ORIGINAL RESEARCH

Airway

Emergency physician use of end-tidal oxygen monitoring for rapidsequence intubation

Matthew Oliver MBBS1,2 | Nicholas D. Caputo MD, MSc3 | Jason R. West MD3 | Robert Hackett MBBS4 | John C. Sakles MD5

1 Department of Emergency Medicine, Royal Prince Alfred Hospital, Sydney, Australia
2 Sydney Medical School, University of Sydney, Sydney, Australia
3 Department of Emergency Medicine, Lincoln Medical Center, Bronx, New York, USA
4 Department of Anaesthesia, Royal Prince Alfred Hospital, Sydney, Australia
5 Department of Emergency Medicine, University of Arizona College of Medicine-Tucson, Arizona, USA

Correspondence
Matthew Oliver, MBBS, Department of Emergency Medicine, Royal Prince Alfred Hospital, Sydney, Australia.
Email: drmatoliver@gmail.com

Presented at the American College of Emergency Physicians Scientific Assembly, October 2019, Denver, CO.

Funding and support: By JACEP Open policy, all authors are required to disclose any and all commercial, financial, and other relationships in any way related to the subject of this article as per ICMJE conflict of interest guidelines (see www.icmje.org). The authors have stated that no such relationships exist.

Abstract

Background: End-tidal oxygen (ETO2) monitoring is used by anesthesiologists to quantify the efficacy of preoxygenation before intubation but is generally not used in emergency departments (EDs). We have previously published our findings describing preoxygenation practices in the ED during blinded use of ETO2. The purpose of this investigation is to determine whether the unblinded use of ETO2 monitoring led to improvements in preoxygenation during rapid sequence intubation in the ED and also the oxygen device or technique changes that were used to achieve higher ETO2 levels.

Methods: We conducted an interventional study at 2 academic EDs in Sydney, Australia and New York City, New York using ETO2 monitoring to investigate the preoxygenation process and effectiveness. We used data collected during a previous descriptive study for the control group, in which care teams in the same 2 EDs were blinded to the ETO2 value. In the study group, clinicians could utilize ETO2 to improve preoxygenation. Following an education process, clinicians were able to choose the method of preoxygenation and the techniques required to attempt to achieve an ETO2 level >85%. The primary outcome was the difference in ETO2 levels at the time of induction between the control and study group and the secondary outcome included the methods that were attempted to improve preoxygenation.

Results: A convenience sample of 100 patients was enrolled in each group. The median ETO2 level achieved at the time of induction was 80% (interquartile range 61 to 86, overall range 73) in the control group and 90% in the study group (interquartile range 83 to 92, overall range 41); the median difference was 12 (95% confidence interval: 8, 16, P = < 0.001). The majority of oxygen device changes were from non-rebreather
mask to bag-valve-mask (BVM) (15%, n = 15) and changes in technique from improvements in mask seal (54%, n = 34). The final device used in the study group was BVM in 87% of cases.

Conclusions: In 2 clinical studies of ETO₂ in academic EDs, we have demonstrated that the use of ETO₂ is feasible and associated with specific and potentially improved approaches to preoxygenation. A clinical trial is needed to further study the impact of ETO₂ on the preoxygenation process and the rate of hypoxemia.

KEYWORDS
Airway, Emergency, Intubation, Preoxygenation, Resuscitation

INTRODUCTION

1.1 Background

Patients undergoing rapid sequence intubation (RSI) in the emergency department are at risk of adverse events, with previous literature indicating that adverse events occur in as many as 1 in 4 patients.¹² Hypoxemia is common during emergency intubation and one of the main risk factors for more severe adverse events.³⁻⁸ Preoxygenation creates a reservoir of oxygen in the alveoli and tissues that can help maintain adequate hemoglobin saturation during the apneic period of RSI and therefore help minimize the risk of hypoxemia and its associated complications.

1.2 Importance

Currently, standard preoxygenation in the ED involves either the delivery of a high concentration of oxygen via a non-rebreather mask (NRB) or bag-valve-mask (BVM) with the aim of maximally denitrogenating the lungs thereby creating a large intrapulmonary reservoir of oxygen. Unfortunately, there is no routine objective measurement of the efficacy of preoxygenation in the ED, so clinicians rely on oxygen saturations (SpO₂) and delivering oxygen for a defined period of time, most commonly 3 minutes. The reliance on 3 or more minutes is based on a study performed in 1983 on 12 healthy volunteers and 20 elective surgery patients and therefore the applicability to patients undergoing RSI in the ED is unclear.⁹ The only objective measure of preoxygenation in the ED is to use SpO₂; however, this is an indirect measurement of preoxygenation as SpO₂ levels do not give any information on the level of denitrogenation.

End-tidal oxygen (ETO₂) monitoring is routinely used by anesthesiologists before intubation in the operating room (OR) to objectively measure the efficacy of the denitrogenation process. In critically ill patients, a goal of an ETO₂ level of >85% is recommended and indicates maximal denitrogenation of the functional reserve capacity (FRC).¹⁰ The aim of achieving higher ETO₂ levels is to create the largest possible reservoir of oxygen in the FRC to help maintain hemoglobin saturation during the apneic phase of RSI.

We recently published a study of preoxygenation practices using ETO₂ monitoring in the ED.¹¹ By blinding clinicians to the ETO₂ results and measuring the levels during the preoxygenation period we demonstrated that the vast majority of patients had suboptimal preoxygenation. Only 26% of patients reached the recommended target of >85% and alarmingly 11% of patients were preoxygenated to levels of < 50%.

Currently, ETO₂ monitoring is not typically performed in EDs and so adequacy of preoxygenation before RSI is unknown. Before the introduction of this technology in EDs, it is important to evaluate whether real-time ETO₂ monitoring would provide any improvements in preoxygenation measured by ETO₂ levels. If current clinical practices demonstrate adequate ETO₂ levels without ETO₂ monitoring, then the implementation of the technology may not be necessary.

1.3 Goals of this investigation

We hypothesized that preoxygenation in the ED, measured by ETO₂ levels at induction, is often inadequate and that unblinding ETO₂ monitoring to clinicians alters preoxygenation practices that could improve preoxygenation (ETO₂ at induction). To investigate this, we conducted a study to evaluate preoxygenation in the ED with the use of ETO₂ monitoring and the strategies that were implemented by clinicians to achieve improvements in preoxygenation with the use of ETO₂ monitoring.

METHODS

2.1 Study design and setting

We conducted a prospective, interventional study with convenience sampling of patients at 2 urban, high volume, academic EDs in Sydney, Australia and New York City, New York. We used data from our previously published paper as the control group where clinicians were blinded to ETO₂ results during the preoxygenation process. In the study group, clinicians were able to visualize the ETO₂ result and alter preoxygenation strategies and techniques with the aim to achieve an ETO₂ value of >85% prior to the administration of the induction agent and paralytic agent.
This study was approved with waiver of consent of patients by the institutional review board and ethics board at each institution. A previously published paper by the authors describes the specifics of the departmental settings and clinical management of patients during RSI in the ED. Practices of RSI are very similar at each institution. However, flush rate oxygen delivery was achieved only at the NYC site at ≤50–70 L/min; the Sydney site did not have access to flush rate oxygen. Also, there is a difference in the level of training of the operators, with trainees of all levels performing the intubations at the NYC site and only senior-level residents performing the intubations at the Sydney site.

### 2.2 Selection of participants

Any adult patient (≥18 years) undergoing RSI in the ED was considered for inclusion in the study. Patients who were not considered suitable for the study included those in cardiac arrest, patients who received non-invasive ventilation before intubation, and those who underwent awake intubation.

### 2.3 Intervention

Before the commencement of the study, ETO2 monitors were installed in resuscitation bays at both institutions. Following the completion of data collection for the control group, staff at both sites underwent the same educational intervention describing the role of ETO2 monitoring. During these education sessions staff received education related to how ETO2 monitoring works including the ideal ETO2 level to be achieved of >85%. A brief discussion was conducted during these education sessions on the available options to physicians that may affect the ETO2 level. These options included techniques or oxygen devices that are of common knowledge and routinely used in clinical practice by physicians to improve oxygenation in EDs. These techniques included: improvement of mask seal, increased oxygen flow rate, and/or increased preoxygenation time. The oxygen device options included: addition of conventional nasal cannula oxygen, a change to NRB, a change to BVM, or a change to BVM with a positive end expiratory pressure (PEEP) valve. Physicians were informed of these options during the education session and allowed to choose any of these options if the ETO2 value was ≤85% with these modifications recorded on the data collection sheet; however, alterations using these modifications were not mandatory if the ETO2 was ≤85%. Physicians were not informed of any specific preoxygenation technique or oxygen device that could lead to improvements in ETO2 levels above any other technique or device.

Given the clinical urgency of RSI in the ED, we recommended to physicians that if it was not possible to achieve an ETO2 of >85% after 3 minutes of the highest recorded ETO2, even after an intervention described previously, then they were advised to proceed with intubation. This was to prevent physicians attempting multiple different methods that may subsequently cause a delay to patients receiving a definitive airway.

### 2.4 Methods of measurement

A full methodology has been outlined in a previous paper. In brief, ETO2 monitoring commenced at the start of preoxygenation, that is, at the decision for RSI and continued until successful tracheal intubation was achieved. For patients preoxygenated with a BVM, a sidestream gas sampling line was connected between the bag and the mask of the device. For patients preoxygenated with a NRB, nasal prongs were used to sample gas for analysis. ETO2 levels were measured by Phillips G5 Gas Analyzer (Philips) at the NYC site and by a Philips G7 Gas Analyzer (Philips) at the Sydney site. Data were recorded during the RSI by observers independent of the clinical team on data collection sheets. ETO2 values were recorded at the initiation of preoxygenation, at induction, and at the first exhalation following tracheal intubation. The techniques that were used to improve the preoxygenation (listed in “intervention”) were also recorded on the data collection sheet by the observers. To ensure the accuracy of the data collected, waveform capnography tracings were recorded and classified as good (rectangular), poor (non-rectangular), or absent (flat).

### 2.5 Outcomes measures

The primary outcome for the study was to determine the effect of unblinded use (study group) of ETO2 monitoring on the median difference in ETO2 levels achieved at the time of induction compared to the blinded (control group) use of ETO2. ETO2 levels were also stratified into the following groups for comparison: >85%, 70%–85%, 50%–69%, and < 50%. The secondary outcomes included the changes in preoxygenation techniques that clinicians employed to optimize ETO2. Also, the prevalence of hypoxemia, defined as SpO2 <90% recorded during the peri-intubation period of up to 2 minutes post-intubation, was compared between the control and study group.

### 2.6 Primary data analysis

Medians and proportions with 95% confidence intervals (CI) are reported. The primary outcome was compared using the Wilcoxon
2-sample test. Statistical significance was determined if $P = < 0.05$. Data were imported into and analyzed with Microsoft Excel (version 2018.7; Addinsoft, New York, NY) and JASP (JASP Team [2019], JASP Version 0.9.2).

3 | RESULTS

3.1 | Characteristics of study subjects

During the 19-month study period 100 patients were enrolled in both the control group and study group. Baseline demographic characteristics, indications for RSI, and intubation details were similar between both groups (Table 1).

However, the oxygen delivery devices used at the commencement of preoxygenation varied between the 2 groups by around 20%, with starting device of BVM in 55% of patients in the control group and in 73% of patients in the study group (Table 1). Capnography traces were deemed to be good (rectangular) in 89% of patients, poor (non-rectangular) in 4%, and absent (flat) tracings in 1% (missing data in 6%).

3.2 | Main results

The median $\text{ETO}_2$ level achieved at the time of induction during RSI in the control group was 80% (interquartile range 61 to 86, overall range 73) and in the study group was 90% (interquartile range 83 to 92, overall range 41) with a median difference of 12 (95% CI: 8, 16, $P = < 0.001$)(Figure 1). The proportion of patients in whom an $\text{ETO}_2$ of $>85\%$ was achieved in the control group was 26% (n = 26, CI: 18% to 36%) compared to 67% in the study group (n = 67, CI: 57% to 76%) (Figure 2).

In the study group, in order to attempt to improve $\text{ETO}_2$ values, the oxygen delivery device was changed from NRB to BVM in 15% of patients (n = 15, flush rate = 12, non-flush rate = 3) and 11% remained with NRB in (n = 11). One patient (1%) changed from BVM to NRB and 73% remained with BVM (n = 73). Thus, the final preoxygenation device used was BVM in 87% (n = 87). Changes in preoxygenation technique were made in 63% (n = 63) of patients. These changes were an improvement in mask seal (54%, n = 34), followed by increased duration of preoxygenation (22%, n = 14), increased oxygen flow (11%, n = 7), and increased PEEP (8%, n = 5).

In order to compare whether the preoxygenation device or the use of $\text{ETO}_2$ monitoring may be responsible for the improvement in preoxygenation we compared $\text{ETO}_2$ levels using only the BVM as the initial preoxygenation device and found the $\text{ETO}_2$ at induction in the control group was 80% and in the study group was 90% (Figure 3). The prevalence of hypoxemia ($\text{SpO}_2 < 90\%$) in the control group was 18% (n = 18, 95% CI: 11% to 27%) and was 8% in the study group (n = 8, 95% CI: 4% to 15%).

| TABLE 1 | Comparison of baseline characteristics between the control group and study group |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Characteristic   | Control group   | Study group     | Control group   | Study group     |
|-----------------|-----------------|-----------------|-----------------|-----------------|
| Age, median (IQR), y | 53 (43 to 65) | 56 (40 to 69) | Male sex, no. | 56 | 59 |
| Indication, no. | Pulmonary | 37 | 30 | Neurologic | 25 | 24 |
| | Trauma | 19 | 15 | Infections (not including pulmonary) | 7 | 9 |
| | Other | 12 | 22 |
| Starting preoxygenation, no. | BVM at 15 L/min | 12 | 33 | BVM at FR | 17 | 10 |
| | BVM PEEP at 15 L/min | 13 | 16 | BVM PEEP at FR | 13 | 14 |
| | NRB at 15 L/min | 12 | 6 | NRB at FR | 17 | 15 |
| | NRB NC at 15 L/min | 12 | 5 | NRB NC at FR | 4 | 0 |
| Intubation characteristics | SpO2 at commencement of preoxygenation, median, (IQR), | 95 (88 to 100) | 97 (87 to 100) |
| | Preoxygenation time, median (IQR), min | 12 (10 to 14) | 10 (6 to 13) |
| | Cormack/Lehane grade, median, (IQR) | 1 (1 to 2) | 1 (1 to 2) |
| Intubation attempt, % (no.) | First | 90.9 (90/99) | 87.5 (84/96) |
| | Second | 9.1 (9/99) | 12.5 (12/96) |
| | Missing | 1 | 4 |
| Operator level of training, no. | PGY | 1 | 8 | 2 | 7 |
| | ≥3 | 65 | 79 |

BVM, bag-valve-mask; FR, flush rate; IQR, interquartile range; NC, nasal cannula; NRB, non-rebreather; PEEP, positive end-expiratory pressure; $\text{SpO}_2$, saturation of oxygen. PGY, Post graduate year.

4 | LIMITATIONS

This study is limited by a number of factors. This was a before/after study with a convenience sample of patients undergoing RSI in the
ED. This is one of the most stressful procedures performed in the ED, and so we gave clinicians the option to use the ETO2 monitors when possible; however, not all patients undergoing RSI were captured during the study period and it may be argued that more critically ill patients were not captured during this study, although the reasonably large number of patients, similarity of baseline characteristics, and biological plausibility in this study may mitigate this limitation. The sampling of ETO2 from patients using an open system with nasal cannula may also be a limitation of the study. We have previously described a validation of the current gas sampling methods; however, this was on healthy volunteers and not patients. Further research into the validation and accuracy of different methods of gas sampling to measure ETO2 in patients are warranted. This is of importance when comparing open systems (using a NRB mask with nasal cannula gas sampling) to closed systems (using a BVM with an occlusive face mask seal and sidestream gas sampling). Patients with low FRC or hypoventilation may have falsely elevated ETO2 levels that may be a limiting factor in this study, although capnography tracings were recorded to ensure adequacy of ventilation and accuracy of the data. Also, the specific relationship between the implemented changes to preoxygenation device or technique to the ETO2 value was not recorded. Finally, this study was completed at 2 academic urban EDs where trainees performed the intubations, and therefore our results may not be generalizable to other types of practices.

**FIGURE 1** Comparison of end-tidal oxygen levels (%) at induction between the control group and study group

We have demonstrated that the introduction of ETO2 monitoring may be associated with improvements in preoxygenation, primarily with the use of the BVM, and with a possible reduction in hypoxicemic events for patients undergoing RSI in the ED. The percentage of patients achieving ETO2 > 85% was greater when the ETO2 monitoring was utilized, with only 26% (n = 26) reaching ETO2 > 85% in the control group compared to 67% (n = 67%) in the study group. However, we recognize that this study does not account for the multiple confounders that relate to preoxygenation and hypoxia. Patients in both groups were similar in age, sex, indication for RSI, difficulty of intubation, and preoxygenation time, but there are many other confounders that may play a role that were not recorded in this study. These confounders include patient factors such as the airway anatomy, body habitus, hemodynamic condition, or comorbidities. There are also non-patient factors such as operator experience, department pressures, RSI checklist utilization, and resource availability.

We did observe that compared to the control group, clinicians in the study group were using BVM more frequently to commence preoxygenation (55% vs 73% respectively). An analysis of the patients using BVM as the preoxygenation device (Figure 3) reveals that the difference in ETO2 at induction remains, indicating that the device alone is not responsible for the difference but may be related to the use of ETO2 monitoring. It is not clear why there was an increase in use of BVM in the study group. One possibility could be that clinicians learnt by visualizing the ETO2 result during the study that BVM produced higher ETO2 levels and so during subsequent intubations this method of preoxygenation became the routine option.

When we analyzed the techniques utilized to improve preoxygenation, we found that the majority of clinicians (54%) used an improved mask seal to achieve higher ETO2 levels, which can be achieved only with the BVM. Other strategies included longer preoxygenation time (22%), increased oxygen flow (11%), and the addition of PEEP (8%). Previous studies have investigated the optimal strategy for preoxygenation, but so far these have only been completed on healthy volunteers or stable patients in the OR. Given clinicians used the BVM in nearly 90% of patients in the study group our results suggest that utilizing a BVM allows a good mask seal and real-time feedback with ETO2 monitoring, which may therefore lead to better preoxygenation.

5 | DISCUSSION

We have demonstrated that the introduction of ETO2 monitoring may be associated with improvements in preoxygenation, primarily with the use of the BVM, and with a possible reduction in hypoxicemic events for patients undergoing RSI in the ED. The percentage of patients achieving ETO2 > 85% was greater when the ETO2 monitoring was utilized,
Anesthesiologists have utilized ETO₂ monitoring for decades to optimize preoxygenation before intubation.24 Interestingly, little evidence exists to support the use of this technology among patients undergoing RSI, and no evidence seems to exist that demonstrates clinical benefit to patients. Machlin et al studied the use of ETO₂ during preoxygenation in 200 patients undergoing elective surgery.25 They demonstrated that using a standard time interval for preoxygenation (3 minutes) is not a reliable method to achieve optimal preoxygenation as 23% (n = 46) failed to reach the target ETO₂ level of above 90% within this time frame. The authors did not report any patient-related outcomes, for example, hypoxemia, for those who failed to be adequately preoxygenated but highlight the challenges that emergency clinicians face without the use of ETO₂ to gauge adequate preoxygenation. Despite the lack of evidence for clinical benefit to patients, ETO₂ monitoring is routinely used in the operating theatre and is recommended by current clinical practice guidelines for airway management.10

The aim of achieving higher ETO₂ levels is to create the largest possible reservoir of oxygen in the FRC to help maintain hemoglobin saturation during the apneic phase of RSI. RSI remains one of the most dangerous procedures performed in the ED with rates of cardiac
arrest reported to occur in 1%-2% of cases. The reasons for this are multifactorial, but previous studies indicate that one of the major contributing factors to severe adverse events during intubation is hypoxemia. Previous studies have demonstrated a high prevalence of oxygen desaturation during intubation in the ED. Bodily et al found that hypoxemia (SpO2 < 90% or a further reduction in SpO2 in patients with starting SpO2 < 90%) occurred in 35.5% of 166 ED patients undergoing RSI.

In our study, we found a decrease in the prevalence of hypoxemia from 18% of patients in the control group to 8% of patients in the study group by simply implementing ETO2 monitoring. Perhaps by improving preoxygenation by utilizing ETO2 monitoring during RSI in the ED, the frequency of hypoxemia and its associated adverse events can be reduced. Prior to any consideration for the routine use of ETO2 in EDs a large randomized controlled trial (RCT) is warranted to account for the multiple confounders and answer the question of whether ETO2 monitoring leads to an improvement in hypoxic events during RSI in the ED. Based on data from our study to calculate the sample size for an RCT with the clinically important outcome of hypoxemia (80% power, α 0.05, 2-sided calculation) ≈350 patients in total would be required.

In summary, we have demonstrated that the use of ETO2 monitoring in EDs is feasible and associated with potentially improved approaches to preoxygenation, specifically with the use of the BVM. A larger clinical trial is needed to further study the potential impact of ETO2 on the preoxygenation process and the rate of hypoxemia.

CONFLICTS OF INTEREST
None of the authors declare any conflicts of interest.

AUTHOR CONTRIBUTIONS
All authors contributed to the conception and design of the study. MO, NDC, and JRW supervised the conduct of the study and data collection at their respective sites. MO, NDC, and JRW contributed to data analysis. MO drafted the manuscript and all authors had substantial contributions to produce the final manuscript. MO takes responsibility of the manuscript as a whole.

REFERENCES
1. Alkhouri H, Vassiliadis J, Murray M, et al. Emergency airway management in Australian and New Zealand emergency departments: a multicentre descriptive study of 3710 emergency intubations. Emerg Med Australas. 2017;29(5):499-508.
2. Bodily JB, Webb HR, Weiss SJ, Braude DA. Incidence and duration of continuously measured oxygen desaturation during emergency department intubation. Ann Emerg Med. 2016;67(3):389-395.
3. Davis DP, Dunford Jv, Poste JC, et al. The impact of hypoxia and hyperventilation on outcome after paramedic rapid sequence intubation of severely head-injured patients. J Trauma. 2004;57(1):1-8. discussion 8-10.
4. Mort TC. The incidence and risk factors for cardiac arrest during emergency tracheal intubation: a justification for incorporating the ASA Guidelines in the remote location. J Clin Anesth. 2004;16(7):508-516.
5. De Jong A, Molinari N, Terzi N, et al. Early identification of patients at risk for difficult intubation in the intensive care unit: development and validation of the MACOCHA score in a multicenter cohort study. Am J Respir Crit Care Med. 2013;187(8):832-839.
6. Shiima Y, Berg RA, Bogner HR, et al. Cardiac arrests associated with tracheal intubations in PICUs: a multicenter cohort study. Crit Care Med. 2016;44(9):1675-1682.
7. De Jong A, Rolle A, Molinari N, et al. Cardiac arrest and mortality related to intubation procedure in critically ill adult patients: a multicenter cohort study. Crit Care Med. 2018;46(4):532-539.
8. Heffner AC, Swords DS, Neale MN, Jones AE. Incidence and factors associated with cardiac arrest complicating emergency airway management. Resuscitation. 2013;84(11):1500-1504.
9. Berthoud M, Read DH, Norman J. Pre-oxygenation--how long? Anaesthesia. 1983;38(2):96-102.
10. Higgs A, McGrath BA, Goddard C, et al. Guidelines for the management of tracheal intubation in critically ill adults. Br J Anaesth. 2018;120(2):323-352.
11. Caputo ND, Oliver M, West JR, Hackett R, Sakles JC. Use of end tidal oxygen monitoring to assess preoxygenation during rapid sequence intubation in the emergency department. Ann Emerg Med. 2019;74(3):410-415.
12. Benuhof JL, Herway ST. High end tidal oxygen concentration can be a misleading sole indicator of the completeness of preoxygenation. Anesth Analg. 2017;124(6):2093.
13. Mosier JM, Joshi R, Hypes C, Pacheco G, Valenzuela T, Sakles JC. The Physiologically difficult airway. West J Emerg Med. 2015;16(7):1109-1117.
14. Carlson JN, Wang HE. Emergency airway management: can we do better? Resuscitation. 2013;84(11):1461-1462.
15. Mosier JM, Sakles JC, Law JA, Brown CA, 3rd, Brindley PG. Tracheal intubation in the critically ill: where we came from and where we should go. Am J Respir Crit Care Med. 2020;201(7):775-788.
16. Groombridge C, Chin CW, Hanrahan B, Holdgate A. Assessment of common preoxygenation strategies outside of the operating room environment. Acad Emerg Med. 2016;23(3):342-346.
17. Driver BE, Klein LR, Carlson K, Harrington J, Reardon RF, Prekker ME. Preoxygenation with flush rate oxygen: comparing the nonrebreather mask with the bag-valve mask. Ann Emerg Med. 2018;71(3):381-386.
18. Driver BE, Prekker ME, Kornas RL, Cales EK, Reardon RF. Flush rate oxygen for emergency airway preoxygenation. Ann Emerg Med. 2017;69(1):1-6.
19. Hayes-Bradley C, Lewis A, Burns B, Miller M. Efficacy of nasal cannula oxygen as a preoxygenation adjunct in emergency airway management. Ann Emerg Med. 2016;68(2):174-180.
20. McQuade D, Miller MR, Hayes-Bradley C. Addition of nasal cannula can either impair or enhance preoxygenation with a bag valve mask: a randomized crossover design study comparing oxygen flow rates. Anesth Analg. 2018;126(4):1214-1218.
21. Ramez Salem M, Joseph NJ, Crystal GJ, Nimmagadda U, Benumof JL, Baraka A. Preoxygenation: comparison of maximal breathing and tidal volume techniques. Anesthesiology. 2000;92(6):1845-1847.
22. Nimmagadda U, Salem MR, Joseph NJ, et al. Efficacy of preoxygenation with tidal volume breathing. Comparison of breathing systems. Anesthesiology. 2000;93(3):693-698.
23. Baraka AS, Taha SK, Aouad MT, El-Khatib MF, Kawabani NI. Preoxygenation: comparison of maximal breathing and tidal volume breathing techniques. Anesthesiology. 1999;91(3):612-616.
24. Roe PG, Tyler CK, Tennant R, Barnes PK. Oxygen analysers. An evaluation of five fuel cell models. Anaesthesia. 1987;42(2):175-181.
25. Machlin HA, Myles PS, Berry CB, Butler PJ, Story DA, Heath BJ. End-tidal oxygen measurement compared with patient factor assessment for determining preoxygenation time. Anaesth Intensive Care. 1993;21(4):409-413.
AUTHOR BIOGRAPHY

Matthew Oliver, MBBS, is an emergency physician at the Royal Prince Alfred Hospital. He is also a member of the Discipline of Emergency Medicine with the University of Sydney.

How to cite this article: Oliver M, Caputo ND, West JR, Hackett R, Sakles JC. Emergency physician use of end-tidal oxygen monitoring for rapidsequence intubation. JACEP Open. 2020;1:706–713. https://doi.org/10.1002/emp2.12260