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ORIGINAL CONTRIBUTION

First Pass Success Without Hypoxemia Is Increased With the Use of Apneic Oxygenation During Rapid Sequence Intubation in the Emergency Department

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Abstract

Objectives: The objective was to determine the effect of apneic oxygenation (AP OX) on first pass success without hypoxemia (FPS-H) in adult patients undergoing rapid sequence intubation (RSI) in the emergency department (ED).

Methods: Continuous quality improvement data were prospectively collected on all patients intubated in an academic ED from July 1, 2013, to June 30, 2015. During this period the use of AP OX was introduced and encouraged for all patients undergoing RSI in the ED. Following each intubation, the operator completed a standardized data form that included information on patient, operator, and intubation characteristics. Adult patients 18 years of age or greater who underwent RSI in the ED by emergency medicine residents were included in the analysis. The primary outcome was FPS-H, which was defined as successful tracheal intubation on a single laryngoscope insertion without oxygen saturation falling below 90%. A multivariate logistic regression analysis was performed to determine the effect of AP OX on FPS-H.

Results: During the 2-year study period, 635 patients met inclusion criteria. Of these, 380 (59.8%) had AP OX utilized and 255 (40.2%) had no AP OX utilized. In the AP OX cohort the FPS-H was 312/380 (82.1%) and in the no AP OX cohort the FPS-H was 176/255 (69.0%) (difference = 13.1%, 95% confidence interval [CI] = 6.2% to 19.9%). In the multivariate logistic regression analysis, the use of AP OX was associated with an increased odds of FPS-H (adjusted odds ratio = 2.2, 95% CI = 1.5 to 3.3).

Conclusions: The use of AP OX during the RSI of adult patients in the ED was associated with a significant increase in FPS-H. These results suggest that the use of AP OX has the potential to increase the safety of RSI in the ED by reducing the number of intubation attempts and the incidence of hypoxemia.

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Tracheal intubation is a lifesaving procedure that is commonly performed in the emergency department (ED). Due to the critical condition of patients in the ED, intubation is associated with a high incidence of adverse events such as hypoxemia, hypotension, dysrhythmias, aspiration, and cardiac arrest.[1–5] Previous studies have demonstrated that multiple intubation attempts during emergency airway management are associated with an increase in adverse events.[1,2,6] Even after a single failed attempt the

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incidence of adverse events increases drastically.[1] Studies also suggest that hypoxemia is associated with adverse outcomes in some critically ill patients such as those with traumatic brain injury.[7–9] To maximize patient safety a reasonable goal for emergency intubation should be to achieve first pass success without the occurrence of hypoxemia (FPS-H).

Apneic oxygenation (AP OX) is a concept that has been understood for decades based on studies performed in the operating room.[10–13] It, however, has only recently been evaluated for use during emergency intubation.[14–16] AP OX involves the delivery of oxygen to the upper airway, typically by nasal cannula, during periods of apnea.[17] Studies in the controlled setting of the operating room on elective surgical patients have demonstrated that the use of AP OX can significantly delay the onset of oxygen desaturation, effectively extending the period of safe apnea.[18,19] AP OX may be a useful technique for rapid sequence intubation (RSI) in the ED as it may be able to improve the safety of the procedure by extending the safe apnea time thereby reducing the number of intubation attempts and the incidence of hypoxemia. The goal of this investigation is to determine the effect of AP OX on FPS-H.

METHODS

Study Design and Setting

This is a single-center observational study of ED intubations performed over the 2-year period from July 1, 2013, to June 30, 2015, recorded in a continuous quality improvement (CQI) database. It was conducted at a 61-bed tertiary care academic ED and Level I trauma center with an annual census of approximately 70,000 visits. This institution has an ACGME-accredited 3-year emergency medicine (EM) residency program, as well as a 5-year combined EM/pediatrics residency program. Intubations in this ED are performed primarily by EM residents under direct EM attending supervision. Multiple laryngoscopes were available in the ED during the study period, including the direct laryngoscope, the GlideScope video laryngoscope, and the C-MAC video laryngoscope. Residents receive extensive training on airway management including both direct laryngoscopy and video laryngoscopy. All residents participate in a 1-month anesthesiology rotation during their first postgraduate year (PGY) and also have extensive training in the simulation lab throughout their residency training. On July 1, 2013, AP OX was introduced in our ED for emergency intubation. EM residents were strongly encouraged to use AP OX with a nasal cannula at an oxygen flow rate of 15 L/min for all patients undergoing RSI. This was not required by protocol, but suggested as a best practice based on expert recommendation.[17] The recommended oxygenation technique is to place a standard nasal cannula at 15 L/min on the patient and then add to that a nonrebreather face mask at 15 L/min. After at least 3 minutes of preoxygenation, RSI drugs are administered and when paralysis ensues the face mask is removed, the AP OX nasal cannula is left in place, and laryngoscopy is performed. A classic RSI technique is used in our ED and thus patients do not receive positive pressure ventilation during RSI, unless necessitated by hypoxemia. The device available in the ED that is used for preoxygenation is the CareFusion AirLife adult oxygen mask (Product No. Ref 001203) and the device available for the administration of AP OX is the TeleFlex Medical Hudson RCI nasal cannula with 7-foot Star Lumen tubing (Product No. Ref 1103).

The study design generally conformed with the recommendations of the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement.[20] This project was granted exemption by the University of Arizona institutional review board.

Study Population

This study included adult patients 18 years of age and older who underwent RSI in the ED by an EM resident. Only patients that had complete oxygen saturation data documented as well as a starting saturation ≥90% were included in the analysis (see Figure 1 for details of patients included in the study).

Methods and Measurements

After each ED intubation a single-page (double sided) paper-based CQI form is completed by the operator

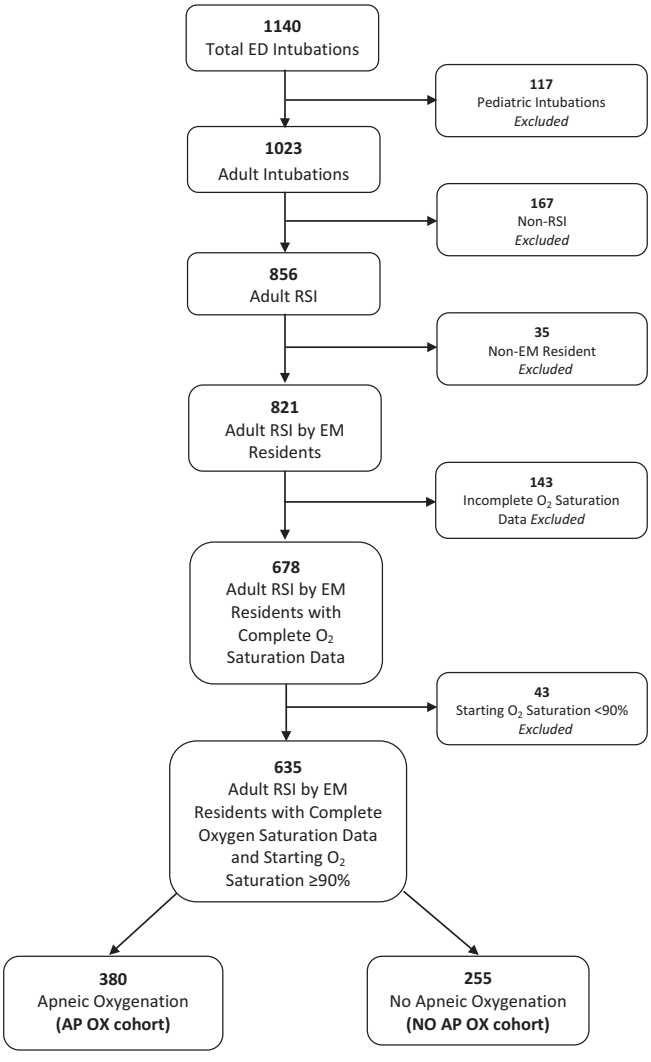

Figure 1. Flow diagram of patients in the study. AP OX = apneic oxygenation; RSI = rapid sequence intubation.

and captures important clinical information regarding the procedure. Data captured on the CQI form included patient, operator, and intubation characteristics. Information collected included patient age, sex and diagnosis, operator PGY, reason for intubation, presence of difficult airway characteristics (DACs), drugs used for intubation, device used on each attempt, outcome of each attempt, and the starting and lowest oxygen saturation during the entire intubation. Oxygenation methods used before and during intubation are also documented. The duration of preoxygenation before intubation is documented as follows: none, 1 minute, 2 minutes, 3 minutes, 4 minutes, 5 minutes, or >5 minutes. This is not formally timed, but rather based on the operator's estimation of time. The use of AP OX and the oxygen flow rate used during intubation is documented as follows: none, 5 L/min, 10 L/min, 15 L/min, or >15 L/min.

An intubation attempt was defined as the insertion of the laryngoscope blade into the mouth of the patient, regardless whether an attempt was made to insert a tracheal tube. First pass success (FPS) was defined as successful tracheal intubation on a single laryngoscope insertion. FPS-H was defined as FPS without oxygen saturations falling below 90% during the intubation.

Difficult airway characteristics documented on the CQI form include blood or vomit in the airway, presence of a cervical collar or immobility, airway edema, facial or neck trauma, small mandible, short neck, large tongue, restricted mouth opening, and obesity.

The senior investigator reviewed all data forms in real time and any incomplete forms were returned to the operator for completion. These forms were included in the study, unless they had missing oxygen saturation data. Based on cross-referencing with the electronic medical record and the hospital admission log there were no missing data forms in the database (100% compliance). The data from the paper forms were entered into Excel for Windows 2013 (Microsoft) and then transferred and coded into STATA 13 (StataCorp) for statistical analysis.

Outcome Measure

The primary outcome was FPS-H, which was defined as successful tracheal intubation on a single laryngoscope insertion without oxygen saturations falling below 90%.

Data Analysis

Patients were categorized into two cohorts: those that had AP OX utilized (AP OX cohort) and those who did not have AP OX utilized (no AP OX cohort). Summary statistics were calculated for patient, intubation, and operator characteristics. Continuous normally distributed variables were reported as means with standard deviations (SDs). Patient age was the only continuous variable in the data set. Categorical variables were reported as percentages.

A standard multivariate logistic regression analysis was performed to evaluate the association between AP OX and FPS-H. Confounders considered to be pertinent based on clinical expertise of the investigators as well as previous investigations were: trauma status, device type (video laryngoscope vs. direct laryngoscope), starting oxygen saturation at time of intubation (>93% vs. ≤93%), duration of preoxygenation (<3 minutes vs. ≥3 minutes), neuromuscular blocking agent (NMBA), induction agent, number of DACs, reason for device selection, and operator PGY (1, 2, or ≥3 years). The intent was not to develop a parsimonious model; thus all potential confounders were included in the model and no automated variable selection techniques were used. There was no theoretical basis to consider any model interactions. The goodness of fit of the model was checked by the Hosmer-Lemeshow test. The model was checked for multicollinearity by evaluating variance inflation factors. Influential observations were identified by Pregibon's Delta-Beta. All analyses were conducted in STATA 13 (StataCorp).

There are no previous studies using the outcome variable FPS-H on which to base a power calculation. Based on our experience in our institution with intubation success and hypoxemia we estimated that FPS-H might increase from a baseline rate of 70% to 80% with the use of AP OX. Thus the study was powered to detect a 10% absolute change in FPS-H. Using an alpha of 0.05 and power of 80%, we estimated that 250 subjects would be required in each cohort.

RESULTS

Characteristics of Study Subjects

A total of 1,140 intubations were performed in the ED over the 2-year study period. After excluding patients who were less than 18 years of age (117), did not undergo RSI (167), were not intubated by EM residents (35), had incomplete saturation data (143), or had a starting saturation <90% (43), 635 patients were eligible for analysis. In this group 380 patients (59.8%) were in the AP OX cohort and 255 patients (40.2%) were in the no AP OX cohort (see Figure 1 for details of the study group).

The majority of patients in both cohorts were intubated for airway protection (AP OX 74.7% and no AP OX 76.9%). Very few patients were on bilevel positive airway pressure (BiPAP) prior to intubation (AP OX 6.8% and no AP OX 6.7%). Trauma patients comprised 26.3% of the AP OX intubations and 42.4% of the no AP OX intubations (see Table 1 for specifics of patient, operator, and intubation characteristics).

Main Results

There were 380 patients who received AP OX and 255 patients who did not receive AP OX. In the AP OX cohort the oxygen flow rates used were as follows: 59 (15.5%) received 5 L/min, 56 (14.7%) received 10 L/min, 158 (41.6%) received 15 L/min and 107 (28.2%) received >15 L/min.

In the AP OX cohort the FPS-H was 312/380 (82.1%) and in the no AP OX cohort the FPS-H was 176/255 (69.0%; difference = 13.1%; 95% confidence interval [CI] = 6.2% to 19.9%). In the AP OX cohort the FPS was 342/380 (90.0%) and in the no AP OX cohort the FPS was 210/255 (82.4%; difference = 7.6%; 95% CI = 2.1% to 13.2%). In the AP OX cohort the incidence of hypoxemia in those with FPS was 30/342 (8.8%) and in the no AP OX cohort the incidence of hypoxemia in those with

Table 1
Patient, Operator, and Intubation Characteristics

Characteristic	AP OX, *n* = 380 (%)	No AP OX, *n* = 255 (%)	% Difference (95% CI)
Age (y)			
Mean (±SD)	51.7 (±19.3)	49.0 (±18.6)	−2.6 (−5.7 to 0.4)
Sex			
Male	239 (62.9%)	169 (66.3%)	−3.4 (−10.9 to 4.2)
Medical/trauma			
Trauma	100 (26.3%)	108 (42.4%)	−16.0 (−23.6 to −8.5)
Reason for intubation			
Airway protection	284 (74.7%)	196 (76.9%)	−2.1 (−8.9 to 4.7)
Respiratory failure	67 (17.6%)	33 (12.9%)	4.7 (−0.1 to 10.3)
Hypoxia	5 (1.3%)	2 (0.7%)	0.5 (−1.1 to 2.1)
Patient control	24 (6.3%)	24 (9.4%)	−3.1 (−7.4 to 1.2)
BiPAP/BVM used prior to intubation			
Yes	28 (7.4%)	20 (7.8%)	−0.4% (−4.7 to 3.7)
Specific DACs			
Cervical immobility	103 (27.1%)	90 (35.3%)	−8.1 (−15.6 to −0.8)
Facial/neck trauma	44 (11.5%)	51 (20.0%)	−8.4 (−14.2 to −2.6)
Airway edema	9 (2.4%)	4 (1.6%)	0.8 (−1.3 to 3.0)
Small mandible	25 (6.6%)	16 (6.3%)	0.3 (−3.6 to 4.2)
Obesity	219 (57.6%)	127 (49.8%)	7.8 (−0.0 to 15.7)
Large tongue	44 (11.6%)	25 (9.8%)	1.8 (−3.1 to 6.6)
Short neck	61 (16.1%)	29 (11.4%)	4.7 (−0.6 to 10.1)
Restricted mouth opening	23 (6.1%)	14 (5.5%)	0.6 (−3.1 to 4.3)
Blood in airway	46 (12.1%)	53 (20.8%)	−8.7 (−14.6 to −2.7)
Vomit in airway	40 (10.5%)	34 (13.3%)	−2.8 (−8.0 to 2.4)
Number of DACs			
None	71 (18.7%)	52 (20.4%)	−1.7 (−8.0 to 4.6)
1	140 (36.8%)	74 (29.0%)	7.8 (0.4 to 15.2)
2	85 (22.4%)	61 (23.9%)	−1.6 (−8.2 to 5.1)
≥3	84 (22.1%)	68 (26.7%)	−4.5 (−11.4 to 2.3)
Reason for device selection			
Standard device	235 (61.8%)	147 (57.6%)	4.1 (−3.5 to 12.0)
Difficult airway	110 (28.9%)	95 (37.3%)	−8.3 (−15.8 to −0.8)
Educational purposes	35 (9.2%)	13 (5.1%)	4.1 (0.1 to 8.1)
NMBA used			
Succinylcholine (vs. rocuronium)	204 (53.7%)	130 (51.0%)	2.7 (−5.2 to 10.6)
Induction agent used			
Etomidate (vs. other)	345 (90.8%)	235 (92.2%)	−1.3 (−5.7 to 3.0)
Operator PGY			
PGY-1	71 (18.7%)	36 (14.1%)	4.6 (−1.2 to 10.4)
PGY-2	155 (40.8%)	91 (35.7%)	5.1 (−2.6 to 12.8)
PGY-3,4,5	154 (40.5%)	128 (50.2%)	−9.7 (−17.5 to −1.8)
Device used			
DL	62 (16.3%)	43 (16.9%)	−0.5 (−6.4 to 5.3)
GVL	233 (61.3%)	124 (48.6%)	12.6 (4.8 to 20.5)
CMAC	78 (20.5%)	84 (32.9%)	−12.4 (−19.5 to −5.4)
Other	7 (1.8%)	4 (1.6%)	0.2 (−1.8 to 2.3)

AP OX = apneic oxygenation; BiPAP = bilevel positive airway pressure; BVM = bag-valve-mask; CMAC = C-MAC video laryngoscope; DACs = difficult airway characteristics; DL = direct laryngoscope; GVL = GlideScope video laryngoscope; NMBA = neuromuscular blocking agent; PGY = postgraduate year.

FPS was 34/210 (16.2%; difference = −7.4%, 95% CI = −13.2% to −1.6%). In the AP OX cohort the overall incidence of hypoxemia was 48/380 (12.6%) and in the no AP OX cohort the overall incidence of hypoxemia was 51/255 (20.0%; difference = −7.4%, 95% CI = −13.3% to −1.4%).

In the multivariate logistic regression analysis, the use of AP OX was associated with an increased odds of FPS-H (adjusted odds ratio [aOR] = 2.2, 95% CI = 1.5 to 3.3; see Table 2 for details). According to the Hosmer-Lemeshow goodness-of-fit test, the model fit the data well (p = 0.349). There were 22 patients with repeat visits. After repeat visits were excluded, the results did not change (aOR = 2.2, 95% CI = 1.5 to 3.3). There was no multicollinearity between variables in the model. There were a few influential observations which when excluded from the model did not change the results.

DISCUSSION

Airway management in the ED frequently requires tracheal intubation, which is typically performed using an RSI technique.[21] Intubation under emergent conditions has been shown to be associated with a high incidence of adverse events.[1–6,9,22,23] There are multiple reasons for this including the precipitous nature of these intubations, the unfasted state of the patients, and the underlying physiologic derangements of the patients. Studies

Table 2
Multivariate Logistic Regression Analysis for FPS-H

Variable	Adjusted OR	95% CI	p-value
AP OX	2.2	1.5 to 3.3	<0.001
Preoxygenation (≥3 min)	1.2	0.6 to 2.4	0.634
Baseline oxygen saturation (>93%)	4.8	2.2 to 10.3	<0.001
Laryngoscope			
DL	[Reference]		
VL (GVL or CMAC)	2.7	1.6 to 4.6	0.001
NMBA			
Rocuronium	[Reference]		
Succinylcholine	1.1	0.7 to 1.6	0.690
Induction agent			
Non-etomidate	[Reference]		
Etomidate	1.0	0.5 to 2.0	0.914
Number of DACs	0.7	0.6 to 0.9	<0.001
Medical/trauma			
Medical	[Reference]		
Trauma	1.5	0.9 to 2.5	0.139
Reason for device			
Standard device	[Reference]		
Difficult airway	0.8	0.5 to 1.3	0.391
Educational purposes	1.4	0.6 to 3.2	0.476
Operator PGY			
PGY-1	[Reference]		
PGY-2	1.1	0.7 to 2.0	0.682
PGY-3,4,5	2.1	1.1 to 3.7	0.017

$p < 0.05$ was considered to be statistically significant.
AP OX = apneic oxygenation; CMAC = C-MAC video laryngoscope; DACs = difficult airway characteristics; DL = direct laryngoscope; FPS-H = first pass success without hypoxemia; GVL = GlideScope video laryngoscope; NMBA = neuromuscular blocking agent; PGY = postgraduate year; VL = video laryngoscope.

have shown that multiple intubation attempts are associated with adverse events.[1,2,6] Hypoxemia in the early phase of some critically ill patients has also been associated with worse outcomes.[7,8] It would seem reasonable, then, that to maximize patient safety, the goal of emergency intubation in the critically ill is to achieve FPS-H. In this study we sought to determine the effect of AP OX on FPS-H in patients undergoing RSI in the ED. We found that the use of AP OX was associated with a significant increase in FPS-H during RSI in the ED by emergency physicians. The improvement in FPS-H was due to both an increase in FPS (+7.6%) and a decrease in the incidence of oxygen desaturation in patients with FPS (−7.4%) in patients who had AP OX utilized.

Maximizing FPS-H is of great clinical importance as studies have demonstrated that multiple intubation attempts, as well as hypoxemia, are associated with an increase in adverse events.[1,2,6–8] A 10-year study by Mort[6] of critically ill patients requiring emergent intubation found that when more than two attempts were needed to successfully secure the airway there was a marked increase in hypoxemia, aspiration, bradycardia, and cardiac arrest. A multicenter ED study by Hasegawa et al.[2] found that when successful intubation was completed in two or less attempts the incidence of at least one adverse event was 9% compared to 35% when more than two attempts were required. A study by Sakles et al.[1] in the ED found that when intubation was successfully completed on the first attempt the incidence of one or more adverse events was 14.2%. However, when a second attempt was required to achieve successful intubation the incidence of adverse events increased to 47.2%. While these studies have shown the importance of minimizing the number of attempts to prevent adverse events, other studies have demonstrated that the occurrence of hypoxemia in some critically ill patients is associated with adverse outcomes.[7,8] For example, Chi et al.[7] demonstrated in a prospective multicenter study that the occurrence of hypoxemia in the prehospital phase of patients with traumatic brain injuries was associated with an increase in the odds of mortality. This is of great importance as hypoxemia has been demonstrated to occur with surprising regularity during emergent intubations. A recent study by Bodily et al.[24] evaluated the incidence and duration of oxygen desaturation during RSI in the ED. They found that of 166 patients undergoing RSI nearly 36% experienced oxygen desaturation, with a median duration of 80 seconds. Strategies to reduce the number of attempts and the occurrence of hypoxemia during intubation can potentially improve the quality of care for patients in the ED.

Although the use of AP OX was encouraged throughout the study period, it was only used in 60% of the patients undergoing RSI in our ED. While this may seem like a low compliance, it must be borne in mind that there is currently very little evidence demonstrating the effectiveness of AP OX during emergency airway management. In fact, when his study was initiated there was not a single paper published evaluating AP OX for emergency airway management. The decision to incorporate AP OX into our practice environment was based on expert opinion, which in turn was based on data extrapolated on stable, elective surgical patients in the operating room.[17] It is noteworthy that the use of AP OX increased greatly over the 2-year study period from 39% in the first month to 88% in the last month. It is interesting that when AP OX was used, the oxygen flow rate used by operators varied considerably, with less than half using the suggested 15 L/min. This is likely a cultural phenomenon due to the fact that physicians have historically been instructed to use no more than 6 L/min when using a nasal cannula.[25] A recent study by Brainard et al.,[26] however, found that 15 L/min of oxygen through a standard nasal cannula was well tolerated by volunteers and produced no adverse events. As practitioners become more comfortable with using high-flow oxygen through standard nasal cannula there will likely be more acceptance of using a flow of 15 L/min. Over our study period the use of AP OX at the suggested flow of 15 L/min increased from 33% in the first month to 61% in the last month.

The literature on AP OX for RSI in critical patients is limited and has yielded somewhat conflicting results.[14,16] A before-and-after study on AP OX by Wimalasena et al.[14] in the prehospital setting demonstrated a reduction in the incidence of oxygen desaturation when AP OX was incorporated into their RSI protocol. AP OX at 15 L/min was incorporated into their RSI protocol and a comparison was made between

the 310 patients who were intubated in the 2-year period before the implementation of AP OX and the 418 patients in the 2-year period after its implementation. In this undifferentiated patient population the use of AP OX was associated with a decrease in the incidence of desaturation from 22.6% to 16.5%. Their 6.1% reduction in the incidence of desaturation during RSI is similar to the 7.4% reduction we found. Interestingly, they found no difference in FPS between patients who had AP OX utilized and those who did not, whereas we found a significant improvement. A possible explanation for this discrepancy is that the intubations performed in their study were performed by experienced physicians and paramedics, whereas in our study the intubations were performed by EM residents during their training. It is conceivable that the possible delay in desaturation afforded by AP OX allowed our less experienced operators more time for laryngoscopy, and thus they were able to achieve a higher FPS.

The only randomized, controlled trial evaluating the effectiveness of AP OX for emergent intubation found that AP OX had no benefit in reducing the incidence of hypoxemia.[16] In this study by Semler et al.[16] 150 critically ill patients in the intensive care unit (ICU) were randomized to receive AP OX at 15 L/min by high-flow nasal cannula or "usual care" (no AP OX). They found no difference in the median lowest arterial saturation (92% vs. 90%) or in the incidence of desaturation to <90% (44.7% vs. 47.2%). Their ICU patient population, however, was significantly different than our ED population. Over half of their patients required intubation for respiratory failure and almost one-third of them were on noninvasive positive pressure ventilation (NIPPV) prior to intubation. This indicates that their patient population had a very high incidence of underlying pulmonary disease. This is in contrast to our patient population where the majority of patients were intubated for airway protection and very few were on non-invasive positive pressure ventilation (NIPPV) prior to intubation. It is possible that AP OX is effective in patients with normal lung function but is of limited or no benefit in patients with severe pulmonary disease, particularly those with significant right-to-left shunts. If a patient requires NIPPV to adequately oxygenate before intubation, it seems unlikely that AP OX is going to be effective in maintaining oxygen saturations during apnea. Clearly, further work is necessary to determine which critical patients can benefit from AP OX during emergent intubation.

In the multivariate logistic regression analysis, which controlled for multiple potential confounders, we found the use of AP OX to be associated with an increased odds of FPS-H. Operators who utilized AP OX were twice as likely to achieve FPS-H. We also identified other factors that were associated with FPS-H, some of which are modifiable and some which are not. A starting oxygen saturation >93% was associated with an almost fivefold increase in FPS-H. This is consistent with the work of Davis et al.[27] who found that patients who had a starting oxygen saturation of ≤93% during prehospital RSI universally desaturated during the intubation attempt. This highlights the importance of optimizing oxygenation prior to any attempts at intubation.[17] Interestingly, in our multivariate regression analysis preoxygenation was not found to be associated with FPS-H. This is likely due to a type II error as the vast majority of patients in our study received preoxygenation. To confidently determine the effect of preoxygenation we may have needed more patients who did not receive preoxygenation in the study.

Our multivariate logistic regression also demonstrated that the use of a video laryngoscope was positively associated with FPS-H. These results are consistent with numerous studies that have demonstrated a higher FPS with the use of a video laryngoscope.[28–32] An operator PGY of 3 or more was also associated with an increase in FPS-H, which is consistent with other studies evaluating the performance of EM residents.[33–35] The only factor identified in the regression analysis that was associated with a reduction in FPS-H was the number of DACs, which has been demonstrated in other studies to be associated with a reduced odds of FPS.[33,36]

LIMITATIONS

This study has several limitations. The main limitation is that this was an observational study and thus the patients were not randomized into the AP OX and no AP OX cohorts. There may be differences in the two cohorts, beside the use of AP OX, which may have an effect on the outcome of FPS-H. For example, there were more trauma patients and more patients with difficult airways in the no AP OX cohort. These differences could be partly responsible for the difference in FPS-H we observed in our study. We attempted to control for the differences by performing a multivariate logistic regression analysis that incorporated many of the likely confounders. These variables included reason for device selection, trauma status, device used, NMBA used, induction agent used, DACs, operator PGY, use of preoxygenation, and starting oxygen saturation. After performing the multivariate regression analysis, we still found that AP OX was associated with a higher FPS-H. Nonetheless, there may be unidentified confounders that we were unaware of that may have affected the results. For example, it may be that operators that chose to utilize AP OX were more skilled and conscientious about maintaining adequate oxygenation saturations during intubation. This potentially could be responsible for some of the increase in FPS-H we observed in this study.

Another limitation is that all data collected in the study, including oxygen saturations, were documented by the operator after the intubation was completed. Thus there is the possibility of inaccuracies in the data set due to the self-report nature of our data collection. It is has been well demonstrated that self-report data on emergent intubations can vary from an objective analysis of the actual events. For example, Kerrey et al.[37] performed a video review of 114 pediatric RSIs in the ED and found that operators tended to overreport FPS and underreport adverse events. FPS, as measured during video review by the investigators, was found to be 6% lower than what the operators had documented in the written record. It would have been preferable to have more objective data in our study, such as that obtained

by video review, but this unfortunately was not possible in our institution. Although there might be some under- or overreporting in our data set, there is no reason to believe that this would be different between the two cohorts. Another limitation is that we had to exclude a large number of patients who had missing oxygen saturation data. Inclusion of these patients in our study could have affected our results. Residents are taught to be cognizant of the oxygen saturations during intubation and document them on the airway data form. However, they are instructed to omit the oxygen saturation data from the form if they do not know the actual saturations. We believe that it is preferable to have missing data rather than inaccurate data in our airway database. Finally, another limitation is that all intubations performed in this study were by EM residents, the majority with video laryngoscopes, and thus our results may not be generalizable to other ED clinical settings. For example AP OX may be of less benefit to operators who are very skilled at laryngoscopy and can complete the intubation very quickly.

CONCLUSIONS

In summary, we found that the use of apneic oxygenation during rapid sequence intubation in the ED was associated with an increase in first pass success without hypoxemia. Apneic oxygenation has the potential to improve the safety of emergency airway management by reducing the number of intubation attempts and the incidence of hypoxemia. A randomized control trial is warranted to confirm these findings.

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