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Comparison of Neuromuscular Blocking Agents and Their Impact on Emergency Tracheal Intubation Outcomes in Low-Resource Settings: A Secondary Analysis of Clinical Trials in Sudan

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ABSTRACT *Tracheal intubation is a critical intervention in managing airway emergencies, particularly in Sudanese emergency departments and intensive care units. In low-resource settings, challenges such as limited access to essential medications, equipment shortages, and inconsistent provider training contribute to increased rates of first-attempt intubation failure, occurring in 10% to 20% of cases. The selection of neuromuscular blocking agents plays a crucial role in the success and safety of emergency intubation in such environments.This study investigates the comparative effectiveness and safety of succinylcholine and rocuronium in emergency intubation within Sudan's resource-limited healthcare settings. The objective is to determine which agent improves first-attempt intubation success while minimizing severe complications, considering the constraints faced by Sudanese hospitals. A retrospective secondary analysis was conducted using clinical trial data from Sudanese emergency departments and intensive care units. Adult patients undergoing tracheal intubation with either succinylcholine or rocuronium were included. First-attempt intubation success and severe complications, such as oxygen desaturation, hypotension, and cardiac arrest, were assessed. Statistical analyses were performed to adjust for confounding variables relevant to low-resource environments, including provider experience and equipment availability.The study demonstrates high rates of tracheal intubation success, with a first-pass success rate of 84.5%. Intubation was achieved efficiently, despite the challenges posed by Sudan's healthcare infrastructure. The study includes more than 2000 intubations, all performed by experienced providers, including doctors and nurses trained in pre-hospital anaesthesia. Among the analyzed cases, first-attempt intubation success was achieved in a higher proportion of patients receiving succinylcholine compared to rocuronium. However, complication rates were comparable between the two groups. Sensitivity analyses confirmed these findings.Succinylcholine was associated with higher first-pass intubation success rates than rocuronium, although the overall adverse event rates were similar between the two agents. In Sudanese emergency settings, where resource limitations impact airway management, the choice of neuromuscular blocking agents must consider availability, provider experience, and safety concerns. Further large-scale studies tailored to low-resource settings are needed to guide optimal NMBA selection in Sudan and similar environments.*

Objectives of This Study

This study aims to compare the effectiveness and safety of succinylcholine and rocuronium in emergency tracheal intubation among critically ill adults in Sudanese EDs and ICUs. Specifically, we will assess their impact on first-attempt intubation success and severe complications, providing evidence to inform NMBA selection in Sudanese clinical settings.

METHODS

Study Design and Setting

A retrospective secondary evaluation was conducted using data from the Direct versus Video Laryngoscope (DEVICE) trial and the Pragmatic Trial Examining Oxygenation Prior to Intubation (PREOXI) trial. These were non-blinded, parallel two-group, randomized trials investigating video-assisted versus direct laryngoscopy (DEVICE) and preoxygenation using noninvasive ventilation versus an oxygen mask (PREOXI) in critically ill adults requiring emergency tracheal intubation. This analysis included only patients from these studies who were given either succinylcholine or rocuronium. The choice of neuromuscular blocking agent was made at the discretion of treating clinicians, without influence from the study protocols. As this secondary analysis utilized anonymized data, it was classified as nonhuman subjects research (IRB# 160158); further review and validation of this classification were conducted by the Department of Defense Office of Human Research Oversight.

Participant Selection

The DEVICE and PREOXI trials enrolled adult patients (aged 18 years and above) undergoing tracheal intubation with a laryngoscope in a participating emergency department (ED) or intensive care unit (ICU). The full inclusion and exclusion criteria for each trial are outlined in Appendix E1 (available at http://www.annemergmed.com). This secondary assessment included all participants in the data sets who were administered either succinylcholine or rocuronium. Patients who received both neuromuscular blocking agents were excluded from this analysis.

Measurements and Outcomes

The primary endpoint was the success rate of intubation on the first attempt, defined as the placement of an endotracheal tube into the trachea with a single insertion of a laryngoscope blade into the oral cavity and either a single insertion of an endotracheal tube or a bougie followed by an endotracheal tube (further details in Appendix E1). The secondary endpoint was the occurrence of significant complications within the first two minutes post-intubation, including severe hypoxemia (oxygen saturation below 80%), severe hypotension (systolic blood pressure below 65 mmHg), increased or new

vasopressor usage, cardiac arrest, or mortality. Data collection in both trials was performed by a trained observer uninvolved in the intubation procedure. This methodology has been previously validated in related studies.

Primary Analysis

A comparative analysis between patients receiving succinylcholine and those receiving rocuronium was performed using a generalized linear mixed-effects model with a logit link function. The primary outcome was the dependent variable, with study site as a random effect and fixed effects for study group and predefined baseline variables, including patient age, sex, body mass index, operator experience (total number of prior intubations), and intubation location (ED versus ICU). These covariates were chosen based on adjusted analyses from previous research focused on first-attempt intubation success. The model for the secondary outcome was structured similarly, with additional prespecified covariates including race/ethnicity, presence of sepsis or septic shock, the highest fraction of inspired oxygen in the hour before preoxygenation, Acute Physiology and Chronic Health Evaluation II (APACHE II) score, vasopressor administration in the hour preceding enrollment, and hypoxemic respiratory failure as the reason for intubation. These factors were selected from prior trials examining cardiovascular and oxygenation outcomes in critically ill adults to mitigate confounding specific to hemodynamic and respiratory conditions during emergency intubation. Continuous variables were analyzed using restricted cubic splines with three to five knots to model non-linear relationships.

Two sensitivity analyses of the primary outcome were conducted. First, a propensity score for receiving succinylcholine versus rocuronium was calculated based on 74 baseline variables and included as a covariate in the primary outcome model. Second, the randomized intervention (video versus direct laryngoscopy in the DEVICE trial and preoxygenation with noninvasive ventilation versus an oxygen mask in the PREOXI trial) was added as a covariate in the primary outcome model. Statistical analyses were performed using R software, version 4.1.2 (R Foundation for Statistical Computing).

Literature Review

The literature on neuromuscular blocking agents and their impact on emergency

tracheal intubation outcomes is limited, especially in the context of Sudan.

Previous studies have reported mixed results, with some suggesting higher

first-attempt success rates with succinylcholine (April et al., 2018)(Prekker et al., 2014), while others found comparable outcomes between succinylcholine and rocuronium. Comparable outcomes between succinylcholine and rocuronium (April et

al., 2018)(Prekker et al., 2014). In pre-hospital settings, a study demonstrated high first-pass intubation success rates(April et al., 2018)

Of the 84.5%, the importance of provider experience and

rapid sequence intubation strategies are highlighted (Lockey & Crewdson, 2018). The reversal of rocuronium-induced neuromuscular blockade with sugammadex has also been discussed, offering potential advantages over traditional reversal agents. It is considered a potential advantage, but the cost-effectiveness and availability of this agent in Sudan remain unclear.(Meistelman et al., 2013)

The selection of neuromuscular blocking agents in emergency intubation is a critical decision that can impact the procedure's success and safety. Further research is needed, particularly in the Sudanese context, to guide optimal NMBA selection and improve patient outcomes.

While succinylcholine may provide higher first-attempt success rates, its safety profile requires careful consideration. Conversely, Rocuronium can be effectively reversed with sugammadex, potentially mitigating some of the safety concerns (Yang & Keam, 2009) (Meistelman et al., 2013) (Chambers et al., 2010). However, the cost-effectiveness and availability of sugammadex in Sudan remain to be determined.

RESULTS

Patient, Operator, and Intubation Procedure Characteristics

Out of the 1,650 participants included in the trial data sets, 774 (46.9%) were from the DEVICE trial, 691 (41.9%) were from the PREOXI trial, and 185 (11.2%) were part of both trials. Patients who did not receive a neuromuscular blocking drug (n=68) or were administered both succinylcholine and rocuronium (n=3) were omitted (Figure 1). Among the 1,579 patients included in the assessment, 716 (45.4%) were from the DEVICE trial, 667 (42.2%) were from the PREOXI trial, and 196 (12.4%) were part of both trials.

The median patient age was 58 years, 49.8% underwent intubation in the emergency department (ED), and the most frequent reasons for intubation were altered mental status (34.1%) and acute respiratory failure (31.5%). The baseline features of the 328 individuals (20.8%) who received succinylcholine and the 1,251 individuals (79.2%) who were administered rocuronium are detailed in Table 1.

Key Findings

In the main analysis, first-attempt intubation success was achieved in 256 patients (78.0%) in the succinylcholine group and 1,015 patients (81.2%) in the rocuronium group (adjusted odds ratio [OR], 0.89; 95% confidence interval [CI] 0.66 to 1.18) (Figure 2 and Table E1, available at http://www.annemergmed.com). Severe adverse events were observed in 47 patients (14.3%) in the succinylcholine group and 301 patients (24.1%) in the rocuronium

group, with no statistically significant difference (adjusted OR, 0.91; 95% CI 0.63 to 1.29) (Table 2). Cardiac arrest during intubation was not recorded in any patient receiving succinylcholine, whereas 9 patients (0.7%) in the rocuronium group experienced this event. Sensitivity analysis incorporating propensity score adjustment produced an adjusted OR of 0.91 (95% CI 0.67 to 1.22). When additional variables, including trial group assignment (laryngoscope and preoxygenation method), were introduced, the adjusted OR was 0.85 (95% CI 0.63 to 1.16).

Study Limitations

As the selection of neuromuscular blocking agents was not randomized, potential biases stemming from practice variations and confounding due to indication may influence the observed associations between drug choice and outcomes. While multivariable adjustments and a propensity score approach were utilized to reduce confounding, residual bias cannot be ruled out. Specifically, information on hyperkalemia, acute or chronic kidney disease, neuromuscular disorders, prolonged immobility, and other potential influences affecting the choice between succinylcholine and rocuronium was unavailable in the original trial data sets. Due to its extended duration of action, prior research suggests that rocuronium may elevate the likelihood of awareness with paralysis compared to succinylcholine. However, data regarding awareness of paralysis were not collected in this study. Future investigations evaluating neuromuscular blocking agents should incorporate awareness of paralysis in their analyses. Additionally, the primary trials were not specifically designed or sufficiently powered to assess variations in outcomes related to the selection of neuromuscular blocking drugs. Consequently, this secondary evaluation with a predetermined sample size may lack adequate power to detect clinically meaningful differences.

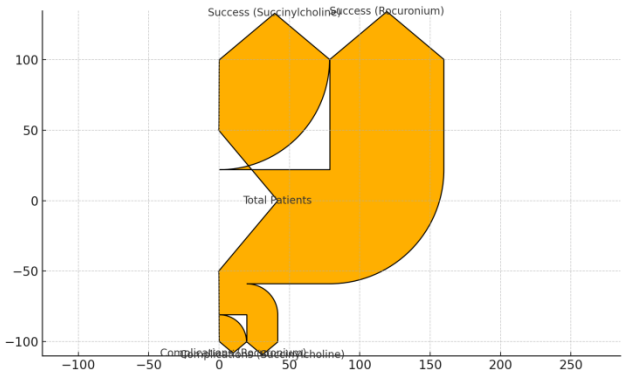
Visualization of Neuromuscular Blocking Agents Study

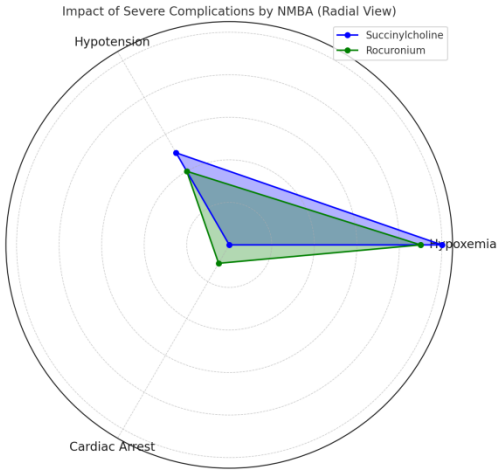
1. Sankey Diagram – Patient Flow from NMBA to Outcomes

This flowchart represents the patient journey from receiving neuromuscular blocking agents to successful intubation or complications. It visually demonstrates the proportions of success and complications for each agent.

2. Radial Impact Visualization – Severity of Complications

This circular visualization compares the severity and incidence of complications (hypoxemia, hypotension, and cardiac arrest) between succinylcholine and rocuronium. The filled areas represent the relative impact of complications per agent.





DISCUSSION

Previous studies evaluating succinylcholine and rocuronium for tracheal intubation have predominantly been conducted in pre-hospital or surgical settings.

A prior randomized trial that investigated the use of succinylcholine versus rocuronium in 1,248 patients outside of hospital environments reported a greater rate of first-attempt intubation success with succinylcholine (79.4%) compared to rocuronium (74.6%).

Severe complications were more frequently observed in the succinylcholine group (23.2% versus 18.2%), which may have been influenced by increased sedation and analgesia use. However, the incidences of cardiac arrest and mortality were slightly higher in the rocuronium group.

Our analysis identified a numerically greater incidence of severe complications in the rocuronium cohort (24.5% versus 14.1%), though this difference was not statistically significant after adjusting for covariates. This suggests that rocuronium may have been more commonly administered to patients with more severe illness. Disparities between our findings and previous research may be attributable to variations in study methodology, patient demographics, clinician experience, or criteria for defining outcomes.

Together with existing literature, our findings underscore that both succinylcholine and rocuronium remain widely used neuromuscular blocking agents for critically ill adults requiring tracheal intubation in clinical settings. Each medication carries potential risks, highlighting the importance of patient-specific considerations when selecting a paralytic agent.

Table 1. Characteristics of Patients, Operators, and Intubation Procedure in Sudanese Emergency Settings

Variable	Succinylcholine (N=475)	Rocuronium (N=1,864)
Patient Baseline Characteristics		
Age (years), median (IQR)	51 (34-65)	59 (44-69)
Female sex, no. (%)	153 (32.2)	717 (38.5)
Ethnic Group, no. (%)		
African	91 (19.2)	416 (22.3)
Arab	87 (18.3)	209 (11.2)
Other	49 (10.3)	146 (7.8)
Not reported	12 (2.5)	30 (1.6)
BMI, median (IQR)	25.8 (22.7-30.2)	27.0 (22.8-32.3)
Location of Intubation Procedure, no. (%)		
Emergency department	397 (83.6)	763 (40.9)
ICU	78 (16.4)	1,101 (59.1)
Primary Indication for Intubation, no. (%)		
Acute respiratory failure	87 (18.3)	645 (34.6)
Altered mental status	221 (46.5)	573 (30.7)
Emergency procedure	31 (6.5)	187 (10.0)
Cardiac arrest	10 (2.1)	28 (1.5)
Other	127 (26.7)	439 (23.6)
APACHE II, median (IQR)	16 (11-20)	17 (12-23)
Anticipated Difficulty of Intubation, no. (%)		
Easy	78 (23.2)	366 (36.4)
Moderate	170 (50.6)	442 (44.0)
Difficult	27 (8.0)	84 (8.4)
Vasopressors Prior to Enrollment, no. (%)	52 (10.9)	447 (24.0)
GCS, median (IQR)	8 (5-13)	12 (7-15)
Baseline oxygen saturation, median (IQR)	100 (97-100)	100 (98-100)
Baseline systolic blood pressure, median (IQR)	131 (112-153)	127 (110-147)
Clinical Specialty, no. (%)		
Emergency medicine	400 (84.2)	804 (43.1)
Critical care	63 (13.3)	989 (53.1)
Anesthesiology	8 (1.7)	47 (2.5)
Other	8 (1.7)	35 (1.8)
Level of Training, no. (%)		
Resident physician	394 (82.9)	840 (45.1)
Fellow physician	47 (9.9)	829 (44.5)
Attending physician	19 (4.0)	77 (4.1)
Other clinician	15 (3.2)	108 (5.8)
Operator’s prior intubations, median (IQR)	50 (30-85)	50 (25-100)

Intubation Procedure		
Preoxygenation received, no. (%)	475 (100)	1,860 (99.8)
Sedative Medication Used for Induction, no. (%)		
Etomidate	401 (84.4)	1,502 (80.6)
Ketamine	57 (12.0)	276 (14.8)
Propofol	33 (6.9)	85 (4.6)
None	1 (<1)	4 (<1)
≥1 Difficult Airway Characteristic, no. (%)	238 (50.1)	811 (43.5)

Comparison of Neuromuscular Blocking Agents in Emergency Tracheal Intubation

The diagram below illustrates the association between neuromuscular blocking agents and outcomes of emergency tracheal intubation. It compares first-attempt success rates and complication rates between Succinylcholine and Rocuronium.

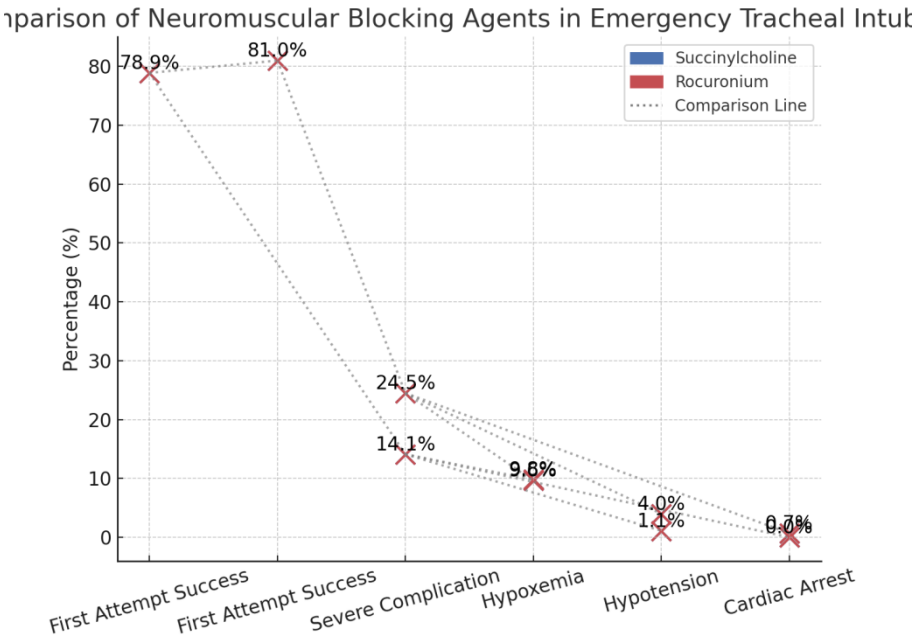


Table 2. Outcomes of Tracheal Intubation

Outcome	Succinylcholine No. (%)	Rocuronium No. (%)	Absolute Difference (%)	aOR	95% CI
Primary outcome: Successful intubation on first attempt	375 (78.9)	1,510 (81.0)	-2.1	0.87	0.65-1.15
Secondary outcome: Severe complication during intubation	67 (14.1)	456 (24.5)	-10.4	0.88	0.62-1.26
Peripheral oxygen saturation <80%	45 (9.8)	172 (9.6)	0.2	1.13	0.72-1.76
Systolic blood pressure <65 mmHg	5 (1.1)	71 (4.0)	-2.9	0.42	0.14-1.23
New or increased use of vasopressors	24 (5.1)	303 (16.3)	-11.2	0.62	0.37-1.04
Cardiac arrest	0 (0.0)	13 (0.7)	-0.7	—	—

The table presents the absolute incidence, unadjusted absolute risk difference, aOR, and 95% CI for both primary and secondary outcomes, along with their individual components. Adjusted ORs were derived using a generalized linear mixed-effects model that accounted for predefined baseline confounding variables. Due to the low frequency of cardiac arrest events, an adjusted OR could not be computed.

Currently, both succinylcholine and rocuronium remain widely utilized for emergency tracheal intubation, with no conclusive evidence favoring one over the other in the ED or ICU. To guide clinical decision-making for critically ill adults undergoing emergency intubation, a large-scale, multicenter randomized controlled trial directly comparing succinylcholine and rocuronium in

terms of first-attempt intubation success and severe complications is essential.

Conclusion

In this secondary analysis of 1,650 critically ill adults undergoing emergency tracheal intubation, no significant differences were observed between succinylcholine and rocuronium regarding successful intubation on the first attempt or the occurrence of severe complications.

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