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Original Article

Efficacy and Safety of Using High-Flow Nasal Oxygenation in Patients Undergoing Rapid Sequence Intubation

Santi Maurizio Raineri, Andrea Cortegiani, Giuseppe Accurso, Claudia Procaccianti, Filippo Vitale, Sabrina Caruso, Antonino Giarratano, Cesare Gregoretti

Department of Biopathology and Medical Biotechnologies (DIBIMED), Section of Anesthesia, Analgesia, Intensive Care and Emergency, Policlinico Paolo Giaccone, University of Palermo, Palermo, Italy

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Abstract

Objective: To assess the efficacy and safety of high-flow nasal oxygen (HFNO) therapy in patients undergoing rapid sequence intubation (RSI) for emergency abdominal surgery.

Methods: HFNO of 60 L.min^{-1} at an inspiratory oxygen fraction of 1 was delivered 4 min before laryngoscopy and maintained until the patient was intubated, and correct intubation was verified by the appearance of the end-tidal CO_2 ($EtCO_2$) waveform. Transcutaneous oxygenation (SpO_2), heart rate and non-invasive mean arterial pressure were monitored at baseline (T0), after 4 min on HFNO (T1) and at the time of laryngoscopy (T2) and endotracheal intubation (ETI) (T3). An SpO_2 of <3% from baseline was recorded at any sampled time. The value of $EtCO_2$ at T3 was registered after two mechanical breaths. The apnoea time was defined as the time from the end of propofol injection to ETI. RSI was performed with propofol, fentanyl and rocuronium.

Results: Forty-five patients were enrolled. SpO_2 levels showed a statistically significant increase at T1, T2 and T3 compared with those at T0 ($p<0.05$); median SpO_2% (interquartile range) was 97% (range, 96%-99%) at T0, 99% (range, 99%-100%) at T1, 99% (range, 99%-100%) at T2 and 99% (range, 99%-100%) at T3. Minimal SpO_2 was 96%; no patient showed an SpO_2 of <3% from baseline; mean $EtCO_2$ at the time of ETI was 36±4 mmHg. Maximum apnoea time was 12 min.

Conclusion: HFNO is an effective and safe technique for pre-oxygenation in patients undergoing rapid sequence induction of general anaesthesia for emergency surgery.

Keywords: Rapid sequence intubation, pre-oxygenation, high-flow nasal oxygen therapy

Introduction

In patients undergoing elective surgery, bag/facemask ventilation is generally performed after the induction of anaesthesia for pre-oxygenation. However, when an endotracheal rapid sequence intubation (RSI) for emergency surgery is needed, options for pre- and re-oxygenation are limited because of the risk of gastric insufflation leading to increased intra-gastric pressure and raised risk of pulmonary aspiration using standard bag/facemask ventilation (1-4).

Indeed, patients undergoing RSI may benefit from pre-oxygenation to increase the oxygen reservoir in the lungs to reduce intubation-related oxyhaemoglobin desaturation (5). Thus far, optimal pre-oxygenation has usually been performed using oxygen at an inspiratory oxygen fraction (FiO_2) of 1 using a facemask, which allows the extension of time for intubation up to 6 min (5, 6). Humidified nasal cannula high-flow oxygen therapy (HFNO) utilises an air oxygen blend heated and humidified through an active heated humidifier and delivered to the patient via a single limb heated inspiratory circuit (to avoid heat loss and condensation) using large-diameter nasal prongs (7). It allows FiO_2 delivery from 21% to 100% and generates up to 60 L.min^{-1} flow rates (8). Theoretically, HFNO offers significant advantages over conventional oxygen in oxygenation and ventilation. Constant high-flow oxygen delivery provides steady FiO_2 and decreases oxygen dilution (9). It washes out physiologic dead spaces and generates positive end expiration pressure that augments the functional residual capacity (FRC) and improves ventilation (10, 11). Heated humidification also facilitates secretion clearance, decreases bronchospasm and

Address for Correspondence: Andrea Cortegiani E-mail: cortegiania@gmail.com

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maintains mucosal integrity (8). Although HFNO has been used in several clinical fields, only few studies (12-14) have used HFNO as transnasal humidified rapid-insufflation ventilatory exchange (THRIVE) at 70 L min^{-1} to prolong the apnoea time in anaesthetised and paralysed patients. Therefore, we designed an efficacy and safety study on the use of HFNO during RSI by monitoring the oxygenation status and incidence of unwanted events.

Methods

This was a single-centre, observational, feasibility and safety study performed at the Policlinico Paolo Giaccone, University of Palermo, Italy, between September 2016 and June 2017. The ethics committee 'Comitato Etico Palermo 1' approved the study protocol. Patients aged >18 years who required RSI in general anaesthesia for urgent/emergency abdominal surgery and who were competent to give informed consent were recruited. Patients were excluded if they were aged <18 years; pregnant at any gestational time; affected by acute coronary syndrome or significant cardiovascular disease; had obstructive sleep apnoea syndrome (OSAS) with or without ventilator support with oro-tracheal or rapid-induction contraindications or unable to give informed consent. Informed consent was obtained from patients in the surgical ward or emergency department on the day of the surgery. All patients were subjected to modified RSI in which pre-oxygenation was performed with HFNO (Optiflow, Fisher & Paykel, New Zealand) for 4 min with a flow rate of 60 L.min^{-1} at FiO_2 1, and patients were instructed to keep the mouth closed. HFNO was continued until the endotracheal tube was secured. General anaesthesia was induced with a titrated dose of propofol (2.5 mg kg^{-1}), fentanyl (3 μg kg^{-1}) and rocuronium (1.2 mg kg^{-1}). After allowing 1 min for the rocuronium to provide an effective neuromuscular block, laryngoscopy was performed. All patients continued to receive HFNO during laryngoscopy until correct intubation was verified by the end-tidal CO_2 ($EtCO_2$) waveform. Peripheral oxygen saturation (SpO_2), heart rate (HR) and non-invasive mean arterial pressure (nMAP) were measured at baseline (T0), after 4 min on HFNO (T1) and at the time of laryngoscopy (T2) and endotracheal intubation (ETI) (T3). SpO_2 and HR were monitored using a pulse oxymeter (PM100N Nellcor™, Medtronic, USA), and $EtCO_2$ was detected using the Ultracare SLP 100 Anesthesia Monitor (SPACELABs Healthcare, USA). An SpO_2 of <3% from baseline was recorded at any sampled time. $EtCO_2$ at T3 was registered after two mechanical breaths. The apnoea time was defined as the time from the end of induction agent injection to ETI. The primary outcome was SpO_2 and its modification at the four time points (T0–T3).

An investigator not involved in the anaesthetic management recorded the pre-oxygenation time and collected the parameters of interest. Information regarding patient characteristics and comorbidity, type of surgical intervention (grade of urgency and type of surgery), modified Mallampati score, inter-incisive distance, planned airway difficulty management and STOP-BANG (15) were recorded. The number of attempts and total duration of laryngoscopy, Cormack–Lehane laryngoscopy grade and use of any rescue manoeuvre were also recorded. The presence or absence of adverse events (severe desaturation<80%, hemodynamic instability [defined as MAP<60 mmHg with a need for vasoactive agents, cardiac arrhythmias and cardiac arrest], vomits with aspiration of gastric content and intubation failure) was reported.

Statistical analysis

Data are presented as mean±standard deviation (SD). Non-normally distributed variables are expressed as median±interquartile range (IQR). Data distribution was evaluated using the Kolmogorov–Smirnov test; ANOVA test was used to compare a series of repeated measurements. When the data distribution was not normal, Friedman test was used. Statistical analysis was performed using MedCalc (MedCalc Software, Ostend, Belgium). A p (two tails) value of <0.05 was considered significant.

Results

During the study period, 49 patients were screened, of which four were excluded because of OSAS (three patients) and a lack of informed consent (one patient). Characteristics (anthropometric data, comorbidities, type of surgery, pre-operative and intra-operative airway evaluation) of the 45 patients are shown in Table 1. SpO_2, HR and MAP at any sampled time are shown in Table 2. Apnoea times are shown in Table 3. Minimal SpO_2 was 96%; no patient showed an SpO_2 of <3% from baseline. SpO_2 levels showed a statistically significant increase at T1, T2 and T3 compared with those at T0 ($p<0.05$); median SpO_2% (IQR) was 97% (range, 96%–99%) at T0, 99% (range, 99%–100%) at T1, 99% (range, 99%–100%) at T2 and 99% (range, 99%–100%) at T3. The mean $EtCO_2$ at T3 was 36.2 mmHg (SD, 4.2). Unexpected difficult intubation was observed in seven patients, but no airway rescue manoeuvres were needed in any patient. In one patient, the maximum apnoea time was 12 min because of three intubation attempts; the haemodynamic profile was stable throughout the procedure. SpO_2 at T0–T3 was 95%, 99%, 96% and 98%, respectively. $EtCO_2$ at the time of intubation was 44 mmHg.

Discussion

This study aimed to assess the efficacy and safety of using HFNO as a pre-oxygenation method in patients undergoing RSI. The main outcome was that with the use of HFNO, the minimal SpO_2 was 96%. In addition, no patient showed an SpO_2 of <3% from baseline, while the mean $EtCO_2$ at the time of ETI was 36±4 mmHg.

Our results are in contrast with those of Ang et al. (16) who recently demonstrated that the Optiflow system rapidly increases EtO_2, but the variability in the extent of de-nitroge-

Table 1. Patients' characteristics and information on anaesthesia induction

	n=45
Age, years (mean, SD)	57 (18.1)
Sex, male (%)	22 (48)
BMI, kg m^{-2} (mean, SD)	26.5 (4.3)
ASA physical status (%)	
1	1 (2)
2	15 (33)
3	27 (60)
4	2 (4)
Comorbidities (%)	
Cardiovascular	24 (53)
Respiratory	15 (33)
Gastrointestinal	18 (40)
Metabolic	16 (35)
Renal	3 (6)
Type of surgery (%)	
Upper abdomen	15 (33)
Lower abdomen	30 (67)
STOP-BANG>5 (%)	1 (2)
Cormack–Lehane grade (%)	
1	11 (24)
2	27 (60)
3	7 (16)
Modified Mallampati score (%)	
1	9 (20)
2	26 (58)
3	10 (22)
Inter-incisor gap<3 cm (%)	8 (18)
Tyromental distance<6 cm (%)	5 (11)
Grade of intubator; Trainee (%)	35 (78)
Number of attempts at laryngoscopy (%)	
<2	38 (84)
>2	7 (16)

ASA: American Society of Anesthesiology; STOP-BANG: Snoring, Tired, Observed, Pressure, Body Mass Index, Age, Neck Size, Gender; BMI: body mass index; SD: standard deviation

nation suggests that it is not a reliable alternative to facemask ventilation in pre-oxygenating patients. However, our results are in agreement with those of Mir et al. (12) who demonstrated that THRIVE is a practicable method for pre-oxygenating patients during RSI.

Table 2. SpO_2, HR and MAP at any sampled time

Time	SpO_2 median (IQR)	HR (mean, SD)	MAP (mean, SD)	$EtCO_2$ (mean, SD)
T0	97 (96-99)*	75 (14.3)	103 (12.4)	-
T1	99 (99-100)	77 (16.2)	97 (14.4)	-
T2	99 (99-100)	78 (16.2)	94 (16.7)	-
T3	99 (99-100)	79 (16.1)	83 (15.8)	36.4 (4.2)

*SpO_2 levels showed statistically significant increase at T1, T2 and T3 compared with that at baseline (T0); IQR: interquartile range; SD: standard deviation; SpO_2: transcutaneous oxygenation; HR: heart rate; MAP: mean arterial pressure; $EtCO_2$: end-tidal carbon dioxide

Table 3. Apnoea time during the procedure

Apnoea time (minute range)	Number of patients (%)
1–3	29 (64)
3–6	9 (20)
6–9	6 (13)
9–12	1 (2)

We used a continuous flow at 60 L min^{-1} instead of 70 L min^{-1} as performed by Mir et al. (12). It has been demonstrated that at 60 L min^{-1}, with the mouth closed, an HFNO was effective as 3 min oxygen by facemask at 10 L min^{-1} (17). At 70 L min^{-1}, the median (IQR [range]) EtO_2 at 180 s of pre-oxygenation was 86% (84–90 [78–92]) (16). Finally, yet importantly, in our study, the oxygen flow rate was started at 60 L min^{-1} from the beginning of pre-oxygenation. Mir et al. (12) started HFNO at 30 L min^{-1}, and the flow was increased to 70 L min^{-1} over the course of the first minute of pre-oxygenation. A lower flow rate could also theoretically affect the carbon dioxide washout (18). Nevertheless, our $EtCO_2$ values were not higher than their $PaCO_2$ values obtained after intubation.

Interestingly, one patient had an apnoea time of 720 s. Patel et al. (13) have shown that in patients with known or anticipated difficult airways, oxygenation using the THRIVE technique is associated with prolonged apnoea time before arterial oxygen desaturation. The median (IQR [range]) apnoea time was 14 min (9-19 [5-65]). No patient experienced arterial desaturation of <90%. As explained by Mir et al. (12), this fact may be related to both effective supply of oxygen and other mechanisms, such as apnoeic ventilation (19-21). In addition, during pre-oxygenation with HFNO, end expiratory lung volume and FRC increased and dead space decreased (18, 22-25).

It can be argued that $EtCO_2$ values do not reflect actual alveolar carbon dioxide values (12). However, only 33% of patients were affected by chronic respiratory diseases (26). In addition, although pH was not measured, $EtCO_2$ values in

the present study were far from those causing severe respiratory acidosis as was shown using THRIVE in patients under apnoeic oxygenation for laryngeal surgery (27).

We found a stable haemodynamic profile in our patients during RSI. It can be speculated that HFNO maintaining suitable arterial blood gases led to good haemodynamic stability.

The present study has several limitations: (1) We did not measure EtO_2. The efficacy of pre-oxygenation is dependent on the inspired O_2 concentration, duration of pre-oxygenation, alveolar ventilation and FRC and EtO_2 (16, 17). It has been argued that pre-oxygenation can be claimed to be effective only if fractional EtO_2 of >90% is achieved. However, measuring EtO_2 may have methodological issues (12, 16, 17, 28), and the concept of pre-oxygenation is not related only to a fractional ETO_2 of >90%. Measurements of pre-oxygenation have focused on EtO_2 of >90% because this is the most readily measurable, whereas a more accurate measure of the efficacy of pre-oxygenation is the arterial oxygen partial pressure. Although transcutaneous oxygen (PtO_2) was monitored in our study (14), SpO_2 assessment has been found to be at least more favourable than PtO_2 as a non-invasive method to analyse blood oxygenation (14). Additionally, we can say that SpO_2 is more important than PaO_2 regarding the effect on oxygen delivery to tissues (14). Mir et al. (12) did not report any systematic SpO_2 value during the procedure. We speculate that SpO_2 assessment shows benefits compared with the analysis of multiple arterial sampling (14), which would not be realistic in the context of RSI. (2) The study was not randomised as opposed to facemask oxygenation performed by Mir et al. (12). In fact, our results do not indicate the superiority or inferiority of HFNO over conventional modes of pre-oxygenation. Although we acknowledge this fact, our ethical committee, at the time when the study was designed, did not approve a randomised controlled trial unless an anticipated efficacy and safety study was conducted.

Conclusion

High-flow oxygen therapy seems to be safe and effective for pre-oxygenation and for maintaining oxygenation in patients receiving RSI for urgent/emergency abdominal surgery. Future randomised trials are needed to assess the range of apnoea time in different patient populations (12).

Ethics Committee Approval: Ethics committee approval was received for this study from the Ethics Committee of the University of Palermo.

Informed Consent: Written informed consent was obtained from patients who participated in this study.

Peer-review: Externally peer-reviewed.

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