Apneic Oxygenation Was Associated With Decreased Desaturation Rates During Rapid Sequence Intubation by an Australian Helicopter Emergency Medicine Service

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Study objective: The Greater Sydney Area Helicopter Emergency Medical Service undertakes in excess of 2,500 physician/paramedic out-of-hospital and interhospital retrievals each year, of which 8% require intubation. Emergency anesthesia of critically ill patients is associated with complications, including hypoxia. In July 2011, the service introduced apneic oxygenation with nasal cannulae to its emergency anesthesia standard operating procedure to reduce rates of desaturation during rapid sequence intubation. We evaluate the association between the introduction of apneic oxygenation and incidence of desaturation during rapid sequence intubation in both out-of-hospital and interhospital retrievals.

Methods: This was a retrospective study of prospectively collected airway registry data. Consecutive patients who underwent rapid sequence intubation by Greater Sydney Area Helicopter Emergency Medical Service personnel between September 2009 and July 2013, spanning the introduction of apneic oxygenation, were included for analysis (n=728). We compared patients who underwent rapid sequence intubation before the service introduced apneic oxygenation (n=310) with those who underwent it after its introduction (n=418). We evaluated the association between the introduction of apneic oxygenation and the incidence of desaturation.

Results: During the study period, 9,901 missions were conducted with 728 rapid sequence intubations (310 pre- and 418 postapneic oxygenation). The introduction of apneic oxygenation was followed by a decrease in desaturation rates from 22.6% to 16.5% (difference=6.1%; 95% confidence interval 0.2% to 11.2%).

Conclusion: Introduction of apneic oxygenation was associated with decreased incidence of desaturation in patients undergoing rapid sequence intubation. [Ann Emerg Med. 2015;65:371-376.]

Please see page 372 for the Editor's Capsule Summary of this article.

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INTRODUCTION

Background

Emergency anesthesia in any setting is associated with recognized complications, including hypoxia and difficulty in intubation.^{1,2} The incidence of these complications increases in non–operating theater environments.^{3,4} Published desaturation rates among physician-staffed out-of-hospital studies range from 10.9% to 18.3%.^{5,6} Suggested reasons for the increased incidence of desaturation in this setting include the severity of illness or injury and the challenging environment. A recent study from the Emergency Medical Retrieval Service in the United Kingdom demonstrated that more than 1 attempt at intubation and a Cormack-Lehane grade III view or worse was associated with a significantly higher incidence of desaturation compared with first-pass intubation and grade II or better view.⁷ Other

factors, such as the background specialty of the team leader, outof-hospital or interhospital setting, and underlying pathology, were not significantly associated with desaturation.⁷

Desaturation during emergency anesthesia is a risk factor for dysrhythmia, hemodynamic instability, hypoxic brain injury, and death.^{8,9} At Greater Sydney Area Helicopter Emergency Medical Service, desaturation is defined as a decrease in SpO₂ below 93% during induction of anesthesia and intubation. This definition cutoff is higher than that of some published literature from the United Kingdom and Europe, which defines desaturation as SpO₂ below 90%, but is a standard used in Australian studies.^{5-7,10} In our service, an SpO₂ of 93% is used because this is the value beyond which the steep section of oxygen dissociation curve begins and further desaturation occurs more rapidly. This conservative definition is consistent with that used in the Australian Emergency Airway Registry.¹⁰

Editor's Capsule Summary

What is already known on this topic Apneic oxygenation increases the time to desaturation during the induction of anesthesia in a controlled hospital setting.

What question this study addressed

This retrospective, before-and-after study addresses whether the introduction of apneic oxygenation into an aeromedical rapid sequence intubation protocol was associated with less desaturation during intubation.

What this study adds to our knowledge

Desaturation occurred less often during rapid sequence intubation after the implementation of apneic oxygenation.

How this is relevant to clinical practice

Apneic oxygenation is a simple, inexpensive intervention that is associated with lower rates of desaturation during rapid sequence intubation. Patient outcomes were not assessed, and a randomized trial is warranted.

Physiologically apneic oxygenation works by allowing passive diffusion of oxygen into alveoli and hence into the bloodstream. In a healthy anaesthetized patient, oxygen consumption remains fairly constant, at approximately 250 mL/minute. This is equal to the rate of oxygen extraction from the alveoli of 250 mL/ minute.¹¹ Hence, when connected to high-flow oxygen by nasal cannula, apneic patients will maintain a diffusion of oxygen of up to 250 mL/minute into the bloodstream, as is demonstrated by the significant increase in time to desaturation during anesthesia induction in several hospital studies. Taha et al¹² demonstrated no desaturation in patients receiving oxygen at 5 L/minute by nasal cannula at 6 minutes compared with the control group, who desaturated on average at 3.65 minutes. Ramachandran et al¹³ showed in a randomized controlled study of 30 obese patients that apneic oxygenation by nasal cannula delivering oxygen at 5 L/minute prolonged desaturation time (SpO₂ 95%) from 3.49 minutes to 5.29 minutes. These studies are summarized in a comprehensive review.¹

In our service, apneic oxygenation is written into our rapid sequence intubation standard operating procedure. Nasal cannula is applied and oxygen flow rate set above 5 L/minute (as tolerated) during preoxygenation, which is by either a non rebreather mask with reservoir bag or self-inflating bag-valvemask connected to oxygen flow at 15 L/minute. After induction drug administration, the nasal cannula oxygen flow is increased to 15 L/minute and maintained until the airway is secured.

Importance

Despite the evidence that apneic oxygenation can prolong time to desaturation during elective anesthesia in operating theaters, to our knowledge there has been no study conducted on critically ill or injured patients receiving emergency anesthesia in an out-of-hospital, retrieval, or emergency department setting.

Goals of This Investigation

We aimed to investigate whether apneic oxygenation is associated with a decrease in the rate of desaturation in both out-of-hospital and hospital rapid sequence intubation by an aeromedical retrieval service.

MATERIALS AND METHODS

Study Design and Setting

The study is a retrospective study of prospectively collected data in the Greater Sydney Area Helicopter Emergency Medical Service airway registry for a period of 22 months pre- and post implementation of apneic oxygenation (July 2011). The service undertakes in excess of 2,500 primary out-of-hospital and secondary interhospital retrievals each year, staffed by a critical care physician/paramedic model. The physicians are specialists or senior trainees in emergency medicine, anesthesia, or intensive care. Slightly more than 8% of patients treated by the service require intubation by aeromedical teams, accounting for nearly 250 emergency intubations annually.

Selection of Participants

All patients who had a rapid sequence intubation delivered by Greater Sydney Area Helicopter Emergency Medical Service staff during out-of-hospital or interhospital missions were included (n=728). Patients intubated by referring health care staff before the arrival of the service team and any patients intubated as part of cardiac arrest management were excluded.

Interventions

The intervention was the availability of apneic oxygenation provided through nasal cannula during preoxygenation and intubation during rapid sequence intubation.

Methods of Measurement

All Greater Sydney Area Helicopter Emergency Medical Service mission data are entered at mission completion into an online database by the retrieval physician. This database includes an electronic airway registry that captures an exhaustive data set used for monthly airway audit presentations as part of a continuous quality improvement program. Data for this study were extracted from the airway registry. For each emergency intubation, demographics such as age, sex, weight, type of mission, and diagnosis were collected. Specific intubation data such as Cormack-Lehane grade, percentage of glottic opening score, number of intubation attempts, operator, and complications including desaturation were also collected and analyzed. Pulse oximeter readings were transcribed into the electronic registry by the retrieval physician from the contemporaneous clinical case notes. Measurements were made on a LifePak 15 (Physio-Control, Sydney, NSW, Australia) for out-of-hospital missions and a Propaq (Zoll, Sydney, NSW, Australia) for interhospital missions.

Outcome Measures

Desaturation was defined as a measurement of SpO₂ below 93% at any time during induction or intubation regardless of any preexisting hypoxemia.

Primary Data Analysis

A χ^2 test was used to examine the association between apneic oxygenation availability and desaturation. To determine whether any of the available variables modified the effect of exposure to apneic oxygenation, stratum-specific odds ratios were examined to determine whether they differed materially in either magnitude or direction. Confounding was defined as a difference between the crude and strata-adjusted odds ratios of greater than or equal to 15%; 95% confidence intervals (CIs) were calculated where appropriate.

RESULTS

During the study period, a total of 9,901 missions were carried out. Of these, 728 patients required rapid sequence intubation (7.4%). See Table 1 for patient characteristics. Overall, 22.6% of preapneic oxygenation patients and 16.5% of postapneic oxygenation patients had an episode of desaturation

Table 1. Patient characteristics.

during rapid sequence intubation (difference 6.1%; 95% CI 0.2% to 11.2%) (Table 2).

The median age for both cohorts was 46 years; the median visual estimate of weight was 75 kg in the preapneic oxygenation and 80 kg in the postapneic oxygenation cohort. The majority of rapid sequence intubations in both cohorts were performed during out-of-hospital missions (preapneic oxygenation 53.9%; postapneic oxygenation 53.6%). There was a slightly higher rate of rapid sequence intubation in the postapneic oxygenation cohort (preapneic oxygenation 6.4%; postapneic oxygenation 8.4%). The majority of patients intubated in both cohorts were men (preapneic oxygenation 71.3%; postapneic oxygenation 66.5%). The main indication for rapid sequence intubation in both cohorts was trauma, which accounted for 60.6% of the preapneic oxygenation and 59.8% of postapneic oxygenation intubations.

In both cohorts, first-look intubation was achieved at a similar frequency, 84.5% versus 87.1%. In comparing operators, 56.0% of intubations (n=408) were first attempted by the paramedics, with 80.9% first-look success and 20.1% desaturation rate (25.8% preapneic oxygenation; 16.5% postapneic oxygenation). A physician subsequently intubated 82.5% of patients who required a second attempt at intubation when the first attempt was made by a paramedic. The remaining patients were successfully intubated at second attempt by the paramedic. Three hundred twenty intubations (43.9%) had a physician as the first operator, with 92.2% first-look success and 17.8% desaturation rate (19.2% preapneic oxygenation; 16.6% postapneic oxygenation). In only 1 case was a patient with an intubation unsuccessfully attempted by the physician then intubated by a paramedic.

		Preapn	eic Oxygenatio	n	Postapneic Oxygenation				
		Desaturatio		tion			Desaturation	ion	
Variable	N	n	%	95% CI	Ν	n	%	95% CI	
Success on first look									
No	48	24	50.0	35.9-64.1	54	23	42.6	29.4-55.8	
Yes	262	46	17.6	13.0-22.2	364	46	12.6	9.2-16.1	
Intubator									
Paramedic	159	41	25.8	19.0-32.6	249	41	16.5	11.9-21.1	
Physician	151	29	19.2	12.9-25.5	169	28	16.6	11.0-22.2	
Sex*									
Female	88	14	15.9	8.3-23.6	140	16	11.4	6.2-16.7	
Male	221	56	25.3	19.6-31.1	278	53	19.1	14.4-23.7	
Setting									
Interhospital	143	33	23.1	16.2-30.0	194	35	18.0	12.6-23.5	
Out-of-hospital	167	37	22.2	15.9-28.5	224	34	15.2	10.5-19.9	
Pathology									
Medical	122	28	23.0	15.5-30.4	168	31	18.5	12.6-24.3	
Trauma	188	42	22.3	16.4-28.3	250	38	15.2	10.7-19.7	
Cormack-Lehane Grade									
1 [†]	170	26	15.3	9.9-20.7	206	22	10.7	6.5-14.9	
2	85	20	23.5	14.5-32.5	143	26	18.2	11.9-24.5	
3	31	12	38.7	21.6-55.9	26	9	34.6	16.3-52.9	
4	16	10	62.5	38.8-86.2	19	8	42.1	19.9-64.3	
Total	310	70	22.6	17.9-27.2	418	69	16.5	12.9-20.1	
*One unknown.									
T									

Table 2. Desaturation pre- and postapheic oxygenat

Phase	Total Pts	Pts Intubated	%	Desaturations	% Desaturation
Main results					
Preapneic oxygenation	4,859	310	6.4	71*	22.6
Postapneic oxygenation	5,042	418	8.4	70 [†]	16.5 [‡]
*Includes 23 pat 93%.	ients who	se pre-rapid s	equen	ce intubation satura	ation was below
[†] Includes 23 pati 93%	ients whos	se pre-rapid s	equend	ce intubation satura	tion was below

[‡]Difference=6.1%; 95% CI 0.2% to 11.2%.

A higher percentage of patients in the preapneic oxygenation group had a Cormack-Lehane grade III or worse view (15.2% versus 10.8%). In the preapneic oxygenation cohort, 6 patients required rescue with a laryngeal mask airway and none needed a surgical airway, whereas in the postapneic oxygenation cohort, 13 patients had a laryngeal mask airway inserted and 2 underwent surgical rescue.

The postapneic oxygenation cohort had decreased desaturation incidence across all characteristics (Table 3). Overall, 22.6% of preapneic oxygenation patients and 16.5% of postapneic oxygenation patients had an episode of desaturation during rapid sequence intubation (difference=6.1%; 95% CI 0.2% to 11.2%). The mean duration of desaturation for the preapneic oxygenation cohort was 169.8 seconds (range=5-1800 seconds); and for the postapneic oxygenation cohort, 92.5 seconds (range=4-840 seconds). The number of patients who were included in the analysis as having desaturation, who despite preoxygenation before rapid sequence intubation had a SpO₂ below 93%, was identical in both cohorts: preapneic oxygenation 23 (7.4%) and postapneic oxygenation 23 (5.5%).

The relative risk of desaturation during rapid sequence intubation after apneic oxygenation became available is estimated to be 0.68 (crude odds ratio), with 95% CI 0.47 to 0.98, compared with before apneic oxygenation was available. A stratified analysis did not reveal any significant effect modification by available variables or any clinically significant confounding by available variables. There was no significant difference in incidence of desaturation between out-of-hospital retrievals (preapneic oxygenation 22.2%; postapneic oxygenation 15.2%) versus interhospital ones (preapneic oxygenation 23.1%; postapneic oxygenation 17.8%) or traumatic pathology (preapneic oxygenation 22.3%; postapneic oxygenation 15.2%) versus medical pathology (preapneic oxygenation 23.0%; postapneic oxygenation 18.5%).

In the preapneic oxygenation cohort, 17.6% of patients who were intubated on first look at laryngoscopy desaturated. Desaturation rates increased to 47.6% if a second attempt was required and 66.6% if a third. After the introduction of apneic oxygenation, desaturation rates for first-, second-, and thirdlook intubation were reduced to 12.9%, 40.4%, and 57.1%, respectively. A similar trend was observed for deteriorating **Table 3.** Stratified analysis examining the presence of effectmodification and confounding by available variables.

		Pre-	Post-			
Variable	Desaturation	AO	AO	0R _{ss}	95% CI	OR MH
Success on						
first look						
No	No	24	31	0.74	0.34-1.62	0.69
	Yes	24	23			
Yes	No	216	318	0.68	0.44-1.06	
	Yes	46	46			
Intubator						
Paramedic	No	118	208	0.57	0.35-0.92	0.67
	Yes	41	41			
Physician	No	122	141	0.84	0.47-1.48	
	Yes	29	28			
Sex*						
Female	No	74	124	0.68	0.31-1.48	0.69
	Yes	14	16			
Male	No	165	225	0.69	0.45-1.06	
	Yes	56	53			
Setting						
Interhospital	No	110	159	0.73	0.43-1.25	0.68
	Yes	33	35			
Out-of-hospital	No	130	190	0.63	0.38-1.05	
	Yes	37	34			
Pathology						
Medical	No	94	137	0.76	0.43-1.35	0.68
	Yes	28	31			
Trauma	No	146	212	0.62	0.38-1.01	
	Yes	42	38			
$\begin{array}{c} \text{Cormack-Lehane} \\ \text{grade}^{\dagger} \end{array}$						
1	No	144	184	0.66	0.36-1.22	0.69
	Yes	26	22			
2	No	65	117	0.72	0.37-1.39	
	Yes	20	26			
3+	No	25	28	0.69	0.30-1.58	
	Yes	22	17			

AO, Apneic oxygenation; $OR_{\rm SS}$, stratum-specific odds ratio; $OR_{\rm MH}$, Mantel-Haenszel odds ratio.

*One unknown.

[†]Thirty-two unknown

Cormack-Lehane grade; in the preapneic oxygenation cohort, desaturation rates varied from 15.9% for a grade I to 62.5% for grade IV, and for postapneic oxygenation, this was 10.1% to 42.1%. See Table 4 for full details.

With regard to other complications, the database was examined to ascertain what other complications patients who had an episode of desaturation experienced (Table 5).

Individual case sheets were reviewed for the patients who arrested during rapid sequence intubation or immediately after in both cohorts. None of these patients arrested because of the inability to secure an airway but because of critical injury and illness.

LIMITATIONS

The main limitation of a retrospective analysis is that all factors that may have contributed to the difference observed cannot be eliminated. For example, unmeasured differences between better

Aŗ	oneic	С	0xygenatio1	1 and	D	ecreased	Ľ	Desaturation	Rates
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Table 4.	Desaturation	rates per	intubation	attempt and
Cormack-	Lehane grade) .		

Variable	Preapneic Oxygenation (n=310)	Desaturation (%)	Postapneic Oxygenation (n=418)	Desaturation (%)
Laryngoscopy 1	262	47 (17.9)	364	47 (12.9)
Laryngoscopy 2	42	20 (47.6)	47	19 (40.4)
Laryngoscopy 3	6	4 (66.6)	7	4 (57.1)
C-L grade				
I	170	27 (15.9)	206	21 (10.1)
11	85	20 (23.5)	143	26 (18.2)
111	31	12 (38.7)	26	9 (34.6)
IV	16	10 (62.5)	19	9 (42.1)
Not recorded	8	2 (25.0)	24	5 (20.1)
C-L, Cormack-Leha	ine.			

training, teamwork, and more rigorous adherence to the existing rapid sequence intubation protocols could have taken place during the study period. Another major limitation of a retrospective analysis is that even with large numbers, this methodology can address only association between the intervention, in this case, the availability of apneic oxygenation and the outcome (desaturation rates); causation cannot be inferred.

Other limitations of this study include that oxygen saturation recordings were reported by clinical staff but not directly corroborated with stored data from the patient monitors and therefore may have been subject to reporting or recall bias. This could also apply to other variables such as documentation of a Cormack-Lehane grade, duration of hypoxia, or percentage of glottic opening score: the operator may be more likely to report a Cormack-Lehane III or IV after a failed laryngoscopy attempt. Although apneic oxygenation was introduced into the standard operating procedure, the electronic registry did not include a dedicated field to capture whether it had been applied in each case. It is therefore possible that it was not applied in every case, and our results may underestimate its potential benefit. However, this relatively novel intervention would be expected to have been documented in the case sheet if used. Conversely, if individual clinicians were using apneic oxygenation before its official implementation in July 2011, this may have narrowed our results. These issues have now been resolved in our service, with direct physiologic data being uploaded from the monitors, as well as a

Table 5. Further complications experienced by patients who

 desaturated during rapid sequence intubation.

Complication	Preapneic Oxygenation, No. (%), N=71	Postapneic Oxygenation, No. (%), N=70
Ventilation using bag-valve-mask	24 (33.9)	28 (39.4)
Laryngeal mask airway inserted	5 (7.0)	11 (15.7)
Surgical airway performed	0	3 (4.3)
Episode of bradycardia	5 (7.0)	1 (1.4)
Cardiac arrest	4 (5.6)	1 (1.4)

DISCUSSION

This study demonstrates that the introduction of apneic oxygenation is associated with a decreased rate of desaturation during rapid sequence intubation in both out-of-hospital and interhospital retrievals. The fact that the introduction of apneic oxygenation was associated with a decrease in desaturation rates across all variables in the postapneic oxygenation cohort compared with the preapneic oxygenation cohort suggests that this simple and inexpensive technique of maintaining oxygenation to critically ill and injured patients undergoing rapid sequence intubation is of clear clinical benefit.

Our preapneic oxygenation desaturation level was 22.9%, which is slightly higher than that of other published desaturation rates among physician-staffed aeromedical retrieval services. Two Norwegian services have reported rates of 10.9%⁵ and 19.0%¹⁴ for desaturation among their rapid sequence intubation patients; London Helicopter Emergency Medical Service has reported a desaturation rate of 18.3%⁶; and Scottish Emergency Medical Retrieval Service, 15.3%.⁷ One of the key reasons for this is likely to be a higher cutoff definition of desaturation used by Greater Sydney Area Helicopter Emergency Medical Service, which is defined as oxygen saturation below 93%, including preexisting hypoxia, whereas other published studies have used a cutoff of oxygen saturations at 90% or a 10% decrease from preinduction saturations.^{6,7} In fact, if we removed the data of patients with preexisting hypoxia (despite preoxygenation), our preapneic oxygenation desaturation level decreases to 15.5% and the postapneic oxygenation desaturation rate decreases to 11.2%. Furthermore, our first-look success rate is equivalent to or better than that of most out-of-hospital studies.

In terms of the operator, first-look success and desaturation rates were better for physicians compared with paramedics. However, our paramedic first-look success rates and desaturation rates are better than those of many other studies.^{15,16} It is also a specification of our rapid sequence intubation standard operating procedure that any patient with difficult airway features or difficulty achieving adequate preoxygenation (SpO₂ of 93%) be intubated by the Helicopter Emergency Medical Service physician. It is also specified in the standard operating procedure that if a paramedic fails at the first attempt at intubation, then the physician takes over for the subsequent intubation attempts.

All new staff at Greater Sydney Area Helicopter Emergency Medical Service, physicians and paramedics, are trained in our rapid sequence intubation protocol during induction and also during 3 monthly rapid sequence intubation currency training sessions. A preintubation checklist is used, which has included apneic oxygenation since apneic oxygenation was introduced. Ongoing simulation training is a requirement for clinical staff, including the compulsory 3 monthly rapid sequence intubation currency assessments, which include use of the checklist and implementation of apneic oxygenation. A monthly airway audit of all intubations is presented during our clinical governance meetings, during which strategies for first-pass success are reiterated.

Our data showed no significant difference in desaturation between out-of-hospital and interhospital rapid sequence intubations in either cohort, which is in keeping with published data from similar retrieval services.⁷ Our data show that more than 1 attempt at laryngoscopy and a grade III or worse view is associated with a higher incidence of desaturation, consistent with existing literature highlighting the importance of optimizing firstlook success.^{6,7,17}

All providers of out-of-hospital anesthesia seek reductions in the rate of desaturation during emergency anesthesia. At Greater Sydney Area Helicopter Emergency Medical Service, our emergency anesthesia standard operating procedure emphasizes maximizing first-look success and minimizing hypoxia. This is achieved by position optimization, maximal preoxygenation, standardized induction drugs and doses, omission of cricoid pressure, routine bougie use, external laryngeal manipulation, use of a challenge-response checklist, and a preintubation team brief. This approach is taught and reinforced through regular online and face-to-face training and assessment and a rigorous quality improvement program with monthly audit of every intubation.

The fact that first-look intubation success and laryngoscopy grade III or worse view were lower for the postapneic oxygenation group compared with the preapneic oxygenation cohort suggests that the above measures, as well as optimizing preoxygenation and maintaining oxygenation during apnea with apneic oxygenation, have helped decrease desaturation during rapid sequence intubation.

In summary, this study demonstrates that apneic oxygenation can be successfully implemented in the out-of-hospital and interhospital retrieval environment and is associated with decreased rates of desaturation in critically ill and injured patients undergoing emergency anesthesia.

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Author contributions: YW conceived, designed, and conducted the study. BB supervised the study design and conduct. SW carried out the statistical analysis and table preparation. YW drafted the manuscript and all the authors contributed substantially to its revision.

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