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Defining Successful Intubation on the First Attempt Using Both Laryngoscope and Endotracheal Tube Insertions: A Secondary Analysis of Clinical Trial Data

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Author contributions: ST, BD, MP, and MS conceived the study and drafted the manuscript. ST performed the analysis. All authors served as site investigators at the medical centers for the 2 studies used in this secondary analysis and, thus, participated in recruitment, data collection, and supervision of these trials at their site. All authors contributed substantially to the revisions of this manuscript. ST takes responsibility for paper as a whole.

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Abstract

Study objectives: Successful intubation on the first attempt has historically been defined as successful placement of an endotracheal tube (ETT) using a single laryngoscope insertion. More recent studies have defined successful placement of an ETT using a single laryngoscope insertion followed by a single ETT insertion. We sought to estimate the prevalence of first-attempt success using these 2 definitions and estimate their associations with the duration of intubation and serious complications.

Methods: We performed a secondary analysis of data from 2 multicenter randomized trials of critically ill adults being intubated in the emergency department or ICU. We calculated the percent difference in successful intubations on the first attempt, median difference in the duration of intubation, and percent difference in the development of serious complications by definition.

Results: The study population included 1,863 patients. Successful intubation on the first attempt decreased by 4.9% (95% confidence interval 2.5% to 7.3%) when defined as 1 laryngoscope insertion followed by 1 ETT insertion (81.2%) compared with when defined as only 1 laryngoscope insertion (86.0%). When successful intubation with 1 laryngoscope and 1 ETT

insertion was compared with 1 laryngoscope and multiple ETT insertions, the median duration of intubation decreased by 35.0 seconds (95% confidence interval 8.9 to 61.1 seconds).

Conclusion: Defining successful intubation on the first attempt as placement of an ETT in the trachea using 1 laryngoscope and 1 ETT insertion identifies attempts with the shortest apneic time.

INTRODUCTION

Background

More than a million critically ill adults undergo endotracheal intubation in emergency departments and ICUs in the United States each year. Almost half of these patients experience a complication during intubation.[1] Successful intubation on the first attempt is a quality and research metric associated with a lower rate of peri-intubation complications, including cardiovascular instability, severe hypoxemia, cardiac arrest, and death.[1–3] As a result, “first-attempt success” has become a common outcome in emergency airway research and reporting.

Importance

Despite its ubiquitous use, successful intubation on the first attempt has never been defined based on a formal consensus process. Historically, successful intubation on the first attempt has been defined as successful placement of an endotracheal tube (ETT) during a single laryngoscope insertion.[1,4,5] However, this definition only considers the first step in intubation (laryngoscopy) while ignoring the second step (ETT delivery and placement). A definition that only evaluates laryngoscopy risks classifies an intubation as successful on the first attempt even if multiple attempts at placing an ETT occur over a protracted period of time, which may be associated with increased complications.

Goals of this Investigation

Recent multicenter randomized trials have used a more granular definition of successful intubation on the first attempt that considers both steps of the procedure: a single insertion of the laryngoscope into the mouth, followed by a single successful insertion of an ETT into the trachea.[6,7] These 2 definitions of successful intubation on the first attempt have never been compared. We sought to compare these 2 definitions and assess whether emergency intubations with 1 insertion of the laryngoscope followed by 1 successful insertion of an ETT are associated with a shorter duration of intubation and fewer serious complications than intubations with 1 insertion of the laryngoscope followed by multiple ETT insertions.

METHODS

Study Design

We conducted a secondary analysis of data from 2 multicenter, randomized trials that enrolled critically ill adults undergoing tracheal intubation in the ED or ICU. The 2 trials included the Bougie or Stylet in Patients Undergoing Intubation Emergently (BOUGIE) trial and the Preventing Cardiovascular Collapse with Administration of Fluid Resuscitation During Induction and Intubation (PREPARE II) trial.[6,7] Each design concealed subject

allocation and had institutional review board approval. Our report is observational and in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology statement.[8]

Setting and Selection of Participants

The trials enrolled adult patients (aged ≥18 years) from 20 sites, including 7 EDs and 13 ICUs, at 16 participating hospitals in the United States between February 1, 2019, and May 24, 2021. Five ICUs enrolled in both the trials, whereas 8 ICUs enrolled only in PREPARE II and 7 EDs and 1 ICU enrolled only in BOUGIE. The BOUGIE trial randomized eligible patients to undergo intubation with a bougie or stylet on the first attempt and limited eligibility to patients being intubated with a standard geometry laryngoscope. The PREPARE II trial randomized eligible patients to receive a fluid bolus or not receive a fluid bolus between induction and laryngoscopy and limited eligibility to ICU patients receiving positive-pressure ventilation with a bag-valve mask or noninvasive ventilation between induction and laryngoscopy. Both trials excluded patients known to be pregnant, prisoners, or children and any patient for whom the procedure was too emergent to perform the study procedures or for whom either intervention was believed to be required or contraindicated by the treating clinician. For the purpose of this secondary analysis, we included all patients included in either trial who underwent orotracheal intubation using a laryngoscope.

Measurements

Both trials used the same methodology for data collection. Trained independent observers collected data in real time during and immediately after intubation using a standardized data collection sheet. The variables collected in real time included the number of insertions of a laryngoscope, bougie, and ETT; blood pressure and oxygen saturation at the time of pharmacologic assistive medication delivery; lowest blood pressure and oxygen saturation between drug delivery and 2 minutes after successful intubation; and vasopressor receipt after drug delivery. Additional recorded data came from the intubating clinician immediately after intubation (eg, glottic view, difficult airway characteristics, and cardiac arrest after induction). Research personnel collected data on baseline patient characteristics and clinical outcomes from electronic medical records and subsequently entered all data from the data collection sheets and electronic medical records into RedCap.

Outcome Variables

The primary outcome was successful intubation on the first attempt, which we defined in the following 2 ways: (1) “successful placement of an ETT in the trachea using a single laryngoscope insertion” and (2) “successful placement of an ETT in the trachea using a single laryngoscope insertion followed by either a single insertion of an ETT into the trachea or a single insertion of a bougie into the trachea followed by an ETT over the bougie into the trachea.”

The secondary outcomes included the duration of intubation and development of serious complications. If a sedative was used, the definition of the duration of intubation was the time from the first sedative administered to the time an ETT was successfully

placed in the trachea. In the absence of a sedative, the definition of the duration of intubation was the time from the first laryngoscope insertion to the time an ETT was successfully placed in the trachea. We defined a serious complication during intubation as the development of severe hypoxemia (new oxygen saturation of <80% within 2 minutes after placement), cardiovascular collapse, cardiac arrest, or death following induction. We defined cardiovascular collapse as any systolic blood pressure of <65 mmHg or new vasopressor administration between induction and 2 minutes after tracheal intubation in a patient with a systolic blood pressure of ≥65 mmHg prior to induction. The definition of cardiac arrest included the occurrence of pulselessness between induction and 1 hour after tracheal intubation in a patient who was not in cardiac arrest prior to induction. Death attribution was between induction and 1 hour after tracheal intubation.

Analysis

We managed and analyzed all data using SAS Enterprise Guide, version 7.1 (SAS Institute, Inc). Our report shares descriptive statistics for all variables adjusted for clustering by site, and nominal and ordinal data are accompanied by proportions with 95% confidence intervals (CIs). We compared the proportions of serious complications between the 2 definitions of successful intubation on the first attempt by calculating percent differences with 95% CIs using bootstrapped samples. Continuous data are reported as median and interquartile ranges; differences between medians with 95% CI are reported for bivariate comparisons. For analysis of serious complications and the duration of intubation, we excluded patients with missing data.

RESULTS

Our primary analysis included 1,863 orotracheal intubations with a laryngoscope. Table E1 shows the patient and site characteristics stratified by trial. Respiratory failure (44%) was the most common reason for intubation, followed by altered mental status (39%). A video laryngoscope was used in 75% of intubations. The majority of intubations occurred in the ICU (62%) and were performed by physician trainees (89%). Intubation experience was mixed: 37% of intubations were performed by clinicians who had performed <50 prior orotracheal intubations and 25% of intubations were performed by clinicians who had performed ≥100 prior orotracheal intubations.

Table 1 shows the difference in successful intubation on the first attempt for each definition. First-attempt success occurred less frequently when defined by 1 laryngoscope and 1 ETT insertion compared with when defined by 1 laryngoscope and any number of ETT insertions (81.2% vs 86.0%, respectively; −4.9% difference; 95% CI −3.9 to −5.9%). When successful intubation occurred with 1 laryngoscope insertion followed by multiple ETT insertions, the median duration of intubation (155 seconds) was 35 seconds longer (95% CI 9 to 61 seconds) than when successful intubation on the first attempt occurred with 1 laryngoscope insertion followed by 1 ETT insertion (median 120 seconds). A recorded serious complication during the intubation procedure occurred in 23.1% of patients who were successfully intubated using 1 laryngoscope and 1 ETT insertion compared with 26.9%

of patients who were successfully intubated with 1 laryngoscope insertion followed by multiple ETT insertions (percent difference −3.8%; 95% CI −13.8% to 5.7%) (Table 2).

LIMITATIONS

As a secondary analysis of an existing data set, we are not powered for each potential comparison. Although we used an existing data set with many patients, the subgroup of intubations that required 1 laryngoscope insertion followed by multiple ETT insertions to be successful was small (n=91). Additionally, the data for this study came from 2 large trials performed at academic medical centers where physician trainees perform the majority of intubations. Thus, our results may not be generalizable to other settings.

DISCUSSION

Now that most intubations in US EDs and ICUs are performed using video laryngoscopes, the use of a definition of successful intubation on the first attempt that incorporates delivery and placement of an ETT is more possible and prudent. When direct laryngoscopes were the only laryngoscopes available to perform intubation, defining first-attempt success as 1 laryngoscope insertion addressed the most difficult part of the intubation procedure, obtaining adequate view. Video laryngoscopes improve visualization and eliminate the need to obtain a direct line of sight to pass the ETT. These differences between laryngoscopes help explain why failure to pass the ETT with a direct laryngoscope is more often due to failure in laryngoscopy and why failure with a video laryngoscope is more often due to failure in ETT placement.[9] A definition of successful intubation on the first attempt that includes ETT insertions is better aligned with clinical needs and equipment in use today.

Including ETT insertions in the definition of successful intubation on the first attempt will alter future emergency airway research. This definition will allow for studying the effect that an intervention may have on 1 or both the steps in the procedure. For example, the BOUGIE trial compared the use of a bougie with the use of a stylet.[6] Because these 2 devices are used after laryngoscopy, the use of a definition of successful intubation on the first attempt that included both the steps of the procedure allowed for identifying how each device may affect the duration of intubation and development of serious complications. Research comparing the effects of laryngoscope devices, the size of ETTs, or other interventions that might affect the ease of ETT delivery or placement might similarly be optimized by the use of a definition of successful intubation on the first attempt that addresses both the steps of the procedure.[10] Additionally, such a definition will increase the granularity of data that need to be available to determine the outcome, which is particularly relevant for studies that collect data retrospectively. Data collection sheets and procedure notes will need to explicitly ask for the number of laryngoscopes, bougies, and ETT insertions used in an intubation rather than simply ask for the number of attempts. Lastly, this change in definition will have an impact on sample size by increasing the prevalence of first-attempt failures.

In conclusion, our observations suggest that the definition of successful intubation on the first attempt should be placement of an ETT in the trachea using 1 laryngoscope insertion followed by a single ETT insertion.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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By *Annals*' policy, all authors are required to disclose any and all commercial, financial, and other relationships in any way related to the subject of this article as per ICMJE conflict of interest guidelines (see www.icmje.org). The authors have stated that no such relationships exist.

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Editor's Capsule Summary

What is already known on this topic

Successful intubation on the first attempt is a research and quality measure but with variable definitions.

What question this study addressed

What is the prevalence of first-attempt success using a newer definition of a single laryngoscope insertion and only a single attempt at endotracheal tube insertion compared with that of first-attempt success using a definition of only a single laryngoscope insertion?

What this study adds to our knowledge

In this secondary analysis using 2 studies of 1,863 patients, the first-attempt success was 5% lower, and there was a shorter apneic time when the new definition was used.

How this is relevant to clinical practice

Airway management observations may consider this new definition to better describe first-attempt success.

Table 1.

Differences in successful intubation on the first attempt by definition.

	1 Laryngoscope+ 1 ETT Insertion		1 Laryngoscope+Any ETT Insertion			
N = 1,863	**n**	**(%; 95% CI)**	**n**	**(%; 95% CI)**	**% Diff**	**(95% CI)**
All intubations	1,512	(81.2; 79.4–82.9)	1,603	(86.0; 84.4–87.5)	−4.9	(−5.9 to −3.9)
Laryngoscope						
Video (n=1,395)	1,173	(84.1; 82.1–86.2)	1,250	(89.6; 87.9–91.1)	−5.5	(−6.7 to −4.4)
Direct (n=468)	339	(72.4; 68.5–76.4)	353	(75.5; 71.7–79.2)	−3.0	(−4.7 to −1.7)
Location						
ED (n=713)	599	(84.2; 81.3–86.6)	638	(89.6; 87.0–91.5)	−5.5	(−7.2 to −3.8)
ICU (n=1,150)	913	(79.4; 77.0–81.7)	965	(83.9; 81.6–85.9)	−4.5	(−5.8 to −3.3)
Prior intubations						
<25 (n=320)	238	(74.4; 68.9–79.2)	262	(82.1; 77.3–86.3)	−7.5	(−10.4 to −4.7)
25–49 (n=367)	291	(79.3; 75.4–83.2)	301	(82.0; 78.4–85.7)	−2.6	(−4.6 to −1.1)
50–99 (n=708)	591	(83.6; 80.7–86.2)	624	(88.2; 85.8–90.5)	−4.7	(−8.3 to −1.0)
≥100 (n=461)	388	(84.1; 80.9–87.6)	412	(89.4; 86.5–92.2)	−5.2	(−7.5 to −3.4)
Trial						
BOUGIE (n=809)	678	(83.8; 81.3–86.3)	724	(89.6; 87.5–91.6)	−5.7	(−7.3 to −4.2)
PREPARE II (n=760)	603	(79.3; 76.3–82.2)	632	(83.2; 80.3–85.9)	−3.9	(−5.3 to −2.5)
Coenrolled (n=294)	231	(78.6; 74.0–83.3)	247	(84.3; 79.8–88.0)	−5.3	(−8.0 to −3.0)

BOUGIE, Bougie or Stylet in Patients Undergoing Intubation Emergently; *CI*, confidence interval; *Diff*, difference; *ED*, emergency department; *ETT*, endotracheal tube; *PREPARE II*, Preventing Cardiovascular Collapse with Administration of Fluid Resuscitation During Induction and Intubation.

Table 2.

Differences in serious complications and duration of intubation by the attempt type.

	1 Laryngoscope+1 ETT Insertion (n = 1,461)		1 Laryngoscope+Multiple ETT Insertions (n = 89)			
N = 1,550*	**n**	**(%; 95% CI)**	**n**	**(%; 95% CI)**	**% Diff**	**(95% CI)**
Complication						
Any complication	338	(23.1; 20.9–25.4)	24	(26.9; 17.9–37.4)	−3.8	(−13.8 to 5.7)
Severe hypoxemia	132	(9.0; 7.7–10.7)	10	(11.0; 5.5–19.0)	−2.1	(−9.8 to 4.3)
Hypotension	223	(15.4; 13.3–17.3)	16	(18.2; 10.3–26.7)	−2.8	(−11.6 to 5.4)
Cardiac arrest	15	(1.0; 0.5–1.5)	1	(1.3; 0.9–4.3)	−0.4	(−3.4 to 0.3)
Death	8	(1.4; 0.4–2.4)	0	—		
Duration of intubation†‡	120	(90–158)	155	(120–190)	−35.0	(−8.9 to −61.1)

CI, Confidence interval; *Diff*, difference; *ETT*, endotracheal tube.

*Analysis excluded patients who required >1 laryngoscope insertion (n=260) and (n=53) who met the definition of a serious complication before induction or had missing data on preinduction cardiac arrest, systolic blood pressure, and oxygen saturation.

†Median seconds (interquartile range).

‡Analysis excluded 27 patients whose duration of intubation was missing and 5 patients whose duration of intubation was ≥1,000 seconds