 113 by CA-2 residents, and 22 by non-anesthesiology physicians. Among patients managed by junior residents without attending physician involvement, they observed a composite complication rate for esophageal intubation, aspiration, and oral trauma/dental injury of 16.9%. We observed a 4.2% incidence for the same outcome definition when senior residents responded without attending physician involvement. Existing literature demonstrates that senior residents may be approaching, although not attaining, attending physician competence in their emergent airway management skills. By using a quality improvement database of 2,833 emergent intubations, Mort[5] demonstrated that CA-3 residents and attending physicians both required three or more intubation attempts in 9% of cases. However, CA-1 residents required three or more attempts in 15% of cases. In addition, our care process of involving a second anesthesia provider, regardless of the level of training, has been demonstrated to be protective against emergent airway management complications.[4]

The value of an experienced attending anesthesiologist during a difficult airway scenario is unquestionable. Multivariate analysis demonstrated that three or more intubation attempts, grade III or IV view, and location on the general care floor or emergency department were independent predictors of an airway complication. This suggests that these are specific scenarios in which it may be important to have more experienced providers present for emergency airway management. Unfortunately, our documentation process does not detail whether an attending anesthesiologist was present with the senior resident as a first responder or as a subsequent responder. As a result, we cannot comment definitely on the role of attending physician presence on airway outcomes and further studies remain necessary.

We report more frequent use of NMB compared with previous studies[3–5,9] documenting rates from 5 to 62%. Overall, 72% of our studied population received NMB. Use of NMB has been shown to optimize intubating conditions[18,19] and may contribute to decreased complication rates. In a prospective multicenter study of ICU patients, Jaber *et al.*[4] observed fewer complications when NMB was used to facilitate emergent intubation (22% *vs.* 37%). In the emergency department, Li *et al.*[20] observed a highly significant decrease in esophageal intubation when patients received NMB (3% *vs.* 18%). Given that 45% of patients in

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the current study were identified as requiring emergent intubation as the result of cardiac arrest, the data suggest that many patients who arrested before, during, or after arrival of the anesthesia team received NMB. This may be because providers documented an airway management indication of "cardiac arrest" for all "periarrest" situations or because NMB was administered to patients who had already arrested.

Some anesthesiologists may choose to avoid NMB so the patient can be woken up or to minimize the risk of life-threatening succinylcholine-induced hyperkalemia.[21,22] However, in the emergent setting with a decompensating patient, awakening a hypoxic or hypercarbic patient may not be feasible.[21] We acknowledge that NMB must be administered thoughtfully on a case-by-case basis. There are particular subsets of patient with difficult airways, muscle disorders, upper motor neuron disease, large burns, or immobility in whom depolarizing or nondepolarizing NMB may be detrimental.[22]

The use of airway adjuvant devices in the emergent airway setting has not been previously reported. We observed a 15.6% rate of airway adjuvant use. The bougie introducer was used most frequently (12.4% overall and 56% among difficult intubations). Data suggest that intubation, particularly when direct laryngoscopy results in a poor glottic view, is facilitated with use of a bougie introducer.[23,24] Patients with a grade IIb or III direct laryngoscopy view were intubated more easily with the bougie compared with the stylet in a randomized trial.[23] Given the increased incidence of difficult intubation, and frequent blood, vomitus, or secretions in the airway,[1] the bougie may be particularly useful in the emergent nonoperating room setting.

Multivariate logistic regression analysis demonstrated that location on the general care floor is an independent predictor of airway-related complications. Much of the literature has used small datasets focused on either general care floor or ICU patients as separate populations, limiting the ability to compare with existing data.[3,4,6] However, Mort[5] demonstrated that aspiration occurs more frequently among general care floor patients compared with ICU patients. An ICU is equipped with functioning suction, oxygen, and resuscitation equipment. Compared with the general care floor, it is staffed by support personnel who are more experienced in identifying, mobilizing, and assisting in emergent clinical scenarios. We hypothesize that despite working with a higher-acuity patient population, ICU providers and monitoring systems are more likely to recognize decompensating patients earlier and invoke emergent airway management requests sooner.

There are several limitations to this study. First, as an observational study, we could not enforce specific care protocols or airway management algorithms, and there is no assurance that expertise or technique in airway management is uniform across providers. Although emergent airway management documentation is a departmental standard of care, there were no protocols in place to validate data entry for each emergent airway management case. Moreover, data were collected by the clinical providers and the possibility of imperfect documentation and underreporting of complications must be considered. Attempts were made to minimize this by implementing a recording system that required specific field selection rather than default categories. Complications remain difficult to define, and events were interpreted by clinical providers rather than objective observers with clearly defined criteria. Furthermore, even if there were perfect definitions for these complications, the timing of events relative to airway management is often impossible to discern. Similarly, although it is often difficult to distinguish airway-related hemodynamic alterations from underlying pathologic states, it may be of interest to document these data in the future. There are limitations inherent in using a composite complication rate,[11] which is difficult to avoid given the relatively low incidence of specific complications. These data are from a single center, and this must be considered when extrapolating the results to other clinical settings. Incorporating a multicenter design in the future could further validate these findings. Finally, we were unable to comment definitively on the impact of attending physician presence on airway outcomes because our documentation does not identify whether the attending physician was part of the initial responder team or physically present as a subsequent responder.

Despite these limitations, our study offers insight into airway management in the nonoperating room emergent setting. There is a high incidence of difficult intubation. Adjuvant airway device use, in particular the bougie introducer, may be helpful. In a care process using a senior resident accompanied by additional providers as first responders, we observed decreased complication rates than previously reported. In this care process, three or more intubation attempts, grade III or IV laryngoscopy view, and location on the general care floor or in the emergency department are associated with increased complication rates during emergent airway management.

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