Implementation of a Clinical Bundle to Reduce Out-of-Hospital Peri-intubation Hypoxia

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Study objective: Peri-intubation hypoxia is an important adverse event of out-of-hospital rapid sequence intubation. The aim of this project is to determine whether a clinical bundle encompassing positioning, apneic oxygenation, delayed sequence intubation, and goal-directed preoxygenation is associated with decreased peri-intubation hypoxia compared with standard out-of-hospital rapid sequence intubation.

Methods: We conducted a retrospective, before-after study using data from a suburban emergency medical services (EMS) system in central Texas. The study population included all adults undergoing out-of-hospital intubation efforts, excluding those in cardiac arrest. The before-period intervention was standard rapid sequence intubation using apneic oxygenation at flush flow, ketamine, and a paralytic. The after-period intervention was a care bundle including patient positioning (elevated head, sniffing position), apneic oxygenation, delayed sequence intubation (administration of ketamine to facilitate patient relaxation and preoxygenation with a delayed administration of paralytics), and goal-directed preoxygenation. The primary outcome was the rate of peri-intubation hypoxia, defined as the percentage of patients with a saturation less than 90% during the intubation attempt.

Results: The before group (October 2, 2013, to December 13, 2015) included 104 patients and the after group (August 8, 2015, to July 14, 2017) included 87 patients. The 2 groups were similar in regard to sex, age, weight, ethnicity, rate of trauma, initial oxygen saturation, rates of initial hypoxia, peri-intubation peak SpO_2, preintubation pulse rate and systolic blood pressure, peri-intubation cardiac arrest, and first-pass and overall success rates. Compared with the before group, the after group experienced less peri-intubation hypoxia (44.2% versus 3.5%; difference −40.7% [95% confidence interval −49.5% to −32.1%]) and higher peri-intubation nadir SpO_2 values (100% versus 93%; difference 5% [95% confidence interval 2% to 10%]).

Conclusion: In this single EMS system, a care bundle encompassing patient positioning, apneic oxygenation, delayed sequence intubation, and goal-directed preoxygenation was associated with lower rates of peri-intubation hypoxia than standard out-of-hospital rapid sequence intubation. [Ann Emerg Med. 2018;72:272-279.]

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INTRODUCTION

Background

Select emergency medical services (EMS) personnel use rapid sequence intubation to achieve advanced airway management in the critically ill.[1-3] However, rapid sequence intubation in both out-of-hospital and inhospital settings is associated with important adverse events.[4-12] For example, peri-intubation hypoxia is common and may be associated with bradycardia, cardiac arrest, and increased mortality.[5,13,14] Hypoxia may occur in up to 36% of rapid sequence intubation attempts in the emergency department (ED) and 57% in the field,[15-17] often without the provider's recognition.[18]

Attentive preoxygenation may reduce the incidence of peri-intubation hypoxia.[19,20] There are numerous strategies for optimizing preoxygenation, including administration of apneic oxyenation,[21-27] patient positioning (eg, head-up, ear-to-sternal-notch ["sniffing"] position),[28-30] and the use of a bag-valve-mask device with positive end-expiratory pressure.[31-33] Delayed sequence intubation (the use of ketamine to facilitate relaxation and preoxygenation, with a delayed administration of paralytics) has also been proposed as a method for facilitating preoxygenation in agitated patients.[34]

Importance

There are only limited individual descriptions of the clinical effectiveness of patient positioning, preoxygenation,

Editor's Capsule Summary

What is already known on this topic

Peri-intubation hypoxia is common and potentially harmful.

What question this study addressed

Can a protocolized bundle of preoxygenation strategies prevent out-of-hospital peri-intubation hypoxia?

What this study adds to our knowledge

In this before-after analysis of 191 out-of-hospital nonarrest patients, protocolized use of head positioning, apneic oxygenation, delayed paralytic administration, and minimum oxygenation saturation thresholds reduced peri-intubation hypoxia from 44.2% to 3.5%.

How this is relevant to clinical practice

The strict use of multiple preoxygenation modalities may help to minimize out-of-hospital peri-intubation hypoxia.

Unanswered questions

What is the relative effectiveness of each bundle element? What are the potential trade-offs and pitfalls? Would we see the same benefits in a randomized trial?

and delayed sequence intubation on peri-intubation oxygen desaturation in the out-of-hospital setting. Furthermore, airway management often entails the bundling of multiple techniques. The combined bundle of measures to prevent peri-intubation hypoxia has not been evaluated, to our knowledge.[15,16]

Goals of This Investigation

The aim of the study was to determine the effectiveness of a clinical bundle consisting of patient positioning, apneic oxygenation, delayed sequence intubation, and goal-directed preoxygenation on the prevention of peri-intubation hypoxia during out-of-hospital intubation.

MATERIALS AND METHODS

Study Design

We assessed before-and-after data from a prospective quality improvement effort. The study was conducted in accordance with Strengthening the Reporting of Observational Studies in Epidemiology 2.0 guidelines and recommendations on decreasing bias in observational studies.[35] This project met the criteria of the Baylor Scott & White Health Institutional Review Board describing a quality improvement project and was determined by the board to not require formal approval.

Setting

Williamson County EMS is a county-based, governmental system covering a population of more than 500,000 in Central Texas, including the cities of Round Rock, Cedar Park, Leander, and Taylor. Williamson County EMS uses career dual-paramedic crews exclusively to staff 16 units on a continuous basis, supplemented by 2 additional peak-load units, a single paramedic rapid response vehicle, and 3 paramedic command units. Williamson County EMS had 26,000 911 responses in 2016. For high-acuity calls, as determined by priority dispatch criteria, an ambulance and a paramedic command unit (both operating under the same protocols) are simultaneously dispatched.

Selection of Participants

We included all adult nonarrest patients requiring intubation during October 2, 2013, to December 13, 2015 ("before" period), and December 14, 2015, to July 14, 2017 ("after" period). The before period contained a transition period (August 8, 2015, to December 13, 2015) in which the airway bundle was introduced into practice. We excluded patients in cardiac arrest. Agency protocols did not allow intubation of children, defined by the inability of the no. 3 King Vision channeled blade to fit in the patient's mouth.

Interventions

Before August 7, 2015, the EMS agency used a standard rapid sequence intubation approach for the intubation of nonarrest patients (the before group) (Figure E1, available online at http://www.annemergmed.com). The components of these intubations included high-flow oxygen through either nonrebreather or bag-valve-mask device and a nasal cannula, the administration of ketamine at 2 mg/kg, and either succinylcholine at 2 mg/kg or rocuronium at 1 mg/kg in rapid succession, followed by intubation. Although preoxygenation was encouraged, no specific time frames, goals, or techniques were mandated. Paramedics underwent initial and continuing training, including monthly simulated cases and annual competence testing. All training used mannequins and simulated human patients. Cadavers and operating room training time were not available.

We devised a clinical bundle of standard enhancements to customary rapid sequence intubation technique, composed of several key elements: placement of the patient

in the head-up, ear-to-sternal-notch (sniffing) position; apneic oxygenation; delayed sequence intubation; and goal-directed preoxygenation requirements. The components of the bundle have been described extensively in both the out-of-hospital and ED setting.[20,21,23-30,32-34,36-43] Ear-to-sternal-notch (sniffing) positioning consisted of elevating the head of the bed, with the lower neck flexed and the face parallel to the ceiling. Apneic oxygenation consisted of placement of a standard nasal cannula at flush rates of oxygen flow throughout the procedure. Delayed sequence intubation involved the initial administration of intravenous ketamine 2 mg/kg to facilitate preoxygenation, with a delay of paralytic administration (succinylcholine 2 mg/kg or rocuronium 1 mg/kg) for least 3 minutes or until preoxygenation goals were achieved. Goal-directed preoxygenation required the use of a tightly sealed bag-valve-mask device with positive end-expiratory pressure and flush-rate oxygen for at least 3 minutes, with SpO_2 greater than or equal to 94%.

The bundle required a second medic to supervise all elements of the intubation effort, including the use of a stopwatch to verify all time-based requirements. If the oxygen saturation were to decrease below 94% at any time during the procedure, adjustments would be made to improve saturation (reposition patient, readjust seal, increase positive end-expiratory pressure, or provide manual ventilations if needed), and the minimum 3-minute preoxygenation period would be restarted. The protocol did not allow EMS personnel to proceed with intubation if oxygen saturation goals were not satisfied. If oxygen saturation goals were not achieved, the protocol prescribed the use of continued bag-valve-mask ventilation or insertion of a supraglottic airway. A revised mandatory checklist served as a reminder of these components (Figure E2, available online at http://www.annemergmed.com).

In addition to the ongoing training in place before adoption of the bundle, additional training was provided before and after implementation on the specifics of the clinical bundle. Initial training was a 2-hour lecture followed by 1 hour of hands-on scenarios. Monthly competency training, already in place before the intervention, was continued by senior paramedics in the field and expanded to focus not only on the psychomotor skill of intubation but also the specifics of the clinical bundle. These specifics included the observed use of proper patient positioning, proper use of a 2-handed "thumbs-down" face mask seal, titrated use of positive end-expiratory pressure, and the time and goal-directed requirements of the bundle.

Between August 8, 2015, and December 13, 2015, we implemented a small-scale pilot trial of the clinical bundle with a small number of medics. After December 13, 2015, all intubations in the system were performed with the new bundle (the "after" group). In the first month after bundle adoption, we switched the neuromuscular-blocking agent from succinylcholine to rocuronium because of the increased price and limited availability of succinylcholine.

Certain elements were present in both the before and after groups. Intubation was accomplished by using only the channeled King Vision (Ambu, Copenhagen, Denmark) video laryngoscope.[44] Paramedics were allowed a maximum of 2 laryngoscopy attempts. Continuous-waveform capnography was required in both groups. Key interventions in before and after groups are summarized in Table 1.

Methods of Measurement

We maintained a quality improvement database for intubation. Developed and implemented in October 2013, the registry included information on the indication for and duration of each intubation attempt, the attempt high and low SpO_2, and the outcome of each attempt. We manually abstracted data from electronic health records (emsCharts, Pittsburgh, PA; ESO Solutions, Austin, TX) and from physiologic data captured by cardiac monitors (Philips MRx; Royal Philips, Amsterdam, the Netherlands).

The protocol required the use of continuous-waveform capnography, as well as pulse oximetry, blood pressure, and ECG monitoring. Continuous data for each of these variables were captured with Philips MRx portable cardiac monitors. We used the proprietary analysis software (Phillips MRx Event Review Pro; version 5; Royal Phillips) to graph each event. A trained abstractor (J.G.) identified all physiologic events (oxygen desaturation, bradycardia, etc) by manual review of graphic and tabular data. Standard definitions were established for the event review (Table 2). To verify accuracy of entries, a random subset of 10% of records was independently evaluated by another author (J.L.J.). Disagreements were resolved by a third author (D.J.). We reviewed data for all events as soon as possible after the clinical episode.

Table 1. Comparison of before-and-after interventions.

Before	After
NRB	Ketamine
Ketamine+paralytic	BVM+PEEP and NC oxygenation
Apneic oxygenation	Head-up/ear-to-sternal-notch/"sniffing" position
Intubation	Minimum of 3 min with SpO_2 >93%
	Paralytic
	Intubation

NRB, Nonrebreather mask; *BVM*, bag-valve-mask; *PEEP*, positive end-expiratory pressure; *NC*, nasal cannula

Table 2. Definitions.

Variable	Variable Definitions
Preintubation SpO_2	SpO_2 measured 1 min before loss of $ETCO_2$ data (onset of intubation attempt)
SpO_2 nadir	The lowest pulse oximetry value recorded between the time the patient stops breathing (as indicated by loss of $ETCO_2$ waveform) and the time ventilations are resumed (as indicated by return of $ETCO_2$ waveform)
Moderate hypoxic episode	Any SpO_2 value between 80% and 90%
Severe hypoxic episode	Any SpO_2 less than 80%
Bradycardia	An absolute HR less than 60 beats/min if not already bradycardic or a decrease in HR by more than 20% from before ketamine administration
Cardiac arrest	Loss of pulses and provision of CPR during or immediately after (within 5 min) intubation
Preintubation HR	The HR measured 1 min before loss of $ETCO_2$ data (onset of intubation attempt)
Preintubation HR nadir	Lowest HR measured from ketamine to 1 min after resumption of ventilations, as indicated by $ETCO_2$ return
Peri-intubation HR high	Highest HR measured from ketamine to 1 min after resumption of ventilations, as indicated by $ETCO_2$ return

$ETCO_2$, End tidal carbon dioxide; *CPR*, cardiopulmonary resuscitation.

Outcome Measures

The primary outcome was the proportion of patients with peri-intubation hypoxia, defined as an oxygen saturation below 90% occurring at any time during intubation attempts. We identified only hypoxic events occurring during laryngoscopy. We did not include episodes of delayed hypoxia occurring after the completion of intubation efforts. Secondary outcomes included the peak and nadir oxygen saturation values, as well as the occurrence rate of peri-intubation bradycardia and cardiac arrest.

Primary Data Analysis

We compared the characteristics of patients between the before and after group, assessing binomial proportions with exact confidence intervals for categorical data and mean differences with exact confidence intervals for the continuous variables. For ordinal or skewed data (such as scene time), we estimated the median difference between groups with a continuity-corrected Wilcoxon rank sum test.

We graphically compared the desaturation rates between the 2 groups with a waterfall plot. We included only initial intubation attempts in the analysis. We excluded subsequent attempts from the analysis because of the potential interaction of multiple attempts and hypoxia. We included only those episodes with sufficient data to compare pre- and periattempt nadir SpO_2.

We also performed a sensitivity analysis that included all initial attempts in the data set, including both those with incomplete pulse oximetry data and those in the after group, in which laryngoscopy and intubation were not attempted because of inadequate preoxygenation. For these "aborted" attempts, we substituted the oxygen saturation at ketamine administration for the preattempt SpO_2 and the saturation 5 minutes after ketamine administration for the peri-intubation low SpO_2. We performed all analyses with SAS (version 9.4; SAS Institute, Inc., Cary, NC).

RESULTS

Characteristics of Study Subjects

We analyzed data on 104 patients in the before group and 87 in the after group. During the most recent calendar year, paramedics in this system attempted an average of 2.3 intubations each (interquartile range 2, 1 to 4). The 2 groups had similar age, weight, sex, ethnicity, proportion of trauma, initial SpO_2, preattempt SpO_2, preattempt pulse rate, and systolic blood pressure measurements, postattempt systolic blood pressure, rates of preattempt bradycardia, pre- and postintubation hypotension, periattempt cardiac arrest, first-pass success, and overall success (Table 3).

Compared with those in the before group, fewer patients in the after group experienced peri-intubation hypoxia (Figure). The after group also exhibited higher periattempt nadir SpO_2, shorter attempt duration, a lower proportion of peri-intubation bradycardia, higher attempt high and low pulse rate, and higher postattempt systolic blood pressure. Scene time was longer with the after group.

We excluded patients from the main analysis if they had incomplete pulse oximetry data or if (in the after group) the bundle was begun but intubation was not attempted. There were 18 (17.1%) aborted attempts in the after group. Five (4.8%) were aborted because of an inability to achieve 3 minutes of a saturation greater than or equal to 94%, and an additional 8 (7.6%) were aborted when SpO_2 readings were lost midprocedure (Table 4). When patients with incomplete SpO_2 data and aborted intubation efforts were included, the rates of peri-intubation hypoxia, bradycardiac, and cardiac arrest remained the same (Table E1, available online at http://www.annemergmed.com).

LIMITATIONS

We did not conduct a randomized controlled trial. Any observed effects reflect associations only and cannot prove causality. The data for this study were abstracted from

Table 3. Characteristics of patients undergoing intubation before and after implementation of airway management bundle.

	Before (n=104)	After (n=87)	Difference (After–Before) (95% CI)
Patient characteristics			
Age, mean (SD), y	59.3 (20.5)	53.7 (21.7)	−5.7 (−11.7 to 0.4)
Weight, mean (SD), kg	85.9 (22.8)	85.3 (25.7)	−0.5 (−7.5 to 6.5)
Men, n/N (%)	49/104 (47.1)	52/87 (59.8)	12.7 (−1.4 to 26.7)
White, n/N (%)	81/104 (77.9)	72/87 (82.8)	4.9 (−6.4 to 16.1)
Trauma, n/N (%)	22/104 (21.2)	13/87 (14.9)	−6.2 (−17.1 to 4.6)
Scene time, median (IQR), min	32 (22.8 to 41.3)	42 (32 to 50)	9.0 (5.0 to 13.0)
Intubation characteristics			
First-pass success, No. (%)	88/104 (84.6)	77/87 (88.51)	3.9 (−5.8 to 13.5)
Overall success, No. (%)	99/104 (95.2)	81/87 (93.1)	−2.1 (−8.8 to 4.6)
Attempt duration, median (IQR), min	2 (1 to 3)	1 (1 to 2)	0 (−1 to 0)
Initial SpO_2, median (IQR)	92 (79.5 to 97)	92 (81 to 98)	0 (−2 to 3)
Initial hypoxia (SpO_2 <90%), No. (%)	42/104 (40.4)	36/87 (41.4)	0.99 (−13.3 to 15.3)
Peri-intubation peak SpO_2, median (IQR)	100 (95 to 100)	100 (100 to 100)	0 (0 to 1)
Peri-intubation nadir SpO_2, median (IQR)	93 (73.8 to 99)	100 (96 to 100)	5.0 (2 to 10)
Peri-intubation hypoxia, No. (%)	46/104 (44.2)	3/87 (3.5)	−40.7 (−49.5 to −32.1)
Preintubation HR, median (IQR), beats/min	100.5 (89.8 to 121.3)	107 (93/128)	6.0 (−1 to 13)
Preintubation bradycardia, No. (%)	1/104 (1.0)	2/87 (2.3)	1.3 (2.4 to 5.1)
Peri-intubation nadir HR, median (IQR), beats/min	88 (77.8 to 105.5)	111 (95 to 129)	22 (15 to 29)
Peri-intubation peak HR, median (IQR), beats/min	99 (84.5 to 117.5)	116 (103 to 133)	16 (9 to 23)
Peri-intubation bradycardia, No. (%)	19/104 (18.3)	2/87 (2.3)	−16.0 (−24.0 to 7.9)
Peri-intubation cardiac arrest, No. (%)	2/104 (1.9)	1/87 (1.2)	−0.7 (−4.2 to 2.7)
Preintubation SBP, median (IQR), mm Hg	134 (119 to 160)	140 (116 to 173)	6.0 (−6 to 18)
Postintubation SBP, median (IQR), mm Hg	131 (109 to 168)	147 (123 to 173)	15 (2 to 27)
Preintubation hypotension, No. (%)	8/104 (7.7)	11/87 (12.6)	4.9 (−3.9 to 13.8)
Postintubation hypotension, No. (%)	17/104 (16.3)	8/87 (9.2)	−7.2 (−16.7 to 2.4)

CI, Confidence interval; *IQR*, interquartile range; *HR*, pulse rate; *SBP*, systolic blood pressure.

medical records by one researcher. There may have been bias or mistakes introduced in this process of abstraction. A second reviewer evaluated a 10% sample of records to minimize this possibility. We noted a decreased attempt duration with the bundle. It is possible that the decreased duration of attempts resulted in fewer observed cases of oxygen desaturation. It is also possible, however, that improved position enhanced the speed of laryngoscopy.

The interventions encompassed a bundle of care. We cannot ascertain the specific bundle components that most

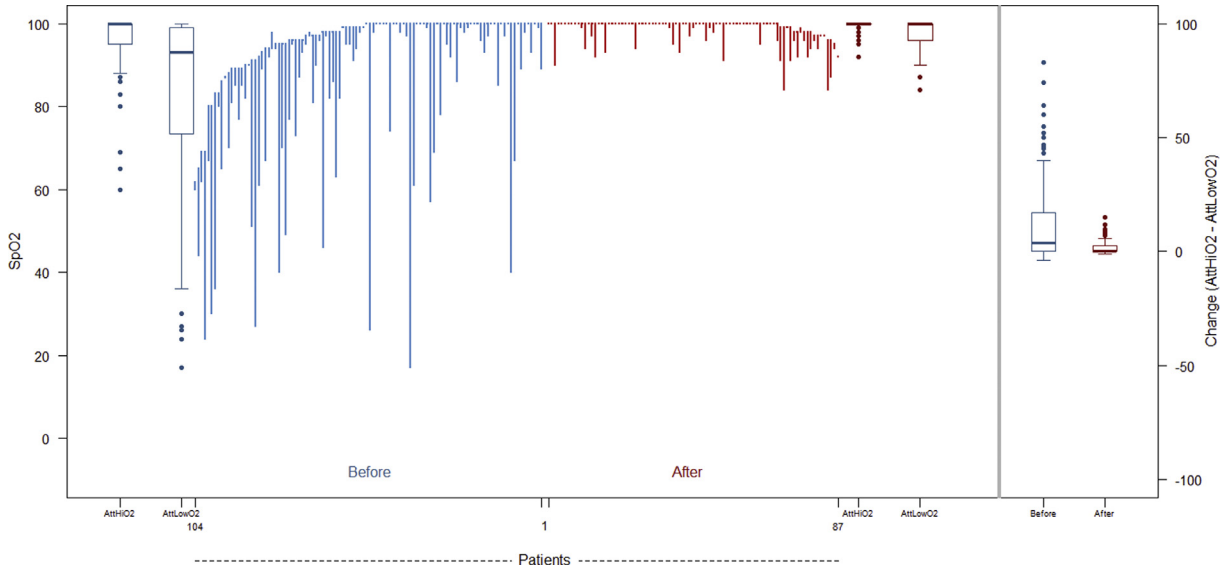

Figure. Waterfall plot.

Table 4. Reasons for aborted intubation attempts after implementation of airway management improvement bundle.

Reason	No. (%)
Loss of SpO_2 signal	8 (44)
Inability to achieve preoxygenation goal	5 (28)
ED arrival before intubation attempt	2 (11)
Hypotension (SBP <90 mm Hg)	1 (6)
Do not attempt resuscitation order identified	1 (6)
No reason given	1 (6)
Total	18 (100)

significantly contributed to the decreased number of hypoxic episodes. EMS personnel practices may have altered as the result of observation (Hawthorne effect).[45] The change in neuromuscular-blocking agents may have contributed to the decreased hypoxia and shorter intubating durations. There is some controversy about this issue in the literature, with some articles suggesting less desaturation and decreased mortality in head-injured patients with rocuronium[46,47] and a Cochrane review showing better intubating conditions with succinylcholine than rocuronium.[48]

Factors such as patient condition, comorbidities, and provider experience over time may have confounded our results. We did not carry out a multivariable analysis because of the limited size of the data set and the inability to fully account for potential confounding. However, the differences in observed clinical endpoints were large and consistent across endpoints and sensitivity analyses. Replication with a larger data set will allow careful assessment of the influence of potential confounders.

Our outcome of interest in this article is not a patient-oriented outcome such as mortality. Although there is evidence that hypoxia is associated with mortality, at least in patients with traumatic brain injuries,[49] we did not have the data to specifically address this question. Finally, the improvement with this specific bundle or protocol should not be considered the only potential approach to prevention of peri-intubation hypoxia. Individual EMS agencies may experience success with alternate strategies.

DISCUSSION

We found that by implementing a clinical bundle emphasizing patient head positioning, apneic oxygenation, delayed sequence intubation, and goal-directed preoxygenation, we were able to decrease the rate of peri-intubation hypoxia in adult nonarrest patients requiring intubation. We also noted an increase in the preintubation oxygen saturation and peri-intubation nadir saturations. Although studies have evaluated individual components of the bundle, to our knowledge no previous efforts have evaluated the combination of these interventions in out-of-hospital intubation.

The practice elements incorporated into the bundle have been well described. The heads-up, ear-to-sternal-notch (sniffing) position has been associated with improved oxygen saturation and longer safe apnea durations.[28-30,41,42] Apneic oxygenation has been shown in the ED and field to decrease peri-intubation hypoxia and increase first-pass success without hypoxia.[23-27] Case reports and series have described delayed sequence intubation.[34,37,38,43] In a small, prospective ICU study, Weingart et al[43] found that delayed sequence intubation increased preintubation saturations in patients who had already had maximal oxygenation efforts. Although we cannot disentangle the specific contributions of each element, our bundle produced results that would be consistent with the improvements observed in studies of individual elements.

There were several findings in this study that are of interest. First, in the after group, paramedics had difficulty maintaining oxygen saturation readings in 8 patients (7.6%). It is unclear whether the loss of SpO_2 signal was due to disconnection or poor placement of the probe, operator error, or patient physiologic changes. However, this phenomenon is common and has been described in both field[50] and ICU settings.[43] This observation signals the need for strategies to prevent loss of SpO_2 measurement during intubation. We were unable to achieve preoxygenation goals in 5 cases (4.7%), leading to avoidance of intubation attempts. Additional work is needed to discern whether these instances resulted from operator technique or patient physiology. Although some may question not attempting intubation in these cases, we believe this is a sound decision. None of these patients developed peri-intubation bradycardia or cardiac arrest, potentially affirming the safety of our management strategy. Because hypoxic patients reach critical desaturation rapidly, there is very little time to safely perform laryngoscopy. In the uncontrolled out-of-hospital environment with relatively inexperienced laryngoscopists, we think it is best to rapidly insert a blind insertion airway device. Once the patient is in a more controlled environment with more experienced providers, intubation may be more safely performed. This strategy of not intubating hypoxic patients clearly warrants further study, though.

We believe our results have important clinical implications for EMS agencies performing intubation in the nonarrest patient. Peri-intubation hypoxia can lead to hemodynamic instability, is associated with cardiac arrest in 6% of rapid sequence intubation cases,[11] and is linked to a 3-fold increase in mortality in patients with traumatic brain

injuries.[49] Between 8% and 57% of patients undergoing EMS intubations may experience peri-intubation hypoxia.[16,17] Given this prevalence and the potential harm associated with these hypoxic events, improvement efforts aimed at decreasing them are warranted. Our approach offers one potential opportunity for such improvement.

We found that a clinical bundle of patient positioning, apneic oxygenation, delayed sequence intubation, and goal-directed preoxygenation decreased peri-intubation hypoxia. A prospective, randomized, controlled trial is needed to affirm the causality of these associations.

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Author contributions: JLJ and JG conceived of the study. JLJ and LS performed the analysis. JLJ wrote the first draft and revisions. All authors edited the article and revisions. JLJ takes responsibility for the paper as a whole.

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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Table E1. Sensitivity analysis of characteristics of patients undergoing intubation, before and after implementation of airway management bundle.

	Before (n=155)	After (n=107)	Difference (After–Before) (95% CI)
Patient characteristics			
Age, mean (SD), y	56.9 (21.6)	54.0 (21.4)	−2.8 (−8.2 to 2.5)
Weight, mean (SD), kg	85.3 (26.0)	86.9 (25.9)	1.6 (−8.4 to 5.2)
Men, n/N (%)	81/155 (52.3)	64/107 (59.8)	7.6 (−5.3 to 20.4)
White, n/N (%)	132/155 (85.2)	90/107 (84.1)	−1.1 (−10.5 to 8.4)
Trauma, n/N (%)	44/155 (28.4)	17/107 (15.9)	−12.5 (−20.8 to 0.6)
Scene time, median (IQR), min	32 (23 to 40)	42 (32 to 51)	10.0 (6 to 13)
Intubation characteristics			
First-pass success, No. (%)	128/155 (82.6)	79/107 (73.8)	−8.7 (−19.1 to 1.6)
Overall success, No. (%)	148/155 (96.1)	83/107 (77.6)	−17.9 (−26.6 to −9.2)
Attempt duration, median (IQR), min	2 (1 to 2.8)	1 (1 to 1)	0 (−1 to 0)
Initial SpO_2, median (IQR)	91 (77.8 to 97)	91 (79 to 97)	0 (−2 to 2)
Initial hypoxia (SpO_2 <90%), No. (%)	69/155 (44.5)	50/107 (46.7)	2.2 (−10.3 to 14.7)
Peri-intubation peak SpO_2, median (IQR)	99 (92 to 100)	100 (98 to 100)	0 (0 to 1)
Peri-intubation nadir SpO_2, median (IQR)	89.5 (62 to 99)	100 (94 to 100)	6.7 (3 to 13)
Peri-intubation hypoxia, No. (%)	60/155 (50.0)	12/107 (11.8)	−38.2 (−48.6 to −27.9)
Preintubation HR, median (IQR), beats/min	103.5 (91 to 127)	106 (93 to 128)	2.0 (−5 to 8)
Preintubation bradycardia, No. (%)	26/155 (16.8)	2/107 (2.3)	−14.5 (−21.2 to −7.9)
Peri-intubation nadir HR, median (IQR), beats/min	90 (78 to 106)	111 (95 to 128)	20.0 (13 to 27)
Peri-intubation peak HR, median (IQR), beats/min	102.5 (88 to 118.8)	116 (103 to 131)	14.0 (7 to 20)
Peri-intubation bradycardia, No. (%)	1/155 (0.7)	2/107 (1.9)	1.2 (−1.7 to 4.1)
Peri-intubation cardiac arrest, No. (%)	5/155 (3.2)	1/107 (1.1)	−2.1 (−5.7 to 1.4)
Preintubation SBP, median (IQR), mm Hg	134 (118 to 161.5)	139 (115 to 172)	5.0 (−6 to 16)
Postintubation SBP, median (IQR), mm Hg	130 (105 to 162.5)	145 (121 to 173)	15.0 (3 to 26)
Preintubation hypotension, No. (%)	13/155 (8.4)	12/107 (11.2)	2.8 (−4.7 to 10.4)
Postintubation hypotension, No. (%)	26/155 (16.8)	10/107 (9.4)	−7.4 (−15.7 to 0.8)