Association Between Operator Experience and Procedural Outcomes of Tracheal Intubation in the Emergency Department and ICU

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Study Objectives: Complications are common during emergency tracheal intubation. Although graduate medical education in emergency medicine and critical care mandate competency in this procedure, thresholds for proficiency are poorly defined. We evaluated the relationship between the operator performing intubation and complications of emergency tracheal intubation.

Methods: We performed a secondary analysis of data from 8 multicenter randomized trials of critically ill adults undergoing emergency tracheal intubation in an emergency department or ICU in the United States. We examined the relationship between an operator's prior intubating experience and procedural outcomes, including successful intubation on the first attempt and lowest oxygen saturation.

Results: Among 2,839 intubations with data on prior intubating experience of the operator, 1,863 (65.6%) were by critical care medicine clinicians and 739 (26.0%) by emergency medicine clinicians. The median number of reported previous intubations by clinicians was 56.0 (interquartile range, 32 to 100). Greater intubation experience was associated with an increased odds of successful intubation on the first attempt (odds ratio [OR], 1.75; 95% confidence interval [CI], 1.30 to 2.36; $P<.001$) and increased lowest oxygen saturation (OR 1.45; 95% CI, 1.21 to 1.73; $P<.001$). Learning curves suggested a plateau effect between 35 and 50 intubations.

Conclusion: For tracheal intubations performed in an emergency department or ICU, intubating experience is associated with improved procedural outcomes, reaching a plateau outcome after a mean 35 to 50 previous intubations. [Ann Emerg Med. 2025;■:1-7.]

Please see page XX for the Editor's Capsule Summary of this article.

Keywords: Intubation, Tracheal, Education, Medical, Graduate, Procedural training, Learning curve.

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INTRODUCTION

Background

Complications are common during emergency tracheal intubation. Hypoxemia, hypotension, or cardiac arrest occurs in approximately 17% of emergency tracheal intubations performed in the emergency department (ED) and 40% performed in the ICU.[1] Although the Accreditation Council for Graduate Medical Education (ACGME) mandates that trainees in both emergency medicine and critical care medicine achieve competency in tracheal intubation, there is controversy regarding the amount of experience required to achieve or maintain competency.[2,3]

Importance

Currently, the ACGME requires emergency medicine residents to perform at least 35 intubations during residency.[4] Although surveys suggest that the majority of pulmonary critical care medicine program directors believe a similar threshold would be sufficient, up to a third of these program directors believe more experience is necessary to ensure adequate procedural competency.[3] This uncertainty may be partly explained by the lack of research regarding the effect of experience on outcomes of emergency tracheal intubation.

One method for understanding the relationship between experience and competency is through evaluation of the

Editor's Capsule Summary

What is already known on this topic

Endotracheal intubation skills improve with practice.

What question this study addressed

What is the learning curve for endotracheal intubation?

What this study adds to our knowledge

In this patient-level analysis of data from 8 multicenter clinical trials, first-pass success and minimum oxygen saturation stabilized after 35 to 50 intubations.

How this is relevant to clinical practice

This study will not change current clinical practice, but it provides evidence to inform future procedural training standards.

"learning curve," which graphically represents how increasing experience affects outcomes.[5] Most learning curves have an exponential shape with a steep portion corresponding with active learning and a late "plateau" corresponding to expert status. The segment of the curve immediately preceding the flattening is representative of "competency."

Prior studies assessing learning curves in tracheal intubation used operating room settings, small sample sizes of providers and intubations, and a reliance on self-reporting of complications or data abstracted from the electronic health record.[5-7] Most of these studies also lack granular data on the number of intubations each provider performed, instead analyzing operators based on their academic rank or year of training.

Goals of This Investigation

Prospectively collected data on the relationship between experience and procedural outcomes in emergency tracheal intubation could inform organizations and program directors responsible for providing recommendations regarding procedural training for emergency tracheal intubation. We hypothesized that greater intubation experience would be associated with improved procedural outcomes in critically ill adults undergoing emergency tracheal intubation.

METHODS

Study Design

We performed a secondary analysis of data from 8 multicenter randomized trials that enrolled critically ill adults undergoing tracheal intubation in an ED or ICU at 16 medical centers in the United States between 2014 and 2021.[8-15] Study protocols, inclusion criteria, and exclusion criteria have been previously published.[8-15] The institutional review board at Vanderbilt University Medical Center approved each study. The institution determined this current secondary analysis of de-identified data to be exempt from full board review.

Setting and Selection of Participants

The trials included adults (age more than or equal to 18 years) being intubated in either an ED (7 sites and 2 trials) or an ICU (13 sites and 8 trials) at participating US hospitals. Trials excluded patients known to be pregnant, a prisoner, or a child, and any patient for whom the procedure was too emergent to perform the study procedures or for whom either trial intervention was felt to be either required or contraindicated by the treating clinician. This secondary analysis included all patients in the datasets for each trial with data available on experience and the relevant outcomes. Because trials coenrolled, some patients could appear in multiple trial databases; we removed duplicate patients from analysis.

Measurements

All trials used the same methodology for data collection. During the procedure, a trained independent observer measured procedural outcomes including successful intubation on the first attempt and lowest oxygen saturation. Following each intubation, the clinician who performed the intubation provided details regarding their prior intubating experience, clinical specialty, and level of training. Trained and independent research personnel collected data from the electronic health record on baseline patient characteristics and clinical outcomes using fixed categories.[15]

Exposure Variable

The primary exposure variable of interest was the clinician's reported prior intubation experience, defined as the total number of tracheal intubations previously performed by the clinician. In each trial, clinicians provided their number of prior intubation attempts using a standardized case report form completed immediately after the intubation procedure. The choice of operator was not prescribed by the clinical trials.

Outcome Variables

We evaluated 2 procedural outcomes of intubation: successful intubation on the first attempt and the lowest

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Table. Overall baseline patient characteristics and study outcomes.

Baseline Characteristics	Overall N=2,839
Age, median (IQR)	59.0 (47.0, 69.0)
Sex, (women %)	1,195 (42.1)
BMI, median (IQR)	27.1 (23.1, 32.5)
APACHE II score, median (IQR)	19.0 (14.0, 25.0)
Hypoxemic respiratory failure as indication for intubation, no. (%)	1,266 (44.6)
Baseline oxygen saturation at induction, median (IQR)	99.0 (96.0, 100.0)
Provider specialty, no. (% of total)	
Critical care	1,863 (65.6)
Emergency medicine	739 (26.0)
Anesthesia	154 (5.4)
Other	83 (2.9)
Location, no. (%)	
ICU	2,145 (75.6)
ED	694 (24.4)
Laryngoscope device, no. (%)	
Video laryngoscopy	1,740 (61.3)
Direct laryngoscopy	1,081 (38.1)
Not available	18 (0.6)
Clinical Outcomes	**Overall**
Successful intubation on first attempt, no. (%)	2,315 (81.5)
Lowest oxygen saturation, percent, median (IQR)	96.0 (87.0, 100.0)
Change in oxygen saturation (IQR)	−2.0 (−8.0, 0.0)
Complications, no. (%)	769 (27.1)
Spo_2<80%	399 (14.1)
SBP<65 mmHg	112 (3.9)
New or increased vasopressors	379 (13.3)
Cardiac arrest	49 (1.7)
Death	26 (0.9)

ED, Emergency department; *IQR*, interquartile range; *SBP*, systolic blood pressure; *Spo_2*, oxygen saturation.
Between-group comparisons calculated with the Pearson's chi-squared test with Yates' continuity correction for categoric variables and the Wilcoxon rank-sum test for continuous variables.

oxygen saturation between induction of anesthesia and 2 minutes after completing intubation.

Analysis

Successful intubation on the first attempt analysis used a logistic regression model that adjusted for age, body mass index (BMI), Acute Physiology Assessment and Chronic Health Evaluation (APACHE) II score, clinical setting (ED versus ICU), and laryngoscope type (video versus direct). Lowest oxygen saturation analysis used a proportional odds model including age, BMI, APACHE II score, clinical setting (ED versus ICU), laryngoscope type (video versus direct), oxygen saturation at the time of induction, and hypoxemic respiratory failure as an indication for intubation.[16,17] Models allowed for nonlinearity of continuous variables using restricted cubic splines with 5 knots with knot location estimated using quantiles with the outer quantiles 0.05 and 0.95. To account for clustering by study site and trial period, we combined the study site and trial period into 40 unique clusters, using the Huber-White method to adjust the variance-covariance matrix of the fitted model to correct for heteroscedasticity and for correlated responses from cluster samples. For each model, we plotted the partial effect of experience (a graph of the predicted outcome across the range of operator experience in the data set) to create "learning curves" that visually demonstrated the relationship between an operator's prior number of intubations and the outcome after adjusting for covariables.

The assessment of the effect of operator experience on the outcome used 2 methods. First, we identified a "plateau" of the learning curve through visual inspection of the learning curve as the inflection point at which the slope of the line approached zero. Second, we calculated the odds ratio (OR) observed when comparing an intubation performed by an operator who had performed 190 prior intubations (the 90th percentile of experience in the data set) with an intubation performed by an operator who had performed 15 prior intubations (the 10th percentile of experience in the data set), henceforth referred to as OR 190/15 intubations.[18] To understand whether setting (ED versus ICU) and laryngoscope type (video versus direct) affected the learning curve, we generated additional models showing the learning curve by setting and device type. All analyses occurred using R Statistical Software Version 4.3.0 (R Core Team) and significance existed with α at 0.05.

RESULTS

Baseline Characteristics

Of the 2,852 critically ill adults who underwent emergency tracheal intubation in 1 of the 8 trials, we included a total of 2,839 (99.5%) intubations with data on prior intubating experience of the operator. Clinicians had a median of 56.0 (interquartile range, 32, 100) previous intubations. Of 2,839 intubations, 1,863 (65.6%) were by critical care medicine clinicians, 739 (26.0%) by emergency medicine clinicians, 154 (5.4%) by anesthesiology clinicians, and 83 (2.9%) by other clinicians (eg, advance

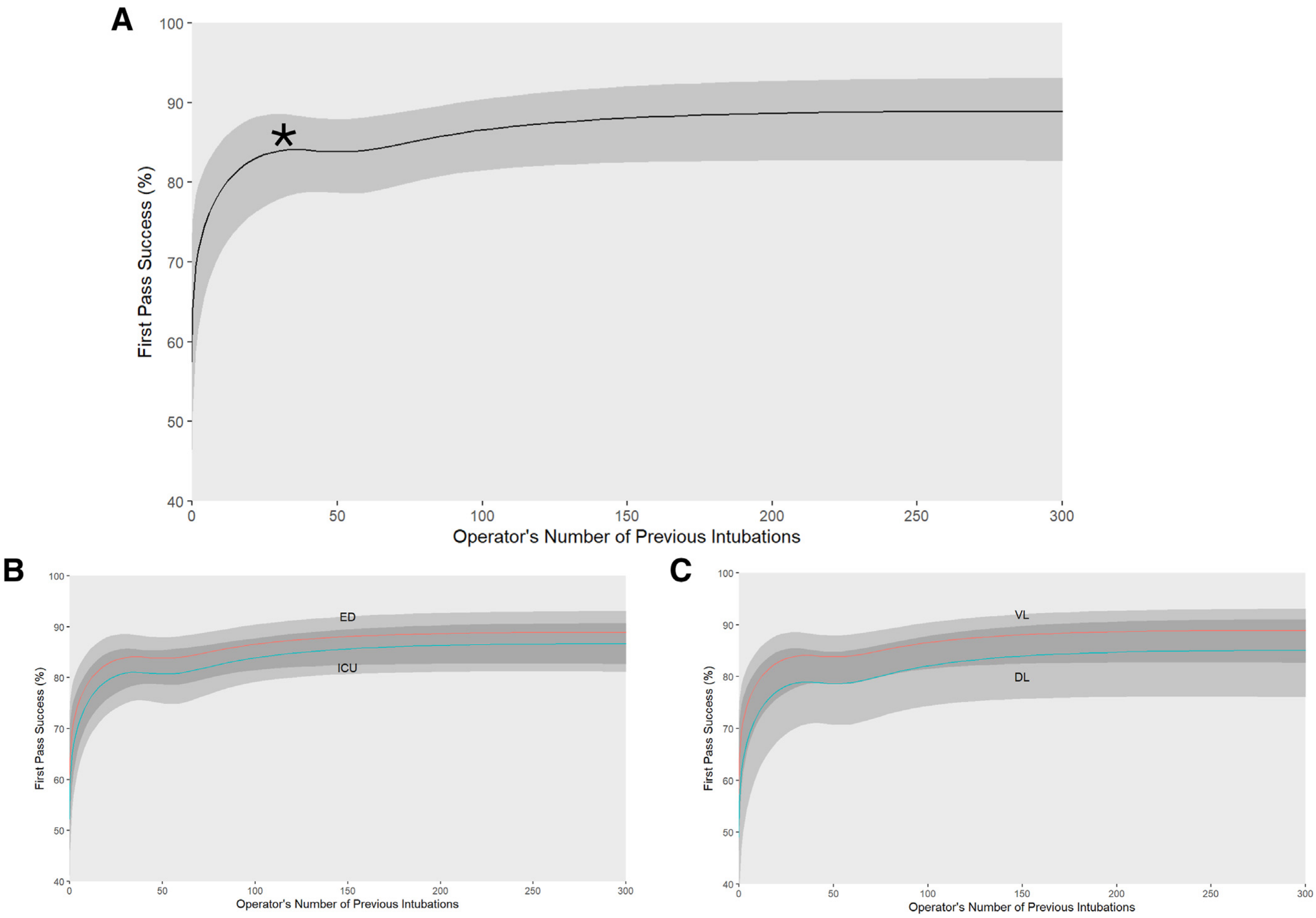

Figure 1. *A*, Effect of operator experience on successful intubation on the first attempt. Shown are the probability of successful intubation on the first attempt (y-axis) by clinician experience (x-axis) for all patients. *B,* Patients undergoing intubation in the ED versus ICU. *C*, Patients undergoing intubation with a video versus direct laryngoscope. Solid lines represent the mean and shaded areas represent 95% CIs and were calculated using a logistic regression model with adjustment for age, BMI, APACHE II score, clinical setting (ED versus ICU), and laryngoscope type (video versus direct laryngoscope). The asterisk marks the inflection point at which the slope of the line changes, representing a decreasing effect of operator experience on successful intubation on the first attempt. *CI*, Confidence interval; *DL*, Direct laryngoscope; *VL*, video laryngoscope.

practice providers and registered nurse anesthetists). Patient and procedural characteristics are shown in the Table.

Study Outcomes

The associations between the previous experience of the operator and the outcomes of successful intubation on the first attempt and the lowest oxygen saturation are shown in the Table. After adjusting for potential confounders, greater experience was associated with improved incidence of successful intubation on the first attempt (OR 190/15 intubations, 1.75, 95% confidence interval [CI] 1.30 to 2.36; *P*<.001) (Figure 1A) and a higher lowest oxygen saturation (OR 190/15 intubations, 1.45; 95% CI 1.21 to 1.73; *P*<.001) (Figure 2A). The effect of setting and laryngoscopy device on the relationship between operator experience and the outcomes of interest are shown in Figures 1, 2B, and 2C.

LIMITATIONS

First, most intubations were by emergency medicine and critical care trainees who primarily gain experience through intubations of critically ill adults, whereas relatively few were performed by anesthesia trainees who gain most of their experience by performing intubation in the operating room to facilitate elective operations. Thus, the results may not generalize to anesthesia trainees. Second, the study did not capture any data on the methods (classroom, simulation) or intensity (amount of time spent) of airway training that routinely occurs for trainees in addition to clinical experience. Although our analyses adjusted for

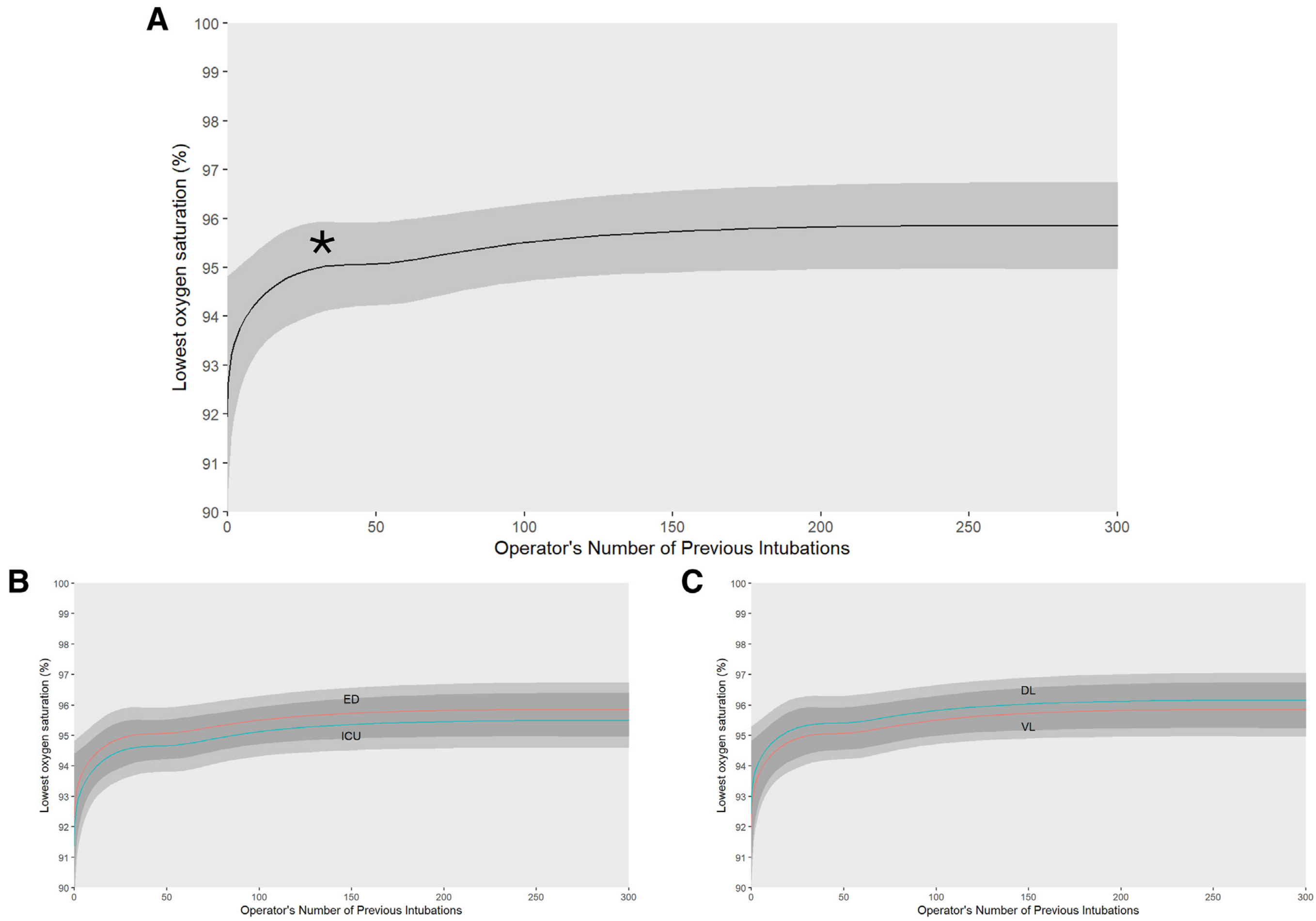

Figure 2. *A*, Effect of operator experience on lowest oxygen saturation. Shown are the lowest oxygen saturation from induction to 2 minutes after tracheal intubation (y-axis) by clinician experience (x-axis) for all patients. *B,* Patients undergoing intubation in the ED versus ICU. *C*, Patients undergoing intubation with a video versus direct laryngoscope. Solid lines represent the mean and shaded areas represent 95% CIs and were calculated using a proportional odds model with adjustment for BMI, APACHE II score, oxygen saturation at induction, presence of hypoxemic respiratory failure, clinical setting (ED versus ICU), and laryngoscope type (video versus direct laryngoscope). The asterisk marks the inflection point at which the slope of the line changes, representing a decreasing effect of operator experience on lowest oxygen saturation.

many prespecified covariables, residual confounding is possible. For example, more experienced operators may be called on to perform intubations that are perceived to be more difficult or at high risk of complications and statistical adjustment may not have completely accounted for this phenomenon. Although clinical outcomes came from by independent observers present during the intubation, operator experience was self-reported and could be susceptible to reporting bias. Third, the parent trials excluded patients for whom the procedure was too emergent to perform the study procedures or for whom the trial intervention was felt to be either required or contraindicated. As a result, it is possible that certain types of difficult intubation conditions (eg, intubation for cardiac arrest) are underrepresented in this analysis, and our results may not generalize to such intubations. Finally, some important intubation complications like cardiac arrest, failed intubation, and cricothyrotomy were rare, leaving our study underpowered to evaluate these outcomes.

DISCUSSION

Although there are many potential methods to assess competency in emergency tracheal intubation, including high-fidelity simulation and standardized recording with review of clinically performed intubations, the number of intubations performed remains the most commonly used metric for assessing competence. These results confirm that intubation outcomes improve with increasing experience.[6] Although outcomes continued to improve with increasing experience across the range of experience levels represented in our cohort, we observed a plateau between 35 and 50 intubations for both outcomes. This supports the concept that the number of prior intubations is an important training metric. Although the plateau point of a learning curve is different from a minimal competency threshold, our findings suggest that trainees and their patients may benefit from performing between 35 and 50 intubations during training to ensure that most of their learning occurs in a mentored setting with readily available instruction and back-up operators. These findings also highlight the need for training methods that speed the achievement of competence and the development of measures to evaluate competency beyond the number of intubations performed.

This study has 2 notable strengths when compared with recent airway learning curve derivation studies. First, this study used data collected prospectively by an independent observer with the explicit goal of evaluating outcomes of tracheal intubation. Second, the learning curves for each outcome demonstrated a consistent relationship with increasing experience. As anticipated, in each of the curves, increased operator experience generally led to more favorable outcomes.

In conclusion, among critically ill adults undergoing emergency tracheal intubation in the ED or ICU, greater intubation experience is associated with improved procedural outcomes, with most of the benefit of experience accruing after the first 35 to 50 intubations performed.

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Data sharing statement: The deidentified data set and data dictionary used for each trial is available for sharing on request. Details regarding the requirements for and mechanism of sharing request are included as part of each initial trial publication. For additional information, contact Dr. Jonathan Casey at jonathan.d.casey@vumc.org.

All authors attest to meeting the four ICMJE.org authorship criteria: (1) Substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work; AND (2) Drafting the work or revising it critically for important intellectual content; AND (3) Final approval of the version to be published; AND (4) Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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