Clinical Investigation

Techniques of preoxygenation in patients with ineffective face mask seal

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ABSTRACT

Background: Ineffective face mask seal is the most common cause for suboptimal pre-oxygenation. Room air entrainment can be more with vital capacity (VC) breaths when the mask is not a tight fit. **Aims:** This study was designed to compare 5 min tidal volume (TV) breathing and eight VC breaths in patients with ineffective face mask seal. **Methods:** Twenty eight ASA I adults with ineffective face mask seal were randomized to breathe 100% oxygen at normal TV for 5 min (Group TV) and eight VC breaths (Group VC) in a cross over manner through circle system at 10 L/min. End tidal oxygen concentration (EtO_2) and arterial blood gas analysis was performed to evaluate oxygenation with each technique. **Statistical Analysis:** Data were analysed using SPSS statistical software, version 16. Friedman's two-way analysis of variance by ranks was used for non-parametric data. **Results:** Significant increase in EtO_2 (median 90) and PaO_2 (228.85) was seen in group TV when compared to group VC (EtO_2 median 85, PaO_2 147.65), $P<0.05$. Mean total ventilation volume in 1 min in group VC was 9.4±3.3 L/min and more than fresh gas flow (10 L/min) in seven patients. In group TV, the fresh gas flow (50 L/5 min) was sufficient at normal TV (mean total ventilation in 5 min 36.7±6.3 L/min). **Conclusions:** TV breathing for 5 min provides better pre-oxygenation in patients with ineffective mask seal with fresh gas flow of 10 L/min delivered through a circle system.

Key words: Face mask, pre-oxygenation, tidal volume, vital capacity

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INTRODUCTION

Pre-oxygenation techniques require a tightly fitting face mask, and do not account for the leaks that occur frequently in practice.[1-3] Leaks have been reported in 10-11.5% of subjects with no facial anomalies and normal dentition.[4] Leak around the mask is expected more frequently during pre-oxygenation of patients who are edentulous, have beards or moustaches, have a nasogastric tube in place, or cooperate poorly. The commonest reason for not achieving a maximum alveolar oxygen concentration during pre-oxygenation is an ineffective face mask seal which causes a leak that allows air entrainment into the circuit and dilutes the oxygen present.[5-7]

The techniques used commonly for pre-oxygenation are breathing of 100% O_2 at normal tidal volume (TV) for 3-5 min[6] and eight vital capacity (VC) breaths in 1 min.[5,6,8,9] Both techniques are equally effective.[6,8] However, in conditions where a leak around the face mask is unavoidable, both TV and eight deep breaths techniques have yielded suboptimal pre-oxygenation.[3,5,7]

We hypothesise that in the absence of a good face mask seal, the fresh gas flow might not be sufficient to meet the peak inspiratory flow generated during VC breaths of the patient. Consequently, room air is entrained to meet the patient's demand resulting in dilution of the inspired O_2 concentration. On the other hand, when breathing at normal TV the delivered fresh gas flows are sufficient to meet the minute volume requirements with lesser dilution of inspired O_2.

This study was designed to compare the efficacy of these two techniques of pre-oxygenation in patients with an ineffective face mask seal.

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METHODS

This study was conducted in a selected population of 28 ASA status I adults of either sex scheduled for elective major surgery. After obtaining informed consent, patients with anticipated difficult mask ventilation in whom maintaining a satisfactory face mask seal was not possible (presence of beard, nasogastric tube, large nasal bridge, facial anomalies and lack of teeth, but normal airway) were recruited, whereas those with pre-existing respiratory/cardiac diseases, anticipated difficult airway, pregnancy, body weight beyond the 30% range of ideal body weight and uncooperative patients were excluded from the study.

All patients were pre-medicated with oral Tab. Diazepam 0.2 mg/kg, Tab. Famotidine 20 mg, and Tab. Metoclopramide 10 mg the night before and on the morning of the surgery. In addition, intramuscular Morphine 0.15 mg/kg was given half an hour before the surgery. In the operating theatre, baseline electrocardiogram, heart rate, mean arterial pressure, and hemoglobin oxygen saturation (SpO_2) were recorded using Datex-Ohmeda S/5 compact anaesthesia monitor (Datex-Ohmeda Inc., 3 Highland Derive, Tewskbury, MA 1876). After performing Allen's test a 20 gauge arterial cannula was secured under local anaesthesia to obtain multiple arterial samples for recording arterial blood gases during the course of the study.

The study was conducted as a cross over design after taking the institutional ethics committee approval. Written informed consent was taken from all patients recruited for the study. The patients were randomly assigned to receive pre-oxygenation by two techniques. A sealed envelope method was used to decide the order of pre-oxygenation technique. Patients assigned to TV group (Group TV) were instructed to breathe at normal TV for 5 min through a tightly held mask. A 10 min stabilization period was allowed with room air breathing to allow the PaO2 to come back to baseline value before crossing over to Group VC. Similarly, patients belonging to VC group (Group VC) were first instructed to take eight VC breaths, which was preceded by maximal exhalation and then followed by 10 min room air breathing before they crossed over to the TV group. All 28 patients underwent both techniques of pre-oxygenation with 14 of them doing TV breathing first and the other 14 doing VC breathing first [Figure 1]. Pre-oxygenation was carried out with 10 litres of fresh gas flow using the circle system.

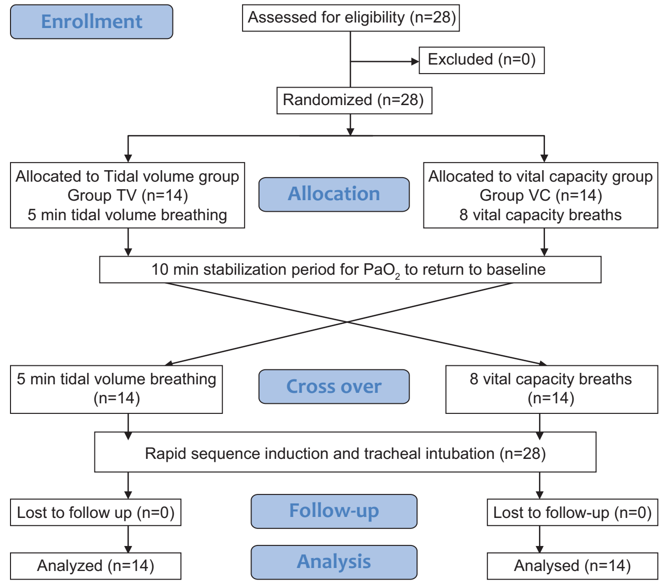

Figure 1: Consort flow chart

The circuit was primed with 100% O_2 by occluding the patient end, the adjustable pressure limiting valve fully closed and discharging the oxygen flush thrice thereby allowing the reservoir bag to fill up. The sensor of the spirometer was connected to the mask of the patient and inspired and expired volumes during both techniques were noted.

End tidal oxygen concentration (EtO_2) was recorded at the patient end of the circuit before and after each technique of pre-oxygenation. Following the 2nd technique of pre-oxygenation, rapid sequence induction (RSI) was performed with Sellick's manoeuvre. Anaesthesia was induced with a sleep dose of 2.5% thiopentone and suxamethonium was used to facilitate tracheal intubation. Time of RSI (from the beginning of induction to completion of tracheal intubation) was noted in all 28 patients. Maintenance of anaesthesia was continued with an inhalational agent and 66% nitrous oxide in 33% oxygen through circle system.

Data were collected and analysed using SPSS statistical software, version 16. Friedman's two-way analysis of variance by ranks was used for non-parametric data. $P<0.05$ was considered as statistically significant. Postpriori response of matched pairs was normally distributed with standard deviation of 59.85. The true difference in the mean response of matched pairs was 45.71 and 28 pairs of subjects to be able to reject the null hypothesis that this response difference is zero with probability (power) 0.82. The Type I error probability associated with this test of this null hypothesis is 0.05.

RESULTS

Patients between 18-65 years undergoing major elective surgeries were included in this study [Table 1]. Baseline TV and VC were comparable in both the groups during crossover. Time for RSI was similar in both groups [Table 2]. The commonest cause of leak around the mask was the presence of nasogastric tube (35.7%). All the patients had one or more factors that contributed to an ineffective face mask seal and leak as observed by the improper filling of the reservoir bag and a difference between the expired and inspired TVs. Seven patients had more than one factor causing an ineffective face mask seal [Table 3].

The baseline EtO_2 was comparable. A greater rise in EtO_2 was noticed after completion of pre-oxygenation by TV technique (median 90) when compared to VC technique (median 85), $P<0.05$. After the first technique, patients were allowed to breathe room air for 10 min and the decline in EtO_2 was again similar in both the groups.

The baseline PaO_2 values were similar in both groups. However, PaO_2 increased from 89.75-318.60 mm Hg and 90.60-238.25 mm Hg in group TV and group VC respectively; $P<0.05$ [Figure 2]. Similarly, the change in PaO_2 from baseline revealed a significant increase in PaO_2 (228.85) in group TV when compared to the increase in PaO_2 that occurred in group VC (147.65), $P<0.05$. When the patients were left to breathe room air for 10 min after completion of the 1st technique, the PaO_2 values remained higher than the baseline value but this difference was similar in both groups. Similarly, after 2nd technique, PaO_2 increased from 102.70-305.30 mm Hg and 100.65-217.30 mm Hg in group TV and group VC respectively; $P<0.05$ [Figure 3].

Table 1: Physical characteristics of study groups

Physical characteristics	Mean±SD
Age (years)	40.4±12.4
Weight (kg)	58.7±13.7
Height (cm)	159.1±9.2
BMI (kg/m²)	23.26±5.1

Data expressed as mean±SD; SD – Standard deviation; BMI – Body mass index

Table 2: Baseline parameters of study groups

Parameter	Group TV	Group VC
SpO_2	97±1.7	96±1.1
Tidal volume (ml)	490±138.4	473.6±142.6
Vital capacity (ml)	1197.1±375	1160.7±431
RSI (s)	89.5±14.4	88.4±14.6

Data expressed as Mean±SD; SpO_2 – Haemogloblin oxygen saturation; RSI – Rapid sequence induction; VC – Vital capacity; TV – Tidal volume

Table 3: Predictors of ineffective face mask seal in study groups

Predictors of improper mask fit	Distribution in patients (%)
BMI >26 kg/m²	8 (28.5)
Lack of teeth (edentulous)	6 (21.4)
Presence of nasogastric tube	10 (35.7)
Presence of beard	1 (3.5)
Facial anomalies with inadequate mask seal	8 (28.5)

Data expressed as number of patients and percentage; BMI – Body mass index

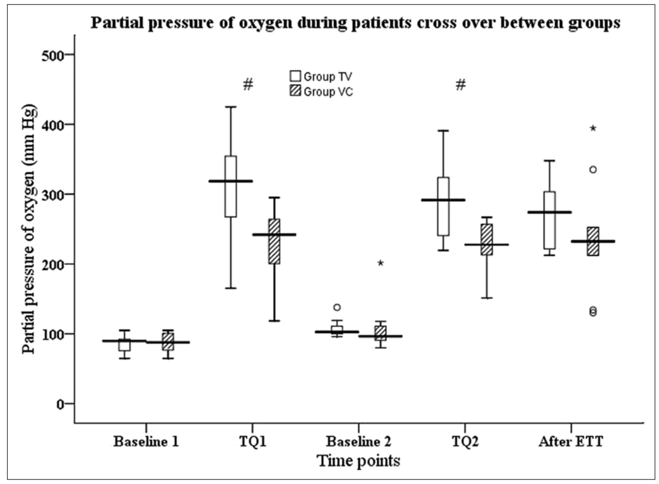

Figure 2: Box and whisker plot illustrating partial pressure of oxygen in both groups; ◦ – Outliers more than 1.5 times the interquartile range; * – Extremes more than three times the interquartile range (# – $P<0.05$. TQ1 – Technique 1, TQ2 – Technique 2)

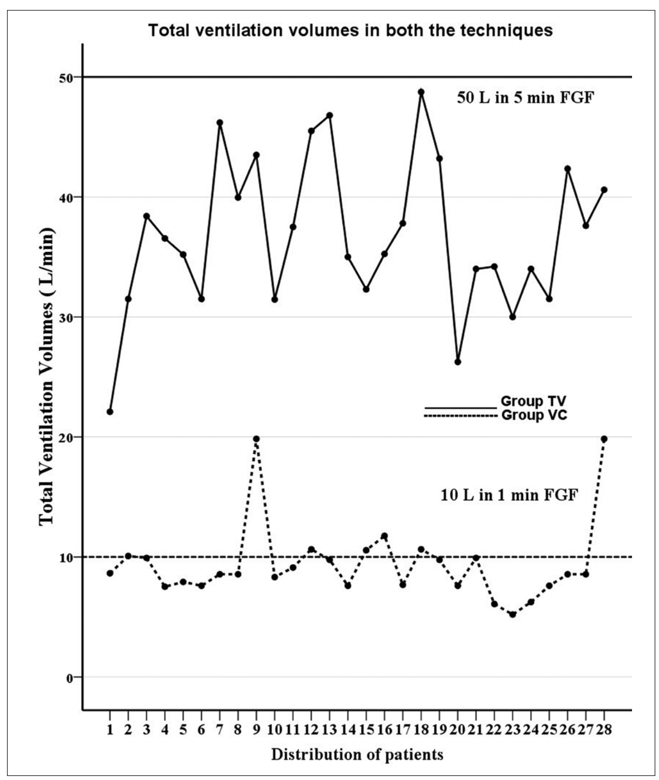

Figure 3: Comparison of tidal volume breathing and vital capacity breathing preoxygenation techniques on total ventilation volumes. (FGF – Fresh Gas Flow)

In seven patients (25%) in the group VC, the total volume of minute ventilation (mean 9.4±3.3 L/min) during the 8 VC breaths/min was more than the delivered fresh gas flow (10 L/min). On the contrary, fresh gas flow of 10 L/min (50 L in 5 min) was sufficiently higher than the total volume of minute ventilation over 5 min (mean total ventilation in 5 min was 36.7±6.3 L/min) in all patients belonging to group TV [Figure 3].

DISCUSSION

We have demonstrated that in patients with an ineffective face mask seal, TV breathing for 5 min with a 10 L/min fresh gas flow through a circle system provides better oxygen reserve than eight VC breaths taken in 1 min.

Factors affecting the efficacy of pre-oxygenation include FiO_2, the duration of breathing and the ratio of alveolar ventilation to functional residual capacity (time constant).[6] The common reasons for failure to achieve a FiO_2 close to 1.0 include inadequate time for pre-oxygenation, leak under face mask, use of systems incapable of delivering high FIO_2 and rebreathing of exhaled gases when low fresh gas flow is used with a circle system.[1,3,6,10] Gagnon[7] demonstrated that a leak as small as 4 mm in diameter was large enough to prevent achieving high EtO_2 values and can hinder pre-oxygenation significantly. They suggested that VC breathing might have two opposite effects in the presence of a leak. First, the 2 L reservoir bag would partially empty through the leak causing air to enter the circuit if fresh gas flow was insufficient during a VC breath. This would worsen the efficiency of pre-oxygenation with VC breath than with TV breathing. On the other hand, during a VC breath, a large negative pressure was created resulting in a turbulent flow (flow proportional to the square root of the pressure gradient) through the leak than in the rest of the circuit where the flow was laminar (flow proportional to the pressure gradient). The investigators suggested that this "turbulent flow effect" made the leak less important with the VC breath and probably was greater than the empty reservoir effect.

According to our study, the fresh gas flow of 10 L/min was insufficient to meet the peak inspiratory demand of the patients breathing VC breaths. The mean total ventilation volume in 1 min with eight VC breaths was 9.4±3.3 L/min and was more than 10 L/min in seven patients. On the other hand, the fresh gas flow (50 L/5 min) was more than sufficient when the same patients were breathing at normal TV (mean total ventilation in 5 min 36.7±6.3). Minute ventilation during VC breaths may exceed the fresh gas flow resulting in rebreathing of exhaled gases in addition to room air entrainment in presence of improper mask seal[3,6,7] and fresh gas flow rates of 10 L/min may not be sufficient to achieve optimum pre-oxygenation. Although the anaesthetic circuits can deliver 100% oxygen concentration, the FiO_2 is influenced by the pattern of breathing, the breathing system used, leak around the mask and the fresh gas flow.[6] The bag is an essential component of the circuit because it provides the reservoir necessary when the patient's peak inspiratory flow (30 L/min) exceeds the fresh gas flow. If this reservoir is empty or partially empty, the patient's demand is compensated from leaks present under the face mask seal.[3,6,7]

EtO_2 can be used as a measure of pre-oxygenation in the presence of ineffective face mask seal since it is a continuous and non-invasive method. EtO_2 of expired gases cannot reach 100% due to the inevitable presence of moisture, CO_2 and N_2.[6] An end tidal O_2 of 90-91% indicates maximal pre-oxygenation and a store of O_2 in the functional residual capacity of 2000 ml with a tight fitting face mask.[11] However, EtO_2 values can extend over a wide range from 0.76 to 0.97[3,4,7] depending upon the amount of leak. Such that 0.9 EtO_2 can be achieved if the leak is small but lower values are likely to be observed when the leak is large.[4] Most studies aim for an EtO_2 value of 0.9 as the endpoint of optimal pre-oxygenation[4,6,12,13] but there is insufficient data suggesting EtO_2 end point values in presence of the leak due to an improper face mask seal. The authors suggest that EtO_2 can help to gauge the extent of leak and pre-oxygenation should be performed for a longer time if the leak is large. In our study, significantly higher EtO_2 values were recorded with TVs breaths than with VC. Nevertheless, the likelihood of obtaining high $EtCO_2$ values should be kept in mind if sampling port is placed near to the site of fresh gas entry on the face mask. The ideal site would be placing a nasal cannula at the nostril connected to the sampling line which is not always possible.[4,7] In our study, the sampling port was placed at the patient end of the circuit.

PaO_2 values after TV breathing were significantly higher than that with eight VC breaths in 1 min in our group of patients. PaO_2 is proportional to the alveolar PO_2 in the functional residual capacity which is the main oxygen store. Rapid techniques of pre-oxygenation (VC breaths) may result in rapid arterial oxygenation without a significant increase in the tissue oxygen stores and hence result in more rapid haemoglobin desaturation during subsequent apnea than would a longer period of TV pre-oxygenation.[14] Storage of oxygen in the tissue is more difficult to assess but assuming that Henry's law applies and that the partition coefficient for gases approximates the gas water coefficients, breathing 100% oxygen for 3 min or more significantly increases tissue oxygen stores.[8,14] Deep breathing for a 2 min period is the practical upper limit and if extended beyond 2 min, can lead to hypocapnia causing an increase in oxygen consumption, cerebral vasoconstriction, dizziness and nausea.[9]

CONCLUSIONS

To conclude, TV breathing for 5 min is a better method of ensuring optimal pre-oxygenation in patients with ineffective face mask seal with fresh gas flow of 10 L/min delivered through a circle system. EtO_2 may not accurately reflect the pre-oxygenation status but gives an indication of the presence of leak in the system.

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