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CAUSES OF SUBOPTIMAL PREOXYGENATION BEFORE TRACHEAL INTUBATION IN ELECTIVE AND EMERGENCY ABDOMINAL SURGERY

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Optimal preoxygenation (PO) prior to tracheal intubation reduces the risk of arterial desaturation and prolongs the period of safe apnoea. The common methods of PO are mask ventilation with 100% O_2 for 3–5 minutes or, alternatively, asking the patient to take eight deep breaths in a minute. Our study group conducted a prospective study to assess the impact of the most common risk factors on PO and to compare the efficiency of PO in patients undergoing elective and emergency abdominal surgery without premedication. PO was performed using mask ventilation with 6 l/min of 100% oxygen for 5 minutes. End-tidal oxygen (EtO_2) was documented in 30-second increments. We found that optimal PO ($EtO_2 > 90\%$) was not achieved by almost half of the patients (46%) and that this was more common in the elective surgery group. Effective PO was not impacted by any of the evaluated risk factors for suboptimal oxygenation. Despite these findings, we believe that the identification of potential risk factors is crucial in the pre-anaesthesia stage, given the benefits of optimal PO.

Keywords: *general anaesthesia, end-tidal oxygen, EtO_2.*

INTRODUCTION

Preoxygenation (PO) is performed prior to tracheal intubation in order to prolong the period of safe apnoea without hypoxia by increasing pulmonary oxygen reserves. Prolonged apnoea leads to arterial oxyhaemoglobin desaturation, especially in patients with reduced functional residual capacity (FRC), such as obese or pregnant patients, and those with increased oxygen consumption (Baillard *et al.*, 2014). This increases the risk of arrhythmias, haemodynamic decompensation, hypoxic brain injury, and even death (Cook and MacDougall-Davis, 2012). PO may prove crucial in cases of unsuccessful intubation, or when manual ventilation is unwanted, e.g., rapid sequence induction and intubation before emergency surgery.

The standard methods of PO are mask ventilation with 100% O_2 for 3–5 minutes (Bouroche and Bourgain, 2015), or, alternatively, asking the patient to take eight deep breaths in a minute (Baraka *et al.*, 1999; Tanoubi *et al.*, 2009). The latter method is not optimal for obese patients or patients who are unable to take deep breaths. PO is considered optimal when the end-tidal oxygen fraction (EtO_2) reaches 90% (Bhatia *et al.*, 1997; Kang *et al.*, 2010; Baillard *et al.*, 2014). This results in an oxygen reserve of around 2000 ml in adults (Sirian and Wills, 2009; Nimmagadda *et al.*, 2017).

PO may fail due to a variety of factors that impede mask ventilation, such as lack of teeth, the presence of facial hair, obesity, snoring, and a small mouth (Baillard *et al.*, 2014;

Akbudak and Mete, 2018). It may also be affected by additional factors, such as comorbidities, hypercatabolic states due to acute illness, and increased tissue oxygen use (Bouroche and Bourgain, 2015). PO in patients undergoing emergency surgery may be further complicated by the severity of their condition, which may cause sluggishness and pain, among other difficulties (Weingart and Levitan, 2012). An important factor in achieving optimal PO is avoiding oxygen leaks, which can be avoided by using a mask of adequate size and fit (Sakalauskaitė *et al.*, 2019).

We hypothesise that risk factors for suboptimal PO negatively impact the success-rate of optimal PO using the aforementioned standard methods of PO, and that emergency surgery has an additional negative impact on PO.

The goal of our study was to evaluate the influence of the most commonly reported risk factors of suboptimal PO and the effectiveness of PO in patients undergoing elective and emergency surgery. These findings could help anaesthesiologists provide better care in their day-to-day practice – knowledge of common risk factors for suboptimal PO could help clinicians identify patients at risk for suboptimal PO if using standard methods, and to make the necessary preparations in advance. Furthermore, if emergency surgeries prove to be a risk factor for suboptimal PO, further measures could be used to prepare for these cases in advance to provide successful preoxygenation.

MATERIALS AND METHODS

A prospective study was conducted at Vilnius University Hospital Santaros Klinikos after approval by the regional bioethics committee (ref. nr. 2019/5-1028-622). Written informed consent was obtained from all study participants. The study was registered on ClinicalTrials.gov (ID - NCT04070404).

Adult patients undergoing general anaesthesia for elective or emergency abdominal surgery who were able to give informed consent were included in the study. Exclusion criteria were not having enough time to inform the patient prior to operation, not obtaining informed consent, or the patient withdrawing their consent at any point before or after the operation. Demographic data, lists of comorbidities, risk factors for suboptimal PO (lack of teeth, no teeth, facial hair, small mouth, obesity, snoring) and vital parameters (pulse oximetry, mean arterial pressure, etc.) were collected prospectively. None of the patients received premedication prior to surgery. PO was performed in the reverse Trendelenburg position (25^o upwards tilt), using the standard method of mask ventilation with 6 l/min of 100% oxygen for 5 minutes. All patients were preoxygenated by the same physician, using the same type of mask in sizing appropriate for the individual. EtO_2 was documented in 30-second increments for 5 minutes. PO was considered optimal when EtO_2 values of 90% or more were achieved within 5 minutes. Failure to reach this was considered as suboptimal PO. Statistical analysis was performed with IBM SPSS Statistics v.28.0. Patient data was analysed by comparing the optimal and suboptimal PO patient groups. Baseline characteristics were defined using descriptive statistics. Continuous variables were represented as a mean ± SD and minimum and maximum values. The normality of distributions was tested by the one sample Shapiro–Wilk test. Categorical variables were given as absolute number (n) and relative frequency (%). The Chi-square test was performed to compare categorical variables,. To compare the continuous variables, the independent samples-t test was used for normally distributed and Mann–Whitney test for non-parametric data. Cramer's V test was used to test for association between categorical variables. The results were considered statistically significant if the *p* value was lower than 0.05.

RESULTS

Thirty-seven patients consented to participation in the trial during the study period and were included in the study, of which 19 (51%) were female and 18 (49%) were male (Table 1). The average age of the patients was 58 ± 20 years. Mean BMI was 27.6 ± 4.6 kg/m^2. Emergency surgery was performed on 18 patients, and 19 patients underwent elective surgery. Twenty patients (54%) achieved optimal PO, with $EtO_2 \geq 90\%$.

Seventeen participants (46%) did not receive optimal PO. There were more patients in the elective surgery group who did not achieve $EtO_2 \geq 90\%$ (63% vs. 27.7% in the emergency surgery group, Phi = –0.355, $p = 0.031$). In the optimal PO group, the mean time to $EtO_2 \geq 90\%$ was 196 ± 64 s and did not differ significantly between emergency and elective surgery patients (180 ± 66 s and 226 ± 51 s, respectively, $p = 0.345$).

The success of PO did not depend on age or BMI (p = 0.179; 0.681, respectively), nor on higher Mallampati or ASA scores (p = 0.574; 0.396). The number of factors known to hinder PO did not differ significantly between the groups ($p = 0.987$). No single risk factor was more prevalent in the group of suboptimally preoxygenated patients compared to the optimal PO group (Table 2).

Figure 1 shows the changes of EtO_2 over time in the optimal and suboptimal PO groups. EtO_2 in the optimal PO group exceeded 90% within 5 minutes, while the average EtO_2 value in the suboptimal group reached a plateau at 76%. Within 90 s, the optimal PO group reached roughly the same EtO_2 level as that of the suboptimal group in 5 minutes. The mean EtO_2 values were significantly higher in the optimal PO group at each 30-second increment ($p <$ 0.05) (Fig. 1).

DISCUSSION

A common cause of suboptimal preoxygenation is leakage under the face mask, which leads to mixing of surrounding

Table 1. Comparison of optimal and suboptimal preoxygenation patient groups

		Optimal PO	Suboptimal PO	*p*
Sex, n (%)	Male	7 (18.9)	11 (29.7)	0.072
	Female	13 (35.1)	6 (16.2)	
Age (years)		53.4 ± 20.9 [19; 86]	63.1 ± 18.8 [31; 88]	0.179
BMI (kg/m^2)		27.3 ± 4.6 [19.4; 35.5]	27.9 ± 4.8 [21.3; 37.9]	0.681
ASA, n (%)	1	5 (13.5)	2 (5.4)	0.473
	2	8 (21.6)	7 (18.9)	
	3	4 (10.8)	6 (16.2)	
	4	3 (8.1)	1 (2.7)	
	5	0 (0.0)	1 (2.7)	
Mallampati, n (%)	1	12 (32.4)	9 (24.3)	0.533
	2	8 (21.6)	7 (18.9)	
	3	0 (0.0)	1 (2.7)	
MAP (mmHg)		100.7 ± 16.4 [70; 131]	97.9 ± 16.6 [52; 115]	0.608
SpO_2 before PO (%)		97.7 ± 2.2 [93; 100]	95.8 ± 3.8 [87; 100]	0.168
Respiratory comorbidities,n (%)		1 (2.7)	3 (8.1)	0.217
Urgency of surgery, n (%)	Elective	7 (18.9)	12 (32.4)	0.031
	Emergency	13 (35.1)	5 (13.5)	

BMI, body mass index; ASA, American Society of Anaesthesiologists' physical status classification system; E, emergency surgery; MAP, mean arterial blood pressure; SpO_2, blood oxygen saturation; PO, preoxygenation; EtO_2, end-tidal oxygen.

Table 2. Comparison of individual risk factors for poor preoxygenation between the study groups

	Optimal preoxygenation group (n)	Suboptimal preoxygenation group (n)	*p*
Small mouth	1	0	0.350
Beard	3	2	0.774
Missing teeth	6	4	0.659
No teeth	2	3	0.498
Snoring	1	0	0.350
Obesity	6	3	0.383

air and pure oxygen, reducing the fraction of inhaled oxygen (Benumof, 1999). The negative impact of air leaks is not offset by prolonged PO and should be prevented or identified in good time. Even in patients with normal dental status and normal facial anatomy, mask leaks have been reported in up to 11.5% of cases (Machlin *et al.*, 1993). They may be even more frequent in cases where the mask does not fit properly or when orofacial variations (e.g., inappropriate mask size, presence of a beard, lack of teeth, facial anomalies, burns, or a nasogastric tube) are present and

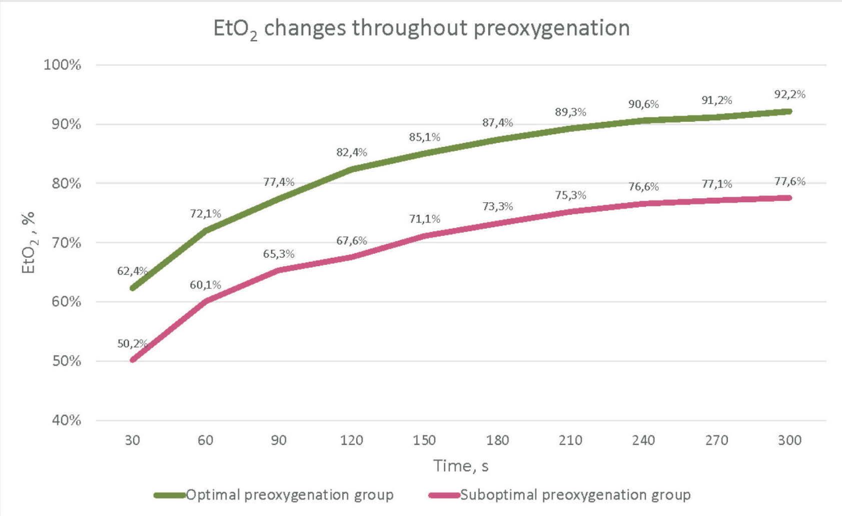

Fig. 1. Average EtO_2 values during preoxygenation in optimal and suboptimal preoxygenation groups.

compromise the seal (Bouroche and Bourgain, 2015). Leaks may be suspected if EtO_2 plateaus in the 50–80% range (Hanouz *et al*., 2018). A number of other factors leading to suboptimal PO, such as a low fresh gas flow of oxygen and insufficient PO time, have also been identified and should be accounted for (Nimmagadda *et al*., 2001; Hanouz *et al*., 2018).

PO may prove to be difficult or impossible if the patient is uncooperative or very anxious. Anxiety might be a factor that contributed to more effective PO of emergency surgery patients in our study, as it impacts the respiratory rate and often leads to hyperventilation (Gardner, 1996). Other patient-related risk factors that require special attention are pregnancy, obesity (due to increased abdominal pressure) and rapid sequence induction (Azam Danish, 2021).

PO may be aided by placing the patient in the reverse Trendelenburg position (15 to 30 degrees head-up), using pressure support ventilation and/or positive end-expiratory pressure. This is especially useful during PO of obese patients (De Jong *et al*., 2014; Xu *et al*., 2018).

Our study results are in line with previously published data showing rates of suboptimal PO in as many as 56% of cases (Bouroche and Bourgain, 2015). None of the individual patient factors recorded during our study (gender, old age, missing teeth, beardedness, and higher ASA scores, obesity, among others) were more prevalent among those who did not receive optimal PO. They have, however, been implicated as independent risk factors for suboptimal PO in previously published literature (Baillard *et al*., 2014). As the benefits of optimal PO in lowering the risk of life-threatening complications cannot be understated, we recommend that they should be taken into consideration during pre-anaesthesia evaluation.

In this study, EtO_2 values were significantly higher in the optimal PO group even at the earliest stages of the procedure. Within 90 seconds, the optimal PO group had achieved the same EtO_2 values as the suboptimal PO group did during the entire 5 minutes. Therefore, the speed at which EtO_2 rises during the early stages of PO may be a good indicator of its success. This is especially important, considering that PO using the alternative technique of eight deep breaths usually lasts approximately 60 to 90 seconds. Based on these observations, we suggest that, in cases where EtO_2 fails to reach 70% within 60 seconds, leaks or other procedural mistakes should be controlled for. This is, however, an empirical observation and further studies to confirm its validity are needed.

The limitation of our study was a small sample size. In order to achieve more accurate results and provide a clearer view of why emergency surgery seems to have lower risk of suboptimal PO, the number of patients enrolled in the study should be higher. While we show that suboptimal PO is exceedingly common in daily practice, identification of the most adequate methods to ensure optimal PO is beyond the scope of our study.

CONCLUSIONS

Almost half of the patients in this study did not achieve optimal preoxygenation and, surprisingly, this was more common in elective surgery patients. None of the evaluated risk factors for suboptimal preoxygenation were more prominent in patients who did not receive optimal preoxygenation. Despite these findings, we believe that the identification of potential risk factors in the pre-anaesthesia stage and following standardised preoxygenation procedures is crucial given the benefits of optimal preoxygenation.

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SUBOPTIMĀLAS PREOKSIGENĀCIJAS CĒLOŅI PIRMS TRAHEJAS INTUBĀCIJAS PLĀNVEIDA UN NEATLIEKAMĀ VĒDERA DOBUMA ORGĀNU ĶIRURĢIJĀ

Optimāla preoksigenācija (PO) pirms trahejas intubācijas veikšanas samazina arteriālās desaturācijas risku un pagarina drošas apnojas periodu. Izplatītākās PO metodes ir maskas ventilācija ar 100% O_2 3–5 l/min vai, alternatīvi, lūgums pacientam veikt astoņas dziļas elpas vienā minūtē. Tika veikts perspektīvs pētījums, lai novērtētu izplatītāko riska faktoru ietekmi uz PO un salīdzinātu PO efektivitāti pacientiem, kuriem tiek veikta plānveida un ārkārtas vēdera dobuma operācija bez premedikācijas. PO tika veikta, izmantojot maskas ventilāciju ar 6 l/min 100% skābekļa 5 minūtes ilgi. EtO_2 tika dokumentēts ik 30 sekundes. Mēs noskaidrojām, ka gandrīz puse pacientu (46%) nesasniedza optimālu PO (EtO_2 90%) un ka tas bija biežāk plānveida ķirurģisko pacientu grupā. Efektīvu PO neietekmēja neviens no novērtētajiem suboptimālās skābekļa padeves riska faktoriem. Neskatoties uz šiem novērojumiem, mēs uzskatām, ka potenciālo riska faktoru identificēšana ir ļoti svarīga pirmsanestēzijas stadijā, ņemot vērā optimālās PO priekšrocības.