

# Predictors of first pass success without hypoxemia in trauma patients requiring emergent rapid sequence intubation

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## ABSTRACT

**Objective** The predictors of first pass success (FPS) without hypoxemia among trauma patients requiring rapid sequence intubation (RSI) in the emergent setting are unknown.

**Methods** Retrospective study of adult trauma patients requiring RSI during a 5-year period comparing the trauma patients achieving FPS without hypoxemia to those who did not. The primary outcome was FPS without hypoxemia evaluated by multivariate logistic regression adjusting for the neuromuscular blocking agent used (succinylcholine or rocuronium), hypoxemia prior to RSI, Glasgow Coma Scale (GCS) scores, the presence of head or facial trauma, and intubating operator level of training.

**Results** 246 patients met our inclusion criteria. The overall FPS rate was 89%, and there was no statistical difference between those receiving either paralytic agent. 167 (69%) patients achieved FPS without hypoxemia. The two groups (those achieving FPS without hypoxemia and those who did not) had similar mean GCS, mean Injury Severity Scores, presence of head or facial trauma, the presence of penetrating trauma, intubating operator-level training, use of direct laryngoscopy, hypoxemia prior to RSI, heart rate per minute, mean systolic blood pressure, and respiratory rate. In the multivariate regression analysis, the use of succinylcholine and GCS score of 13–15 were found to have adjusted ORs of 2.1 (95% CI 1.2 to 3.8) and 2.0 (95% CI 1.0 to 3.3) for FPS without hypoxemia, respectively.

**Conclusion** Trauma patients requiring emergency department RSI with high GCS score and those who received succinylcholine had higher odds of achieving FPS without hypoxemia, a patient safety goal requiring more study.

**Level of evidence** IV.

**Study type** Prognostic.

## INTRODUCTION

The first priority during the resuscitation of trauma patients begins with the airway evaluation to ensure a patent airway can facilitate adequate oxygenation and ventilation. The preferred method of emergency tracheal intubation for the injured trauma patient is rapid sequence intubation (RSI).<sup>1</sup> Previous studies in the general population of patients undergoing emergent intubation have shown that more than one attempt at intubation is associated with a substantial increase in the frequency of adverse events.<sup>2–4</sup> The importance of obtaining intubation on the first attempt has also been demonstrated in

the prehospital and critical care settings to prevent adverse events.<sup>5</sup> This supports the concept that every effort should be made to maximize the success of the first attempt at laryngoscopy during the intubation of trauma patients requiring intubation.

Hypoxemia during the intubation of trauma patients has been associated with adverse outcomes in a select group of injured patients.<sup>6,7</sup> Therefore, a reasonable patient safety goal for patients requiring RSI is to achieve first pass success (FPS) without the occurrence of hypoxemia. No study has assessed the predictors of FPS without hypoxemia in trauma patients undergoing RSI. The objective of this study was to determine the predictors of FPS without hypoxemia among trauma patients undergoing RSI using multivariate logistic regression analysis.

## METHODS

### Settings

This was a retrospective cohort study performed at NYC Health + Hospitals | Lincoln, a municipal and academic level 1 trauma center (designated by the American College of Surgeons) in the Bronx borough of New York City that admits over 1200 trauma patients per year. This article generally adheres to the applicable EQUATOR (Enhancing the Quality and Transparency of Health Research) guideline. Our institution has an Accreditation Council for Graduate Medical Education-accredited 4-year emergency medicine (EM) residency program, and trauma intubations are performed by an EM resident under direct supervision by EM and anesthesia attendings or by an attending at their discretion. EM residents have training in airway management through simulation lab, critical care, and anesthesia rotations. Our emergency department (ED) prepares RSI medication kits that contain etomidate for induction of sedation and both succinylcholine and rocuronium for paralysis. The neuromuscular blocking agent (NMBA) used for RSI was guided by attending physician preference. Data on peri-intubation oxygenation values (pre-RSI oxygen saturation and hypoxemia during RSI), NMBA, operator level of training, direct versus video laryngoscopy methods, and attempts at tracheal intubation were entered into the electronic medical record (EMR) after the intubation by the intubating operator.

### Study design and data collection

We conducted a retrospective study attempting to reduce bias inherent in study designs.<sup>8</sup> EMRs

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were searched to find adult trauma patients intubated in the ED using both an NMBA and induction of anesthesia agent for RSI between January 1, 2011 and December 31, 2016 to adhere to the accepted definition of RSI according to the Eastern Association for the Surgery of Trauma (EAST) practice management guideline.<sup>1</sup> Data were retrospectively collected via manual chart review by abstractors blinded to our study hypothesis from the EMR on patient age, presenting Glasgow Coma Scale (GCS) score, calculated Injury Severity Score, heart rate, systolic blood pressure, respiratory rate, the presence of head or facial injury, a penetrating injury mechanism, and mortality. Patients were excluded from our data analysis if they were missing documentation or did not meet the definition of trauma RSI (the use of an induction/sedation agent and an NMBA). FPS without hypoxemia was defined as a successful tracheal intubation on the first laryngoscope insertion without oxygen saturation falling below 90% during the intubation.<sup>3</sup> Pre-RSI oxygen saturation was defined as the most recent SpO<sub>2</sub> obtained before the RSI medications were administered, and hypoxemia during RSI was defined as the lowest oxygen saturation after induction and within 2 minutes after confirmation of intubation.<sup>9 10</sup> We found no previous studies on predictors of FPS without hypoxemia among trauma patients requiring intubation on which to base a sample size or power calculation. The primary outcome was to identify the predictors of FPS without hypoxemia using a multivariate logistic regression model to obtain adjusted ORs (aOR) among a cohort of traumatically injured patients undergoing RSI.

### Statistical analysis

Patients were categorized into two groups based on whether they achieved FPS without hypoxemia and those who did not. The Wilcoxon rank-sum and  $\chi^2$  tests were used to compare the continuous variables and proportions, respectively; and the difference between the means with 95% CI is reported between the two groups.

A multivariate logistic regression analysis was performed to evaluate the association between available factors potentially associated with the outcome of FPS without hypoxemia. We considered all confounding variables available in our data and intended to create a model based on relevance to the outcome of FPS without hypoxemia. We included the following confounding variables in the model: choice of NMBA, presence of hypoxemia prior to RSI, GCS, presence of head or facial trauma, and the intubating operator level of training. The goodness of fit of the model was checked by the Hosmer-Lemeshow test. The model was checked for multicollinearity by evaluating the variance inflation factors among the included variables. A *p* value <0.05 was used to determine significance. Statistical analyses were conducted using SPSS V.24.0 (IBM, SPSS) and R V.3.5.3.

### RESULTS

Two hundred and sixty patient cases were identified for inclusion; eight were excluded for lack of NMBA, and six were excluded for lack of induction agent. Two hundred and forty-six patients were identified during the 5-year period who met our inclusion criteria. One hundred and sixty-seven (68%) patients achieved FPS without hypoxemia, and 79 (32%) of patients did not. The comparison of patient age, operator demographics, mechanism of injury, severity of injury, and RSI variables between the two groups of patients achieving FPS without hypoxemia and those who did not are available in [table 1](#). No patients in our study had previously identified end-stage renal disease or prolonged downtime (>1 hour) prior to ED arrival. The overall FPS rate was

89% (219/246). The FPS rate among patients receiving succinylcholine and rocuronium was 87.9% (145/165) and 91.4% (74/81), respectively, resulting in a difference of 3.5% (95% CI -5.6% to 10.8%; *p*=0.41).

In the multivariate logistic regression model to identify variables associated with the FPS without hypoxemia among trauma patients undergoing RSI, only the use of succinylcholine and high GCS score<sup>11-13</sup> were associated with statistically significant aORs. The aORs for the use of succinylcholine and high GCS score were 2.1 (95% CI 1.2 to 3.8) and 1.8 (95% CI 1.0 to 3.8), respectively ([table 2](#)). According to the Hosmer-Lemeshow goodness-of-fit test (*p*=0.728), the model fit the data well. There was no multicollinearity detected between variables included in the model.

### DISCUSSION

This is the first study to assess the factors associated with first pass success (FPS) without hypoxemia in traumatically injured patients requiring RSI. Patients requiring emergent intubation require first pass success to reduce adverse events, including hypoxemia.<sup>2-5</sup> The most important finding of our study is that the use of succinylcholine (aOR 2.3; 95% CI 1.3 to 4.2) and patients with high GCS score (aOR 1.8; 95% CI 1.0 to 3.3) were associated with FPS without hypoxemia via multivariate logistic regression among patients requiring RSI after a traumatic injury at a level 1 trauma center. Our analysis of variables affecting FPS without hypoxemia included both physician and patient-dependent variables.

The physician-dependent variables included the choice of NMBA (succinylcholine vs. rocuronium) and operator level of training. Our results support the EAST guideline<sup>1</sup> recommendation of succinylcholine as the first-line NMBA for injured patients, in the absence of any contraindication for its use. Certainly, acutely injured patients with risk factors for hyperkalemia should be considered for the use of rocuronium in these settings; however, we did not identify any patients in this cohort to have pre-existing contraindications for succinylcholine. Although succinylcholine was associated with FPS without hypoxemia in this study, it is important to note that our FPS success rates did not differ between those receiving either NMBA. These findings are consistent with a large retrospective study in the ED setting which demonstrated no difference in FPS between the two NMBAs.<sup>14</sup> The indication for intubation in this large study was trauma in one in four patients, and the mean dose of rocuronium given was 1.2 mg/kg. The onset of rocuronium is dose dependent with doses of 1.2 mg/kg or higher resulting in more rapid paralysis than the labeled dose of 0.6 mg/kg. A Cochrane review and meta-analysis found that rocuronium creates similar intubating conditions to succinylcholine only when dose at or above the threshold of 1.2 mg/kg.<sup>15</sup> Since we do not have data on the dose of NMBAs, the strength of our findings regarding their performance is reduced. The choice of NMBA is a physician-dependent variable that may be affected by peri-intubation physiology,<sup>11</sup> and further studies are warranted regarding the physician choice of NMBA for the emergent tracheal intubation of trauma patients.

Furthermore, we did not find that the intubating operator level of training of PGY 1-2 versus greater formal PGY education status had an impact on achieving FPS without hypoxemia in this trauma cohort, compared with a study in the general ED population undergoing RSI.<sup>3</sup> This may be due to the high frequency of non-trauma patients (67%) included in this previous study evaluating FPS without hypoxemia.<sup>3</sup> Alternatively, this difference

**Table 1** Patient demographics, injury severity, physiological variables, intubating operator level of training, perioperative oxygenation, neuromuscular blocking agent, and device used for laryngoscopy

	First pass success without hypoxemia n=167	No first pass success without hypoxemia n=79	Difference (95% CI)	P value
Age (mean)	36	44	-8 (-3.3 to -12.7)	0.001
ISS (mean)	34	31	-2.9 (-7.8 to 2.2)	0.25
GCS (mean)	10	9.3	-0.7 (-1.9 to 0.5)	0.25
GCS, median (IQR)	11 (6, 14)	9 (6, 13.5)		
GCS score 13–15 (n)	73 (43.7%)	23 (29.1%)	14.6% (2.1 to 27.1)	0.03
Heart rate (mean)	100	93	-6.7 (-13.9 to 0.4)	0.06
Systolic BP (mean)	133	131	-2.0 (-10.7 to 6.7)	0.65
Respiratory rate (mean)	21	21	0.05 (-2.0 to 2.0)	0.99
Head or facial injury (n)	76 (46%)	32 (40%)	5.0% (-8.2 to 18.2)	0.38
Penetrating injury (n)	48 (28.7%)	15 (18.9%)	9.8% (-2.0 to 20)	0.10
<b>Operator training level (n)</b>				
Attending	45 (27%)	19 (24%)	3% (-9.1 to 13.8)	0.62
EM PGY 4	16 (10%)	4 (5%)	5% (-3.1 to 11.2)	0.19
EM PGY 3	29 (17%)	18 (23%)	-5.4% (-16.3 to 5.5)	0.26
EM PGY 2	49 (29%)	20 (25%)	4.0% (-7.8 to 15.8)	0.51
EM PGY 1	28 (17%)	18 (23%)	-6.0% (-17.5 to 4.1)	0.26
<b>Oxygen saturation</b>				
O <sub>2</sub> pre-RSI (mean)	97%	97%	-0% (-2 to 2)	0.99
Hypoxemia at confirmation (n)	0 (0%)	59 (75%)	75% (65 to 84)	<0.0001
O <sub>2</sub> at time of confirmation (mean)	96%	85%	-11% (-12 to -8.3)	<0.0001
<b>Laryngoscopic device (n)</b>				
Direct	159 (95%)	77 (97%)	-2.3% (-7 to 2.5)	0.47
Video	8 (5%)	2 (2.5%)	2.3% (-2.5 to 7)	0.36
<b>NMBA (n)</b>				
Succinylcholine	121 (72.5%)	44 (55.7%)	16.8% (4.1 to 29.4)	0.01
Rocuronium	46 (27.5%)	35 (44.3%)	-16.8% (-4.1 to -29.4)	0.01

O<sub>2</sub>=SpO<sub>2</sub>. Hypoxemia=SpO<sub>2</sub><90%. O<sub>2</sub> pre-RSI=most recent SpO<sub>2</sub> obtained before the RSI medications were administered. O<sub>2</sub> at time of confirmation=the lowest SpO<sub>2</sub> after induction and within 2 min after confirmation of intubation.

BP, blood pressure; EM, emergency medicine; GCS, Glasgow Coma Scale; ISS, Injury Severity Score; NMBA, neuromuscular blocking agent; RSI, rapid sequence intubation.

could be due to the high use (82%) of video laryngoscopy in the previous study. In a previous study evaluating whether EM residents have different learning curves for the use of direct and video laryngoscopy to achieve FPS, the learning curve for direct laryngoscopy was nearly flat. No significant improvement in FPS occurred over the course of EM PGY 1–3 training when using direct laryngoscopy.<sup>12</sup> It may be possible that we did not find an association between intubating operator PGY status and FPS without hypoxemia because our physicians almost exclusively used direct laryngoscopy.

The patient-dependent variables in our logistic regression analysis included hypoxemia prior RSI, GCS scores, and the presence of head or facial injury. We found that injured patients undergoing RSI with a GCS score of 13 or greater had higher odds of achieving FPS without hypoxemia. We think the majority of patients with GCS score of 15 were intubated for airway protection in the setting of head injury. We thought it possible that patients with higher GCS status likely had less compromised physiology and would have been better able to help intubating operators with maximal preoxygenation prior to intubation due to voluntary control of respiration.

Our FPS rate among our trauma cohort in this study is consistent with a previous study including all ED patients requiring intubation<sup>3</sup> and slightly higher than the FPS rate reported in a recent systematic review and meta-analysis

of FPS rates in the ED.<sup>13</sup> In this meta-analysis, the pooled frequency of FPS for the subgroup of traumatically injured patients was 81.8% (95% CI 76.3% to 86.2%). Our FPS rate for trauma patients requiring RSI in this study was higher than the pooled results of trauma patients in this meta-analysis.<sup>13</sup> All four of the included studies were performed at academic centers with most intubations being performed by EM resident physicians under the direct supervision by anesthesia or EM attendings.<sup>16–19</sup> The rate of FPS without hypoxemia was not reported in these studies.

There are limitations to this study. First, only etomidate was available as an induction agent, and it is possible that our results may have been different if another induction agent was used or available. A previous review has shown that the use of etomidate versus ketamine has no effect on trauma patients undergoing RSI regarding mortality or hospital length of stay.<sup>20</sup> Second, the performance of NMBAs in our data may have been affected by suboptimal dosing. Third, our findings may not be generalizable to non-academic centers or centers predominantly using video laryngoscopy, which may reduce adverse events and lead to greater FPS among trainees. Fourth, we were unable to collect data on anatomic variables (other than the presence of head injury) or other difficult airway characteristics, such as high Mallampati score, signs of obstructive sleep apnea or obstructive sleep apnea, restricted

**Table 2** Multivariate logistic regression analysis for first pass success without hypoxemia among trauma patients requiring emergent tracheal intubation

	Adjusted OR	95% CI	P value
<b>NMBA</b>			
Rocuronium	Reference		
Succinylcholine	2.1	1.2 to 3.8	0.014
<b>Hypoxia</b>			
No hypoxemia prior to RSI	Reference		
Hypoxemia prior to RSI	1.7	0.5 to 6.1	0.395
<b>GCS score</b>			
3–12	Reference		
13–15	1.8	1.0 to 3.3	0.049
<b>Head or facial injury</b>			
No head or facial injury	Reference		
Head or facial injury	1.3	0.7 to 2.2	0.445
<b>Level of training</b>			
PGY 1–2	Reference		
PGY 3 or greater	1.1	0.6 to 1.8	0.867

Hypoxemia=SpO<sub>2</sub>< 90%. Hypoxemia prior to RSI=most recent SpO<sub>2</sub> obtained before the RSI medications were administered.

GCS, Glasgow Coma Scale; NMBA, neuromuscular blocking agent; RSI, rapid sequence intubation.

cervical spine mobility, and limited mouth opening.<sup>21</sup> Fifth, we did not have data on preoxygenation methods or time from ED arrival to intubation which may have affected our results. The preoxygenation methods for this study may have been similar to those of our recent prospective study.<sup>22</sup> Lastly, physician operators performing the intubation documented a portion of our study variables themselves, and it possible that measurement bias was introduced. Under-reporting of hypoxemia during intubation may have occurred via recall or self-report biases. For example, Kerrey *et al* found that both FPS and hypoxemia during RSI were under-reported in procedure notes when compared with video review of intubations performed in a pediatric ED.<sup>23</sup>

In summary, this study assessed the predictors of FPS without hypoxemia among trauma patients undergoing ED RSI. We found that the use of succinylcholine and patients with high GCS score were associated with the achievement of FPS without hypoxemia. Strategies to reduce the number of attempts at laryngoscopy and facilitate the maintenance of adequate oxygenation during tracheal intubation should be a goal to improve the quality of care. The use of FPS without hypoxemia is a patient safety outcome for traumatically injured patients requiring RSI as opposed to the coarser outcome of FPS. Future observational studies studying this outcome should include difficult airway characteristics and preoxygenation methods.

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