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Pre-oxygenation in obese patients: facemask versus facemask with nasal prong

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Abstract

Introduction: Anatomical and physiological changes of the respiratory system in obese patients predispose them to rapid oxygen desaturation during apnoea. Adequate pre-oxygenation before anaesthesia induction allows a period of safe apnoea. The efficacy of pre-oxygenation with facemask versus facemask with nasal prong was compared. The time taken for expired end-tidal oxygen (F_EO_2) to reach 0.8 ($T_{0.8}$) from commencement of pre-oxygenation (T_0), and time to oxygen desaturation to 95% ($T_{95\%}$), following apnea (T_A) was studied.

Methods: This prospective, randomised study recruited 36 surgical patients of body mass index (BMI) ≥ 30 kg/m^2 requiring general anaesthesia with endotracheal intubation. They were randomised to receive pre-oxygenation with oxygen facemask at 12 L/min, or concurrent pre-oxygenation with facemask at 7 L/min and nasal prong at 5 L/min. Oxygen saturation (SpO_2) and F_EO_2 were recorded at T_0, $T_{0.8}$, and at T_A following completion of rocuronium administration. Oxygen was then discontinued, and the patient left apnoeic with no ventilation. Intubation was performed 60 seconds after T_A, and the patient left apnoeic with the endotracheal tube exposed to room air. Duration from T_A until the patient's SpO_2 reached 95 % ($T_{95\%}$) was documented.

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Results: Pre-oxygenation with facemask and nasal prong resulted in a shorter $T_{0.8}$ compared to facemask alone (48.61 s ± 23.3 versus 77.72 s ± 26.15), $p = 0.001$. There was no difference in $T_{95\%}$ between the groups.

Conclusion: Pre-oxygenation with facemask plus nasal prong resulted in a shorter time taken to reach F_EO_2 0.8, but with comparable time to oxygen desaturation between both groups.

Keywords: apnoea, general anaesthesia, nasal cannula, obesity, oxygen

Introduction

Obesity is associated with a higher incidence of difficult bag-mask ventilation and intubation, compounded by a shorter safe apnoea time.[1-3] The safe apnoea time is the duration following cessation of breathing, until the point when oxygen saturation (SpO_2) reaches 90%.[4-7] An SpO_2 of 90% marks the upper inflection point of the oxyhaemoglobin dissociation curve. Any further reduction in SpO_2 will result in rapid oxygen desaturation.[4-7] Rapid oxygen desaturation during hypoventilation or apnoea in the obese patient is contributed by the combination of reduced functional residual capacity, increased oxygen consumption, and a potentially difficult airway.[1-3] Pre-oxygenation before anaesthesia induction creates an alveolar oxygen reservoir, leaving adequate safe apnoea time while awaiting the onset of muscle relaxant and during intubation attempts.[8,9] In a patient of normal weight, oxygen moves from alveolus into bloodstream at 250 ml/min, but in the obese patient, resting metabolic oxygen consumption increases up to 5-fold ,leaving a shorter safe apnoea time.[10-13]

Jense *et al.* found a negative linear relationship between the safe apnoea time and increasing obesity, where mean time to SpO_2 90% in patients of normal weight was 6.06 minutes, compared to 2.72 minutes in morbidly obese patients.[6] Ramachandran *et al.* compared pre-oxygenation via oxygen facemask at 12 to 15 L/min, versus via facemask plus nasal cannula through which oxygen was delivered at 5 L/min. Following anaesthesia induction, these male patients with body mass indices (BMI) ranging from 30 to 35 kg/m^2 were left apnoeic, where the control group received no oxygen and the study group continued to receive nasal oxygen at 5 L/min. The latter group maintained $SpO_2 \geq 95\%$ for a longer duration during simulated difficult laryngoscopy.[7]

Most studies continued oxygenation via nasal prong during apnoea.[7,8] We ceased oxygenation during apnoea with the aim of assessing the efficacy of 2 pre-oxygenation techniques by measuring the time taken for expired end-tidal O_2 (F_EO_2) to reach 0.8, and time to oxygen desaturation to SpO_2 95%.

Methods

This was a prospective, randomised study which was conducted following approval from the Dissertation Committee and the Medical Research and Ethics Committee. Thirty-six patients aged ≥ 18 years, with BMI ≥ 30 kg/m^2, of American Society of Anesthesiologists (ASA) class I and II, for elective surgery under general anaesthesia requiring endotracheal intubation, were recruited after obtaining informed consent. Excluded were patients who were smokers, pregnant, patients with significant respiratory or cardiac pathology, anticipated difficult airway, and nasal obstruction. Additional information including the STOP-BANG score (Appendix)[14] and apnoea-hypopnoea index, if available were documented.

Patients were randomised by means of computer-generated randomisation table into 2 groups: Group F patients were pre-oxygenated with facemask and Group FN patients were pre-oxygenated with facemask and nasal prong. Patients were fasted for at least 6 hours and pre-medicated with acid aspiration prophylaxis as per institution's protocol.

In the operating room, standard monitoring included non-invasive blood pressure, electrocardiograph, pulse oximetry, and capnography. Baseline haemodynamic parameters and SpO_2 were documented. The general anaesthesia machine with the circle breathing circuit was checked to ensure no leakage at a minimal flow of 0.3 L/min. The patient was placed in the ramped position, so that the external auditory meatus and sternal notch were horizontally aligned to achieve optimal intubating conditions.[1,2]

Perioperative airway management was performed by anaesthesia trainees with more than 3 years of experience in anaesthesia and familiar with the video laryngoscope (C-MAC®, Karl Storz SE & Co. KG, Tuttlingen, Germany). All patients were propped 30° head up and pre-oxygenated for at least 3 minutes. Group F patients were pre-oxygenated via facemask with 100% oxygen delivered at 12 L/min. Group FN patients were given 100% oxygen delivered at 7 L/min via facemask with concurrent nasal prong oxygen flow of 5 L/min. Hence, both groups received a total oxygen flow of 12 L/min. An F_EO_2 of 0.8, which indicated adequate pre-oxygenation was targeted, as this value corresponded to 90% lung denitrogenation.[15] Once an

F_EO_2 of 0.8 was achieved, induction of anaesthesia proceeded with intravenous (IV) fentanyl 2 µg/kg, and IV propofol 2 mg/kg of total body weight. Upon the patient losing consciousness, cricoid pressure was applied by the assisting nurse, followed by the administration of IV rocuronium 1.2 mg/kg of the adjusted body weight. Following rocuronium, all patients were left apnoeic with no manual ventilation prior to tracheal intubation. During this apnoeic period before laryngoscopy, oxygen was ceased via facemask and nasal prong in both groups. Oxygen saturation was continuously monitored, and anaesthesia maintained with propofol delivered via the target-controlled infusion (TCI) device (Fresenius Kabi Injectomat TIVA Agilia®, Germany), using the Marsh Model, at target plasma concentration ranging from 3 to 6 µg/ml.

All study time points were recorded using a stopwatch. Time zero (T_0) was taken as the time of initiation of pre-oxygenation, $T_{0.8}$ when F_EO_2 0.8 was achieved, and time apnoea (T_A) commenced at completion of rocuronium administration. Laryngoscopy with the video laryngoscope (C-MAC) was performed 60 seconds after T_A. Both groups received no oxygen during laryngoscopy. Patients with Cormack–Lehane III or IV views were dropped out from the study and subsequent airway management followed the institution's protocol. External laryngeal manipulation and the use of airway adjuncts, such as the endotracheal tube (ETT) stylet and gum elastic bougie, were allowed during the first intubation attempt. Following intubation, the patient was left apnoeic with the proximal end of the ETT exposed to room air. Once the patient's SpO_2 reached 95% ($T_{95\%}$), the ETT was connected to the breathing circuit and 100% oxygen was delivered via positive pressure ventilation. The patient was subsequently managed as per standard anaesthesia.

Patients in whom SpO_2 reached 95% before laryngoscopy, $T_{95\%}$ was taken at that point and manual ventilation with 100% oxygen was resumed. These patients were included in the study. In the event of difficult or failed intubation at the first attempt, subsequent management followed the difficult intubation protocol and the patient was dropped out from the study.

Sample size calculation was carried out with alpha value set at 0.05 and power of study at 95%. Based on a study conducted in 2010 by Ramachandran *et al.*,[7] the addition of nasal oxygen during apnoeic oxygenation maintained $SpO_2 \geq 95\%$ for a longer duration of 5.29 ± 1.2 minutes versus 3.49 ± 1.33 minutes.[7] The sample size calculated using the 'Power and Sample Size Calculations', was 15 for each arm. Taking into account a 20% drop out rate, the total sample size calculated was 36.

Data were analysed using the SPSS software (22.0, IBM Corp, Chicago, IL, USA). Continuous data that was normally distributed was analysed using the independent *t*-test, and the Mann-Whitney U test was used to analyse continuous data that were

not normally distributed. Chi-square test/Fisher's exact test was used for categorical data. A *p* value less than 0.05 was considered statistically significant.

Results

A total of 36 patients were enrolled, of which one was dropped out due to difficult intubation. There was no statistical difference between the groups in patient demography or type of surgery (Table 1). Mean BMI was comparable between Group F (37.34 kg/m^2 ± 5.79) and Group FN (36.18 kg/m^2 ± 4.55), p = 0.509. Similarly, the number of patients in Obese Class I, II, and III, and STOP-BANG scores were not significantly different between the groups (Table 2).

Haemodynamic parameters were comparable between the groups. Table 3 depicts respiratory parameters where no difference was observed in baseline SpO_2 and F_EO_2, and SpO_2 at F_EO_2 0.8. All patients achieved F_EO_2 of 0.8, and the mean time taken for F_EO_2 to reach 0.8 was faster in Group FN, p = 0.001. The time to oxygen desaturation to SpO_2 95% was longer in Group FN than Group F, but not statistically significant, p = 0.052.

Table 1. Patient demography and type of surgery

Variable	**Group F (n = 18)**	**Group FN (n = 18)**	**p < 0.05**
Age (years)	47.3 ± 11.4	43.3 ± 15.3	0.094
Gender			
Male	3 (16.7)	7 (38.9)	0.137
Female	15 (83.3)	11 (61.1)	
Types of surgery			
Upper gastrointestinal	4 (22.2)	5 (27.8)	0.073
Hepatobiliary	4 (22.2)	2 (11.1)	
Colorectal	0 (0)	2 (11.1)	
Ear, nose, throat	1 (5.6)	4 (22.2)	
Endocrine & breast	3 (16.7)	0 (0)	
Orthopaedic	2 (11.1)	3 (16.7)	
Urology	1 (5.6)	2 (11.1)	
Neurology	1 (5.6)	0 (0)	
Gynaecology	2 (11.1)	0 (0)	

Values are shown as mean ± standard deviation and number (percentage) where appropriate. Continuous data was analysed using the independent *t*-test. The Chi-square test/Fisher's exact test was used for categorical data. p <0.05 was considered statistically significant.

Table 2. Patient body mass index class and STOP-BANG score

Variable	Group F (*n* = 18)	Group FN (*n* = 18)	*p*–value
Obesity classification*			
Class I	7 (38.9)	8 (44.4)	
Class II	5 (27.8)	6 (33.3)	0.756
Class III	6 (33.3)	4 (22.2)	
STOP-BANG score			
2	10 (55.6)	5 (27.8)	
3	2 (11.1)	5 (27.8)	
4	4 (22.2)	4 (22.2)	0.329
5	2 (11.1)	3 (16.7)	
7	0 (0)	1 (5.6)	

Values are shown as number (percentage) where appropriate. $p < 0.05$ was considered statistically significant.
*****Obesity Class I: body mass index (BMI) 30–34.9 kg/m^2; Class II: BMI 35–39.9 kg/m^2; Class III: BMI > 40 kg/m^2

Table 3: Perioperative respiratory parameters

Respiratory parameter	Group F (*n* = 18)	Group FN (*n* = 17)	*p*–value
SpO_2 at T_0 (%)	96.56 ± 1.58	96.44 ± 1.79	0.845
SpO_2 at $T_{0.8}$ (%)	99.94 ± 0.24	100 ± 0.00	0.324
F_EO_2 at T_0	0.38 ± 0.15	0.34 ± 0.11	0.375
$T_{0.8}$ (s)	77.72 ± 26.15	48.61 ± 23.30	0.001†
$T_{95\%}$ (s)	185.89 ± 80.36	237.41 ± 70.16	0.052

Values are expressed as mean ± standard deviation. Continuous data was analysed using the independent *t*-test. † p <0.05 was considered statistically significant.

Discussion

In this study, all patients achieved F_EO_2 of 0.8, and the efficacy of pre-oxygenation improved with the addition of the nasal prong to conventional mask oxygenation, based on the faster achievement of F_EO_2 0.8 with mean time of 48.61 ± 23.30 seconds. The difference in $T_{0.8}$ was significant between the groups despite both groups receiving the same total oxygen flow of 12 L/min. Ramachandran *et al.* demonstrated no difference in end-tidal O_2 (ETO_2) achieved between obese patients pre-oxygenated with facemask versus facemask and nasal prong, with end-tide O_2 of 88.7 mmHg and 88.3 mmHg, respectively.[7] In contrast, Russell *et al.* found

that the addition of nasal prong to standard facemask pre-oxygenation amongst normal-weight patients significantly increased ETO_2 values compared to solely facemask pre-oxygenation with simulated mask leak (which accounted for any leak that may be contributed by placement of the nasal prong), with mean ETO_2 of 85.8 mmHg and 74.7 mmHg, respectively, $p < 0.001$.[16] However, there was no documentation on the time taken to achieve F_EO_2 0.8.

Ramachandran *et al.* postulated that nasal oxygen administration may have its role in enhancing nasal patency, therefore improving oxygen delivery to the pharynx.[7] Furthermore, the addition of nasal prong oxygenation has been shown to improve the flushing of exhaled carbon dioxide from the mask, thus reducing rebreathing.[7,16,17] These factors may contribute to higher inspired oxygen fractions.[7,16,17] We chose to administer 5 L/min oxygen via nasal prong because the use of higher oxygen flows via the conventional nasal prong in a conscious subject may cause discomfort as no humidification is provided. Previous studies have shown that a concurrent nasal cannula flow of 5 L/min sufficed to prolong the safe apnoea time.[7,18] We found that the duration of $SpO_2 \geq 95\%$ was comparable between the groups, $p = 0.052$. In contrast, Baraka *et al.* found that pre-oxygenation in morbidly obese patients, which was not maintained further with nasopharyngeal oxygen insufflations via a catheter during apnoea, resulted in earlier oxygen desaturation.[8] Hamp *et al.* found no differences in the duration of $SpO_2 \geq 95\%$ and arterial blood gases of morbidly obese patients administered oxygen at 10 L/min via standard nasal prongs, compared to patients administered oxygen at 120 L/min via high-flow nasal cannula during laryngoscopy.[19] The patients in our study administered simultaneous pre-oxygenation via facemask and nasal prong may have gained the benefit of both, hastened achievement of F_EO_2 0.8, and increased duration of $SpO_2 \geq 95\%$ if the duration of oxygenation via nasal prong was extended into the apnoeic phase.

Facemask in addition to simultaneous nasal prong oxygenation theoretically may incur some degree of mask leak, thus preventing proper oxygenation. However, Hayes-Bradley *et al.* found that simultaneous oxygenation via nasal cannula and a non-rebreather mask improved pre-oxygenation compared to facemask with simulated leak.[20] We did not take measures to simulate mask leak in the control group, but despite that, Group FN with leak achieved the targeted F_EO_2 0.8 at a faster rate.

The hastened achievement of F_EO_2 0.8 in our study has an important impact when applying rapid sequence induction of anaesthesia in selected situations, for example, in obstetric emergencies with foetal compromise. Nasal prong oxygenation extended into the apnoeic period may have prolonged the duration of $SpO_2 \geq 95\%$. Findings of previous works and recent modelling comparing low-flow with high-flow nasal oxygen in simulated term pregnant women suggests that facemask preoxygen-

ation, with low-flow or high-flow nasal oxygen during the apnoeic period prolonged the safe apnoea period.[21] Low-flow compared with high-flow nasal oxygen is readily available and may be easier combined with facemask preoxygenation.

One limitation of our study was the fact that SpO_2 readings may lag behind actual arterial oxygen tension. The latter could have been easily obtained via arterial blood gases and allowed us to compare pulse oximetry readings against arterial oxygen partial pressure. Secondly, our subjects were obese patients with stable cardiorespiratory status. Our results cannot be safely extrapolated to obese patients who are a population at risk for cardiorespiratory dysfunction.

Conclusion

This study concluded that simultaneous facemask and nasal prong pre-oxygenation in obese patients facilitated oxygenation but did not prolong the safe apnoea time.

Declarations

Ethics approval and informed consent
This study involving human participants, materials, and/or data has been performed in accordance with the Declaration of Helsinki. The study was conducted following approval from the Dissertation Committee of the Department of Anaesthesiology and Intensive Care Universiti Kebangsaan Malaysia Medical Centre (UKMMC), and the UKMMC Medical Research and Ethics Committee (UKM FPR.4/244/FF-2017-463). A total of 36 patients were recruited into the study after obtaining informed consent.

Competing interests
Dr. Muhammad Maaya and Dr. Rufinah Teo serve as Section Editors in Malaysian Journal of Anaesthesiology. Neither has been involved in any part of the publication process prior to manuscript acceptance; peer review for this journal is double blind. The remaining authors have no competing interests to declare.

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Appendix

STOP-BANG Scoring

STOP-BANG	**Yes**	**No**
Snoring Do you snore loudly (louder than talking or loud enough to be heard through closed doors)?		
Tired Do you often feel tired, fatigued or sleepy during daytime?		
Observed Has anyone observed you stop breathing during your sleep?		
Blood Pressure Do you have or are you being treated for high blood pressure?		
BMI Is your BMI more than 35 kg/m^2		
Age Is your age over 50 years old?		
Neck Circumference Is your neck circumference greater than 40 cm?		
Gender Is your gender male?		
High risk of sleep apnoea if YES answered to 3 or more questions Lower risk of sleep apnoea if YES answered to less than 3 questions		

Table reproduced from Chung *et al.*[14]