# Emergency Department Intubation Success With Succinylcholine Versus Rocuronium: A National Emergency Airway Registry Study

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**Study objective:** Although both succinylcholine and rocuronium are used to facilitate emergency department (ED) rapid sequence intubation, the difference in intubation success rate between them is unknown. We compare first-pass intubation success between ED rapid sequence intubation facilitated by succinylcholine versus rocuronium.

**Methods:** We analyzed prospectively collected data from the National Emergency Airway Registry, a multicenter registry collecting data on all intubations performed in 22 EDs. We included intubations of patients older than 14 years who received succinylcholine or rocuronium during 2016. We compared the first-pass intubation success between patients receiving succinylcholine and those receiving rocuronium. We also compared the incidence of adverse events (cardiac arrest, dental trauma, direct airway injury, dysrhythmias, epistaxis, esophageal intubation, hypotension, hypoxia, iatrogenic bleeding, laryngoscope failure, laryngospasm, lip laceration, main-stem bronchus intubation, malignant hyperthermia, medication error, pharyngeal laceration, pneumothorax, endotracheal tube cuff failure, and vomiting). We conducted subgroup analyses stratified by paralytic weight-based dose.

**Results:** There were 2,275 rapid sequence intubations facilitated by succinylcholine and 1,800 by rocuronium. Patients receiving succinylcholine were younger and more likely to undergo intubation with video laryngoscopy and by more experienced providers. First-pass intubation success rate was 87.0% with succinylcholine versus 87.5% with rocuronium (adjusted odds ratio 0.9; 95% confidence interval 0.6 to 1.3). The incidence of any adverse event was also comparable between these agents: 14.7% for succinylcholine versus 14.8% for rocuronium (adjusted odds ratio 1.1; 95% confidence interval 0.9 to 1.3). We observed similar results when they were stratified by paralytic weight-based dose.

**Conclusion:** In this large observational series, we did not detect an association between paralytic choice and first-pass rapid sequence intubation success or peri-intubation adverse events. [Ann Emerg Med. 2018;■:1-9.]

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## INTRODUCTION

### Background

Intubation is a critical procedure commonly performed in the emergency department (ED) setting. ED intubations typically entail rapid sequence intubation, with coadministration of a sedative agent and a paralytic medication.[1] The 2 most commonly used rapid-acting paralytics in the ED setting are succinylcholine and rocuronium.[2] ED providers have historically used succinylcholine for the majority of ED intubations.[3] However, recent data have suggested the increasing use of rocuronium.[1] Previous studies indicate that the time of onset may differ between rocuronium and succinylcholine.

### Importance

Rapid achievement of ideal intubating conditions is important to facilitate rapid first-pass intubation success and to mitigate adverse events.[4,5] The differences in paralysis onset may influence intubation success rates between succinylcholine and rocuronium.[2] Furthermore, although succinylcholine has more rapid onset than rocuronium, multiple contraindications exist to its use, many of which may not always be readily apparent during emergency intubation.[6] Although the anesthesia literature suggests better conditions for rapid sequence intubation with succinylcholine than rocuronium,[7] the best paralytic for ED rapid sequence intubation remains unknown.

**Editor's Capsule Summary**

*What is already known on this topic*

Although commonly used in emergency department rapid sequence intubation, succinylcholine and rocuronium have different speed of onset and adverse effects.

*What question this study addressed*

Do first-pass intubation success and adverse event rates differ between succinylcholine and rocuronium?

*What this study adds to our knowledge*

In this analysis of 4,275 intubations from the National Emergency Airway Registry, succinylcholine and rocuronium exhibited no differences in first-pass success (87.0% versus 87.5%) or adverse events (14.7% versus 14.8%).

*How this is relevant to clinical practice*

Perceived intubating differences between succinylcholine and rocuronium may not be clinically important. A clinical trial is needed to confirm these observations.

### Goals of This Investigation

The goal of this study was to compare first-pass intubation success and peri-intubation adverse events between rapid sequence intubation performed with succinylcholine versus rocuronium.

## MATERIALS AND METHODS

### Study Design and Setting

We analyzed data from the National Emergency Airway Registry (NEAR), a prospective registry of ED intubations performed at an international network of academic hospitals. Each of these participating sites obtained approval from its local institutional review board to conduct the study.

### Methods of Measurement and Data Collection and Processing

There have been multiple previous iterations of NEAR, spanning 1996 to 2012.[1,8] With each phase, the data collection methodology has evolved. Intubating providers at each participating site for the present iteration used a standard data collection instrument to provide information about each patient encounter involving intubation or another advanced airway management technique.[9] Variables included patient demographics, body habitus and estimated weight, impression of airway difficulty, reduced neck mobility (eg, presence of cervical collar), airway characteristics (eg, mouth opening, Mallampati score), intubation position and device, medications and doses, operator characteristics, first-pass intubation success or failure, adverse events, and patient disposition. Sites uploaded data into a centralized Web-based data management database (StudyTRAX; version 3.47.0011; ScienceTRAX, Macon, GA). After data upload, study investigators reviewed all data, using quality assurance algorithms to identify and correct data entry errors.

Each participating center had a designated site investigator ensuring entry of greater than or equal to 90% of all intubations performed in his or her ED. Each site investigator prepared and submitted a study compliance plan approved by the coordinating center (Brigham and Women's Hospital, Boston, MA). These plans specified methods for using electronic billing or procedure reports to identify numbers of intubations performed at each center monthly. The coordinating center then cross-referenced numbers of intubations performed at each site against numbers of intubations entered into the NEAR database to determine the overall proportion of intubations captured. Each participating site obtained approval from its institutional review board to participate in the registry. We reported all data in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology statement.[10]

### Selection of Participants

We included patients older than 14 years whose data had been entered into the NEAR database from January 1 through December 31, 2016. Periods of participation vary for individual centers because facilities joined NEAR on a rolling basis. Inclusion criteria included receipt of succinylcholine or rocuronium before the first intubation attempt. We excluded patients with missing data or data inconsistencies precluding determination of age. We did not exclude patients with other missing data unrelated to these variables.

### Outcome Measures

The primary outcome was first-pass intubation success. For the purposes of the NEAR data collection forms, we defined an intubation attempt as any single effort to place an endotracheal tube in which the leading edge of the laryngoscope blade entered the oral cavity past the alveolar ridge. Secondary outcomes included incidence of any adverse event. We defined an adverse event as the occurrence of any of the following events captured by the

NEAR data collection forms, all of which were diagnosed clinically by the intubating provider except where otherwise specified: cardiac arrest (loss of pulses during or immediately after intubation), dental trauma, direct airway injury, dysrhythmias, epistaxis, esophageal intubation (per clinical diagnosis, visualization, or capnography), hypotension (systolic blood pressure <100 mm Hg), hypoxia (oxygen saturation <90%), iatrogenic bleeding, laryngoscope failure, laryngospasm, lip laceration, main-stem bronchus intubation (as diagnosed clinically or by chest radiograph), malignant hyperthermia, medication error, pharyngeal laceration, pneumothorax (diagnosed clinically or by chest radiograph), endotracheal tube cuff failure, or vomiting (forceful expulsion of gastric contents). Other outcomes examined included best Cormack-Lehane view[11] and lowest peri-intubation oxygenation saturation.

### Primary Data Analysis

We first compared the primary outcome of first-pass intubation success between encounters with succinylcholine versus rocuronium by calculating risk difference with 2-sided 95% confidence interval (CI). We also compared first-pass intubation success stratified by paralytic agent across participating sites, using a Cochran-Mantel-Haenszel $\chi^2$ test. We then constructed a logistic regression model to compare the odds of first-pass intubation success between these 2 paralytic agents. Nominal covariates included sex (male versus female), body habitus (very thin/thin versus normal versus obese/morbidly obese), indication (medical versus traumatic), initial impression of difficult airway (yes versus no), intubation position (full sniffing versus neutral versus other), laryngoscope type (video versus direct), induction medications (etomidate versus ketamine versus other), operator characteristics (nonemergency medicine versus emergency medicine postgraduate year 1/postgraduate year 2 versus emergency medicine postgraduate year 3/4 versus emergency medicine fellow/attending physician), and paralytic used (succinylcholine versus rocuronium). In the interest of reducing the number of collinear predictors in the model, we created the composite variable of "difficult airway characteristics" and assigned a "yes" if the patient had at least one of the following: reduced neck mobility (eg, presence of a cervical collar), Mallampati score greater than 1, reduced mouth opening, airway obstruction, facial trauma, or blood or vomit in the airway. We included "difficult airway characteristics" in the model as a nominal variable (yes versus no), and we included age and weight as continuous covariates. We accounted for clustering by site in the data set by using the Taylor series linearization method with the Morel adjustment to estimate the covariance matrix of the regression coefficients in the logistic regression models.[12] We followed a similar strategy for analyzing adverse events.

We conducted subgroup analyses by calculating the odds ratio of first-pass intubation success between paralytic types (succinylcholine versus rocuronium) for each level of the following variables: age (<65 years, ≥65 years), sex (male, female), body habitus (very thin/thin, normal, obese/morbidly obese), weight (<100 kg, ≥100 kg), body mass index (<30 kg/m$^2$, ≥30 kg/m$^2$), indication (medical, traumatic), presence of head injury or intracranial hemorrhage (yes, no), initial impression of difficult airway (yes, no), difficult airway characteristics (yes, no), oxygen saturation at start of intubation attempt (<90%, ≥90%), laryngoscope type (direct, video), and induction medications (etomidate, ketamine, other). We repeated this process twice, using only high doses of each paralytic (succinylcholine at ≥1.5 mg/kg versus rocuronium at ≥1.2 mg/kg) and rocuronium stratified by dose (rocuronium at ≥1.2 versus <1.2 mg/kg).

We excluded from the logistic regression models cases with missing data for any variables included as model covariates by listwise deletion. To prevent exclusion of significant proportions of cases, we did not include variables with greater than or equal to 5% data missing. We conducted all statistical analyses with SAS (version 9.4; SAS Institute, Inc., Cary, NC).

## RESULTS

During the study period, 5,244 intubation encounters occurred at 22 participating centers. NEAR collected data on 5,071 encounters (96.7% data capture). We included 2,275 intubation encounters using succinylcholine and 1,800 encounters using rocuronium (Figure 1). The mean dose of succinylcholine administered was 1.8 mg/kg (median 1.6 mg/kg), whereas the mean dose of rocuronium administered was 1.2 mg/kg (median 1.1 mg/kg).

Table 1 displays baseline characteristics, stratified by paralytic category. Patients receiving succinylcholine were younger and less obese. Proportions of patients with difficult airway characteristics were comparable between the 2 groups. Patients receiving succinylcholine were also more likely to undergo intubation with video laryngoscopy and more likely to undergo intubation by more experienced providers.

First-pass intubation success was 87.0% among succinylcholine encounters and 87.5% among rocuronium encounters (risk difference 0.5%; 95% CI –1.6% to 2.6%)

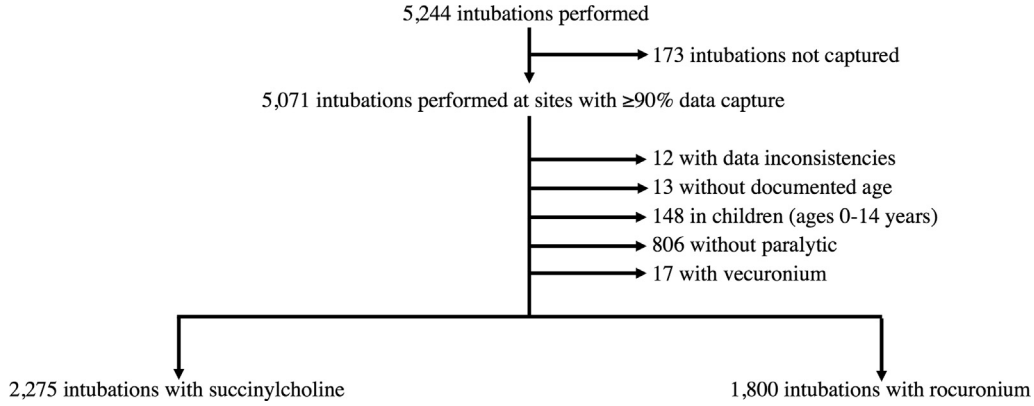


**Figure 1.** Intubations included from 22 sites participating in the NEAR during the study period.

(Table 2). First-pass intubation success was similar when stratified by NEAR site (Cochran-Mantel-Haenszel $\chi^2$ 0.1; $P$=.79) (Figure 2). Achievement of Cormack-Lehane grade 1 to 2 view on first intubation attempt was 88.5% for succinylcholine and 89.0% for rocuronium (Table 2). On multivariate analysis, first-pass intubation success was similar between succinylcholine and rocuronium after adjustment for difficult airway characteristics, indication for intubation, patient demographics, airway characteristics, intubation position, device, sedative agent, and intubator experience (odds ratio 0.9; 95% CI 0.6 to 1.3) (Table 3).

Subgroup analyses revealed similar first-pass intubation success between rocuronium and succinylcholine when stratified by patient characteristics, intubation modality, and sedative agent (Table E1, available online at http://www.annemergmed.com). The only significant difference noted in comparisons was higher first-pass intubation success among patients without any difficult airway characteristics who were treated with high-dose rocuronium (≥1.2 mg/kg) versus low-dose rocuronium (<1.2 mg/kg) (odds ratio 2.2; 95% CI 1.2 to 3.4).

Adverse events occurred in 14.7% of succinylcholine encounters versus 14.8% of rocuronium encounters (Table 4). Two or more adverse events occurred for 2.2% of succinylcholine encounters and 2.2% of rocuronium encounters in the data set. The most common adverse events included peri-intubation hypoxia and hypotension. There was no association between the incidence of any peri-intubation adverse event and paralytic agent (odds ratio 1.1; 95% CI 0.9 to 1.3).

## LIMITATIONS

Confounding is a risk in any observational study of this nature. Our analysis suggests a lack of association between paralytic choice and rapid sequence intubation outcomes but does not establish the presence or absence of a causal relationship between these variables, given this risk of confounding. Compared with the rocuronium encounters, the succinylcholine encounters included patients who were younger, less obese, and more likely to undergo intubation with video laryngoscopy, and undergo intubation by more experienced providers. Factors such as provider preference or patient contraindications (eg, hyperkalemia, neurologic conditions) may have biased the analysis. However, our observations were consistent across different subgroups.

NEAR also lacks data on other variables of clinical relevance. In particular, our data do not include times from paralytic administration to paralysis onset or offset, both of which are shorter for succinylcholine.[13] The literature discusses the possibility that these pharmacokinetics confer a clinical benefit to patients receiving succinylcholine by shortening the dangerous period during which they may not take spontaneous respirations.[2] Although small differences in paralysis onset may be unimportant for some patients, the time advantage may be important for select acutely ill patients. Examples might include patients with severe hypoxemia or profound acidosis, patient populations on which future investigations might focus.

A final limitation is that our self-reported data are susceptible to recall bias, with the potential for errors such as underreporting adverse events or overreporting intubation success. We surmise that such biases would be evenly distributed between paralytic groups. We strived to minimize such errors by requiring entry of 90% or more of all intubation encounters and encouraging completion of data forms by intubating providers as soon as possible after an intubation procedure.

## DISCUSSION

The most commonly used paralytics in ED rapid sequence intubation are succinylcholine and rocuronium.[2] The existing literature suggests that succinylcholine has

**Table 1.** Patient characteristics.

| Variable | Succinylcholine, All Doses (n=2,275) | % Not Reported | Rocuronium, All Doses (n=1,800) | % Not Reported |
|---|---|---|---|---|
| Mean age (SD), y | 49.8 (19.8) | 0 | 54.3 (19.7) | 0 |
| Sex (female), % | 31.6 | 0 | 34.7 | 0 |
| Mean weight (SD), kg | 80.2 (23.8) | 1.1 | 79.6 (22.3) | <1 |
| **Body habitus, %** | | <1 | | <1 |
| Very thin | 3.4 | | 4.8 | |
| Thin | 15.4 | | 17.0 | |
| Normal | 51.3 | | 45.3 | |
| Obese | 25.5 | | 28.3 | |
| Morbidly obese (BMI >40 kg/m$^2$) | 4.4 | | 4.3 | |
| Starting oxygen saturation (SD), % | 97.1 (9.2) | 7.7 | 97.1 (8.3) | 7.4 |
| **Indication, %** | | <1 | | <1 |
| Medical | 68.6 | | 78.7 | |
| Traumatic | 30.9 | | 21.3 | |
| Initial impression of difficult airway, % | 32.4 | <1 | 32.3 | <1 |
| Reduced neck mobility, % | 33.1 | <1 | 27.4 | <1 |
| Median Mallampati score (IQR) | 2 (1–3) | 61.5 | 2 (1–3) | 59.7 |
| Reduced mouth opening, % | 14.7 | 43.0 | 25.9 | 57.7 |
| Airway obstruction, % | 3.5 | <1 | 2.6 | <1 |
| Facial trauma, % | 13.8 | <1 | 10.5 | <1 |
| Blood or vomit in airway, % | 24.1 | <1 | 22.9 | <1 |
| Any difficult airway characteristic,* % | 65.6 | 0 | 62.9 | 0 |
| **Device, %** | | <1 | | <1 |
| Laryngoscope | 33.6 | | 41.1 | |
| Video laryngoscope | 65.8 | | 58.9 | |
| **Sedation agent, %** | | 3.4 | | 2.6 |
| Etomidate | 84.7 | | 79.0 | |
| Ketamine | 8.4 | | 14.8 | |
| Propofol | 2.7 | | 2.5 | |
| Other | 0.7 | | 1.1 | |
| **Intubator characteristics, %** | | 0 | | 0 |
| Emergency medicine PGY1 | 9.8 | | 10.8 | |
| Emergency medicine PGY2 | 27.2 | | 34.3 | |
| Emergency medicine PGY3–4 | 48.6 | | 47.7 | |
| Emergency medicine fellow | 5.2 | | 1.3 | |
| Emergency medicine attending physician | 3.4 | | 2.6 | |
| Other (nonemergency medicine) | 5.8 | | 3.3 | |

*BMI*, Body mass index; *IQR*, interquartile range; *PGY*, postgraduate year.

*Difficult airway characteristics coded as yes if the patient had at least one of the following: reduced neck mobility, Mallampati score greater than 1, reduced mouth opening, airway obstruction, facial trauma, and blood or vomit in airway.

several advantages, including faster onset, faster offset, and superior intubating conditions.[7] Our multicenter observational study found no association between choice of paralytic and first-pass intubation success.

The most recent Cochrane review and meta-analysis concluded that succinylcholine resulted in superior intubating conditions compared with rocuronium.[7] There are several potential reasons why our study results

**Table 2.** First-pass intubation outcomes.

| Variable | Succinylcholine, All Doses (n=2,275) | % Not Reported | Rocuronium, All Doses (n=1,800) | % Not Reported |
|---|---|---|---|---|
| First-pass intubation success, % | 87.0 | <1 | 87.5 | <1 |
| Overall intubation success, % | 99.6 | <1 | 99.9 | <1 |
| Any adverse event, % | 14.7 | 0 | 14.8 | 0 |
| Cormack-Lehane view grade 1–2, % | 88.5 | 1.5 | 89.0 | 1.0 |
| Median best first-attempt glottic view (IQR) | 1 (1–2) | 1.5 | 1 (1–2) | 1.0 |
| **Peri-intubation desaturation, %** | 9.5 | 5.8 | 9.0 | 6.7 |
| Mean oxygen saturation nadir (SD)* | 71.4 (18.9) | 90.6 | 74.2 (15.2) | 91.0 |

*Values are only for patients who experienced peri-intubation desaturation less than 90% after initiation of intubation attempt (n=217 for succinylcholine encounters and n=162 for rocuronium encounters).

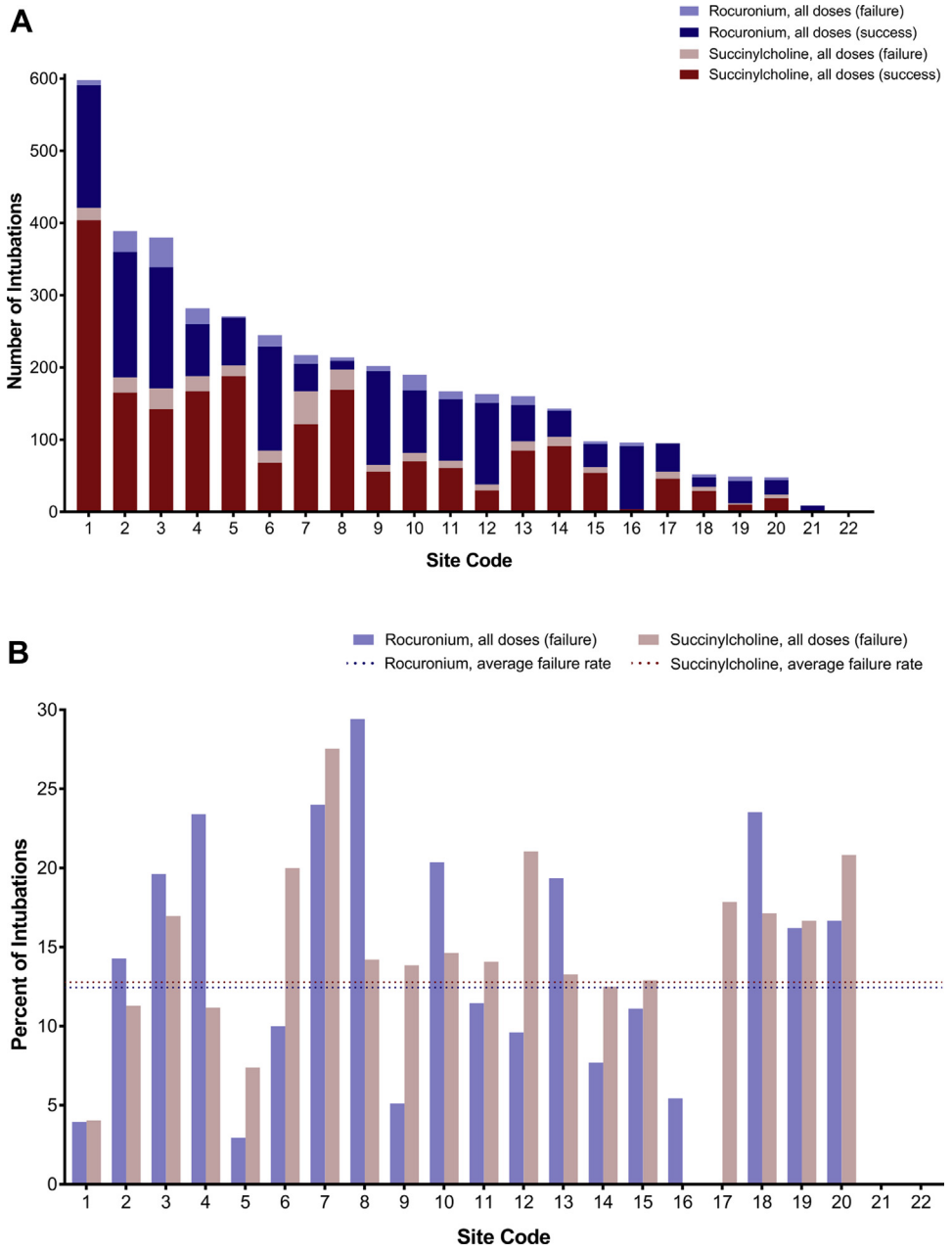


**Figure 2.** First-attempt intubation outcome stratified by NEAR site. (*A*) The vertical axis represents numbers of intubations. The horizontal axis stratifies data by each of the 22 individual sites contributing data to the present iteration of NEAR. Each bar represents a single NEAR site. The red portions of the bars represent encounters using succinylcholine; the blue portions, encounters using rocuronium. Solid portions of the bars represent encounters resulting in first-attempt intubation success, whereas the shaded portions represent those resulting in first-attempt intubation failure. (*B*) The vertical axis represents percentages of intubations performed at each site resulting in first-attempt intubation failure. The horizontal axis stratifies data by each of the 22 individual sites. The blue portions of the bars represents first-attempt intubation failures using rocuronium while the red portions of the bars represents first-attempt failures using succinylcholine. The dashed blue line represents the average percent of all first-attempt intubations with rocuronium resulting in failure. The dashed red line represents the average percent of all first-attempt intubations with succinylcholine resulting in failure.

differed from those of the Cochrane review. First, most of the studies included in the Cochrane review were randomized controlled trials conducted in operating room settings. Conversely, NEAR gathers observational data only on intubations performed in the ED setting, which poses distinct challenges such as noise, more critically ill patients, and limited time to optimize preintubation patient hemodynamics and equipment

**Table 3.** Multivariable adjusted associations between paralytic type and (1) first-pass intubation success and (2) adverse event.

| Variable | Odds Ratio (95% CI) First-Pass Success | Any Adverse Event* |
|---|---|---|
| **Paralytic type** | | |
| (Succinylcholine vs rocuronium, all doses) | 0.9 (0.6–1.3) | 1.1 (0.9–1.3) |
| Age | 1.0 (1.0–1.0) | 1.0 (1.0–1.0) |
| Sex: male vs female | 1.3 (1.0–1.7) | 1.1 (0.9–1.4) |
| **Body habitus** | | |
| Very thin/thin vs normal | 1.0 (0.8–1.4) | 1.3 (1.0–1.7) |
| Obese/morbidly obese vs normal | 0.8 (0.6–1.1) | 1.5 (1.1–2.0) |
| Weight | 1.0 (1.0–1.0) | 1.0 (1.0–1.0) |
| Indication: medical vs traumatic | 1.3 (0.9–1.7) | 0.9 (0.7–1.2) |
| Initial impression of difficult airway: yes vs no | 0.5 (0.4–0.7) | 1.5 (1.2–1.9) |
| Difficult airway characteristics†: yes vs no | 0.7 (0.6–0.9) | 1.5 (1.3–1.8) |
| **Intubation position** | | |
| Neutral vs full sniffing | 0.9 (0.8–1.2) | 1.0 (0.7–1.2) |
| Other vs full sniffing | 1.1 (0.8–1.4) | 1.0 (0.8–1.2) |
| Laryngoscope type: video vs direct | 2.3 (1.7–3.0) | 0.9 (0.7–1.1) |
| **Induction medications** | | |
| Ketamine vs etomidate | 1.2 (0.8–1.9) | 1.4 (1.1–1.8) |
| Other vs etomidate | 1.2 (0.7–1.9) | 0.5 (0.3–0.9) |
| **Intubator group** | | |
| Nonemergency medicine vs emergency medicine fellow/attending physician | 0.3 (0.1–0.7) | 1.3 (0.8–2.1) |
| Emergency medicine PGY1–2 vs emergency medicine fellow/attending physician | 0.6 (0.4–0.9) | 1.0 (0.7–1.3) |
| Emergency medicine PGY 3–4 vs emergency medicine fellow/attending physician | 0.9 (0.6–1.4) | 1.0 (0.7–1.3) |

*Any adverse event includes airway trauma, hypoxia, vomiting, dysrhythmias, cardiac arrest, hypotension, esophageal intubation, failed airway with cricothyrotomy, dental trauma, epistaxis, lip laceration, laryngospasm, main-stem intubation, pneumothorax, endotracheal tube cuff failure, iatrogenic bleeding, and laryngoscope failure.

†Difficult airway characteristics coded as yes if patient had at least one of the following: reduced neck mobility, Mallampati score greater than 1, reduced mouth opening, airway obstruction, facial trauma, and blood or vomit in the airway.

**Table 4.** Adverse events.

| | Succinylcholine, All Doses (n=2,275) | Rocuronium, All Doses (n=1,800) |
|---|---|---|
| **Adverse events (% of encounters)** | | |
| Any adverse event | 14.7 | 14.8 |
| Hypoxia | 8.8 | 8.6 |
| Hypotension | 3.8 | 4.4 |
| Dysrhythmias | 1.1 | 1.0 |
| Esophageal intubation | 0.8 | 0.8 |
| Cardiac arrest | 0.7 | 0.9 |
| Vomiting | 1.0 | 0.4 |
| Main-stem intubation | 0.3 | 0.3 |
| Laryngoscope failure | 0.3 | 0.1 |
| Endotracheal tube failure | <0.1 | 0.3 |
| Iatrogenic bleeding | 0.1 | 0.2 |
| Dental trauma | 0.1 | 0.1 |
| Lip laceration | 0.1 | 0.1 |
| Laryngospasm | <0.1 | 0.1 |
| Epistaxis | 0 | 0.1 |
| Pneumothorax | 0 | 0.1 |
| Direct airway injury | 0 | 0 |
| Malignant hypertension | 0 | 0 |
| Medical error | 0 | 0 |
| Pharyngeal laceration | 0 | 0 |
| **Number of adverse events (% of encounters)** | | |
| 0 | 85.3 | 85.2 |
| 1 | 12.5 | 12.7 |
| 2 | 1.8 | 1.7 |
| 3 | 0.4 | 0.4 |
| 4 | 0 | 0.1 |

setup. Second, the primary outcome measured by most of studies included in the Cochrane review was intubation condition as measured by the Goldberg scale, which incorporates operator assessment of ease of intubation, vocal cord movement, and patient response to intubation.[14,15] We instead measured outcomes we believe to be more patient centered and thus more clinically relevant, including first-pass intubation success and incidence of peri-intubation adverse events. Third, the Cochrane review included subgroup analyses finding better intubating conditions, with analysis restricted to studies examining succinylcholine compared with rocuronium dosed at 0.6 mg/kg,[16-18] but comparable intubating conditions with high-dose (≥1.2 mg/kg) rocuronium.[7] The mean dose of rocuronium administered in the encounters we report was relatively high, at 1.2 mg/kg, which may have contributed to our finding of no association between paralytic agent and first-pass intubation success.

Our finding of no association between paralytic and first-pass intubation success, glottic view, or incidence of adverse events is important, given the potential contraindications to succinylcholine use. Administration of succinylcholine in the setting of disorders upregulating muscle nicotinic acetylcholine receptors can result in acute hyperkalemia because of the flow of intracellular potassium into the plasma. Many clinicians may not be privy to the presence of these pathologic states at the intubation.[6] In contrast, the only established absolute contraindication to rocuronium use is hypersensitivity reaction.[19] To the extent that these medications otherwise result in similar intubation outcomes, it stands to reason that rocuronium is preferable as the default first-line paralytic agent.

NEAR does not include many data parameters pertinent to paralytic choice. Specifically, it does not include measures of muscle relaxation and intubation conditions except indirectly through reported best Cormack-Lehane glottic view.[11] We did capture encounters with peri-intubation

desaturation (oxygen saturation <90%) or hypotension during intubation but we did not capture any continuous vital sign measurements. Hence, our data provide an incomplete picture of peri-intubation physiology. Additionally, we have no data in regard to any patient-specific reasons, if any, for each intubating provider's choice of paralytic, which perhaps caused confounding in our results.

Given these limitations, we cannot make any inferences about causal relationships. Although our results appear to contradict previous data suggesting superior intubating conditions with succinylcholine, without an interventional trial we cannot conclude that succinylcholine is not superior to rocuronium in regard to first-pass intubation success. As such, we believe it would be premature for emergency physicians to guide their paralytic choice according to this report. Nevertheless, our data highlight that a clinical trial comparing these agents in the ED setting would be a valuable contribution to the literature.

In conclusion, we observed no difference between paralytic type and first-pass intubation success. Similarly, we found no association between paralytic type and the incidence of peri-intubation adverse events. Further study is necessary to clarify any causal relationships between paralytic agent choice and ED intubation outcomes.

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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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## REFERENCES

1. Brown CA 3rd, Bair AE, Pallin DJ, et al. Techniques, success, and adverse events of emergency department adult intubations. *Ann Emerg Med*. 2015;65:363-370.e1.
2. Mallon WK, Keim SM, Shoenberger JM, et al. Rocuronium vs. succinylcholine in the emergency department: a critical appraisal. *J Emerg Med*. 2009;37:183-188.
3. Sakles JC, Laurin EG, Rantapaa AA, et al. Airway management in the emergency department: a one-year study of 610 tracheal intubations. *Ann Emerg Med*. 1998;31:325-332.
4. Hasegawa K, Shigemitsu K, Hagiwara Y, et al. Association between repeated intubation attempts and adverse events in emergency departments: an analysis of a multicenter prospective observational study. *Ann Emerg Med*. 2012;60:749-754.e2.
5. Mort TC. Emergency tracheal intubation: complications associated with repeated laryngoscopic attempts. *Anesth Analg*. 2004;99:607-613.
6. Martyn JA, Richtsfeld M. Succinylcholine-induced hyperkalemia in acquired pathologic states: etiologic factors and molecular mechanisms. *Anesthesiology*. 2006;104:158-169.
7. Tran DT, Newton EK, Mount VA, et al. Rocuronium versus succinylcholine for rapid sequence induction intubation. *Cochrane Database Syst Rev*. 2015;2015:CD002788.
8. Walls RM, Brown CA 3rd, Bair AE, et al. Emergency airway management: a multi-center report of 8937 emergency department intubations. *J Emerg Med*. 2011;41:347-354.
9. April MD, Schauer SG, Brown CA 3rd, et al. A 12-month descriptive analysis of emergency intubations at Brooke Army Medical Center: a National Emergency Airway Registry study. *US Army Med Dep J*. 2017;2017:98-104.
10. von Elm E, Altman DG, Egger M, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *PLoS Med*. 2007;4:e296.
11. Cormack RS, Lehane J. Difficult tracheal intubation in obstetrics. *Anaesthesia*. 1984;39:1105-1111.
12. Rao SR, LaRocque RC, Jentes ES, et al. Comparison of methods for clustered data analysis in a non-ideal situation: results from an evaluation of predictors of yellow fever vaccine refusal in the Global TravEpiNet (GTEN) Consortium. *Int J Stat Med Res*. 2014;3:215-223.
13. Dhonneur G, Kirov K, Slavov V, et al. Effects of an intubating dose of succinylcholine and rocuronium on the larynx and diaphragm: an electromyographic study in humans. *Anesthesiology*. 1999;90:951-955.
14. Goldberg ME, Larijani GE, Azad SS, et al. Comparison of tracheal intubating conditions and neuromuscular blocking profiles after

intubating doses of mivacurium chloride or succinylcholine in surgical outpatients. *Anesth Analg*. 1989;69:93-99.

15. Weiss JH, Gratz I, Goldberg ME, et al. Double-blind comparison of two doses of rocuronium and succinylcholine for rapid-sequence intubation. *J Clin Anesth*. 1997;9:379-382.
16. Larsen PB, Hansen EG, Jacobsen LS, et al. Intubation conditions after rocuronium or succinylcholine for rapid sequence induction with alfentanil and propofol in the emergency patient. *Eur J Anaesthesiol*. 2005;22:748-753.
17. Marsch SC, Steiner L, Bucher E, et al. Succinylcholine versus rocuronium for rapid sequence intubation in intensive care: a prospective, randomized controlled trial. *Crit Care*. 2011;15:R199.
18. Sluga M, Ummenhofer W, Studer W, et al. Rocuronium versus succinylcholine for rapid sequence induction of anesthesia and endotracheal intubation: a prospective, randomized trial in emergent cases. *Anesth Analg*. 2005;101:1356-1361.
19. Takazawa T, Mitsuhata H, Mertes PM. Sugammadex and rocuronium-induced anaphylaxis. *J Anesth*. 2016;30:290-297.