Effect of Positive Airway Pressure During Preoxygenation on Safe Apnea Period: a comparison of the supine and 25° head up position

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ABSTRACT

Background

Preoxygenation is performed before induction of anaesthesia which increases oxygen reserve and provides delayed onset of hypoxia during period of apnea. Several techniques such as positive airway pressure and head-up tilt during preoxygenation have shown to prolong safe apnea period compared to conventional technique. However, uniform recommendations have not yet been made.

Objective

To find out the effect of combination of 5 cmH_2O continuous positive airway pressure (CPAP) and 25° head up position during preoxygenation on safe apnea period.

Method

In this comparative study 60 non-obese adult patients were divided into three equal groups; Group C receiving preoxygenation in conventional technique, Group S receiving preoxygenation with 5 cmH_2O continuous positive airway pressure in supine position and Group H receiving preoxygenation in 25° head-up position with 5 cmH_2O continuous positive airway pressure . After 3 min of preoxygenation, intubation was performed after induction of anaesthesia with propofol, fentanyl and succinylcholine. After confirming the tracheal intubation by direct visualization, all patients were administered vecuronium to maintain neuromuscular blockade. Post-intubation, patients in all groups were left in same position with the tracheal tube exposed to atmosphere and without being ventilated till the SpO_2 dropped to 92%. The primary outcome compared between the groups was the safe apnea period (time from loss of consciousness to fall of SpO_2 to 92%).

Result

The duration of safe apnea period was longer ($p < 0.05$) in Group H patients (405.9 ± 106.69 s) as compared to the Group C (296.9 ± 99.01s) and Group S (319.65 ± 71.54s). Although the duration of safe apnea period was longer in the Group S as compared to Group C the difference was not statistically significant.

Conclusion

Preoxygenation in 25° head-up position with 5 cmH_2O continuous positive airway pressure significantly prolongs safe apnea period in non-obese adults compared to supine position, with or without 5 cmH_2O continuous positive airway pressure .

KEY WORDS

Apnea, CPAP, Preoxygenation

INTRODUCTION

Hypoxemia can occur during induction of anaesthesia when securing airway becomes difficult. It makes sense to maximize oxygen stores before induction to prolong safe apnea period. So, preoxygenation is performed before induction of anaesthesia to increase oxygen amount in the functional residual capacity (FRC) of the lung. Conventional preoxygenation is performed by having patient breath 100% oxygen (10-12 litres/min) by tight fitting mask in supine position. This procedure leads to replacement of nitrogen volume of lung with oxygen in order to provide a reservoir for diffusion into alveolar capillary blood. Preoxygenation for three minutes in spontaneously breathing healthy patient can furnish up to several minutes of oxygen reserve after apnea.[1] Though conventional preoxygenation can provide time after onset of apnea, several techniques are being studied to prolong duration of safe apnea period. Functional residual capacity decreases due to alteration of position from erect to supine. So, various degrees of head-up tilt ranging from 20°-90° have been considered for preoxygenation to increase its effectiveness.[2-6]

Induction of general anaesthesia is associated with development of atelectasis in dependent area of lung.[7,8] If patients have not achieved a saturation greater than 93% to 95% after preoxygenation, it is likely that they have pulmonary shunt and early desaturation will occur during apneic period.[9-11] Application of positive end-expiratory pressure (PEEP)/ continuous positive airway pressure (CPAP) during induction has been found to decrease intrapulmonary shunting and increase duration of safe apnea period, but standard recommendations have not yet been made.[12-14]

Our objective is to find out the effect of combination of 5 cm H_2O CPAP and 25° head-up tilt during preoxygenation on duration of safe apnea period since literature comparing combined effect is unavailable or sparse.

METHODS

Ethical clearance for this prospective, comparative study was obtained from the BP Koirala Institute of Health Sciences (BPKIHS) Institutional Ethical Review Board (IERB Ref. No. 1598/ 070/ 071). The study duration was of one year from 15th June 2014 to 15th May 2015 and conducted at BPKIHS, Dharan. After obtaining written consent adult patients of ASA physical status I and II aged 18-60 years undergoing elective surgery under general anaesthesia were included. Patients with anticipated difficult mask ventilation/intubation, individuals with remarkable cardiorespiratory or cerebrovascular disease, pregnant ladies, patient with history of epilepsy, body mass index > 25 kg/m^2, hemoglobin (Hb) < 8 gm/dL were excluded from the study. In addition, patients who were non-ambulant for > 24 h, having oxygen saturation SpO_2 < 97% while breathing in room air, phobia to facemask were also excluded from the study.

All the patients were kept fasting for eight hours before surgery and were premedicated with 10 mg oral diazepam on the night before surgery. Convenient sampling method was done. On arrival to the operating room, the patient was allocated to one of the three groups. All the patients were preoxygenated for three min with tight-fitting face mask connected to a circle system with the fresh oxygen flow of 10 L/min and a two-liter reservoir bag prefilled with 100% oxygen. We used (Datex-Ohmeda, Aespire, GE healthcare, Chicago, Illinios, USA) workstation. In the control group (Group C), the patient was kept in supine position and the adjustable pressure limit (APL) valve of circle system was kept fully open. In Group S, the patient was kept in supine position and a 5 cmH_2O CPAP was provided; and in Group H, the patient was placed supine with the torso tilted 25° head-up from hip upward and, a 5 cmH_2O CPAP was provided. CPAP was created by closing APL valve to 5 cmH_2O, then the patient end was closed with palm and CPAP of 5 cmH_2O was observed in the pressure monitoring gauge. After that the mask was put on patient face for preoxygenation. The 25° head up position was attained by adjusting the operating table and measured with the help of a goniometer.

The parameters monitored during the procedure included electrocardiogram lead II, noninvasive blood pressure, SpO_2, arterial blood gases and end-tidal carbon dioxide. Intravenous access was established in the non-dominant hand of the patient. All the patients were pre-hydrated with 10 mL/kg Ringer's lactate solution intravenously. In the same limb, the radial artery was cannulated under local anaesthetics after performing Allen's test and was kept locked with heparinized saline. Baseline values of heart rate, blood pressure, and SpO_2 were recorded, and the first sample of arterial blood (ABG 1) was taken with the patient breathing room air.

The second sample of arterial blood was obtained after three min of preoxygenation (ABG 2). Heart rate, blood pressure and SpO_2 were recorded at this point. While continuing oxygenation, anaesthesia was induced with intravenous (IV) fentanyl 1.5 µg/kg followed by IV propofol 2 mg/kg. Immediately after loss of consciousness (as assessed by verbal response), 1.5 mg/kg of succinylcholine was given IV and time noted. Tracheal intubation was performed by an experienced anaesthesiologist using conventional laryngoscopy 60 s after the injection of succinylcholine. The endotracheal tube position was confirmed by visual observation of the tube passing between the vocal cords. The cuff of endotracheal tube was inflated and proximal end (machine end) of tube kept open in the room air. Any patient with Cormack and Lehane (CL) laryngoscopy grade III or IV, requiring more than one intubation attempts and intubation time of > 15 s was excluded from study.

Midazolam two milligrams (mg) was administered IV soon after intubation to ensure amnesia during the apneic period following intubation. Vecuronium was administered

IV to maintain neuromuscular blockade. The patient was left unventilated until SpO_2 dropped to 92%. The time from loss of consciousness until fall of SpO_2 to 92% (safe apnea period) was recorded. At this point of time, heart rate, blood pressure, and SpO_2 were recorded, and the third sample of arterial blood (ABG 3) was taken for analysis.

To keep the study conditions uniform, patients were not ventilated manually or mechanically until the endpoint SpO_2 (92%) was reached. After the SpO_2 reached 92%, all the patients were ventilated with 100% oxygen until the arterial oxygen saturation returned to baseline values. The patients kept in the head up position were also returned to supine position. A three mg bolus of mephentermine was given IV if the mean blood pressure fell below 65 mmHg. Subsequently, anaesthesia was managed as per the routine institutional protocols. After the patients became fully conscious and oriented, they were asked if they could recall any intraoperative events. Any other adverse events observed during the study period were also noted.

Sample size was calculated based on finding of a previous study done by Herriger et al.[12] The safe apnea period in their experimental arm was 599 s and the control arm was 470 s with the common standard deviation of 150 s. Keeping these values and setting an alpha of 0.05 and power of 0.8, 19 patients were required in each group. Finally, we included 20 patients in each group.

The data collected was entered into MS excel software 2007 and exported it into SPSS (Statistical Package for Social Science 11.5) for statistical analysis. Differences between groups were assessed using one-way analysis of variance (ANOVA). Further, Post-hoc analysis with Bonferroni correction (adjusted significance level of 0.0167) was done if statistically significant was observed between groups. For categorical data chi-square test or Fisher's exact test was used. A statistically significant difference was considered as a p-value of < 0.05.

RESULTS

Total 62 patients were assessed for eligibility in the study among them two patients refused to give consent (fig. 1).

Demographic parameters, American Society of Anesthesiologists Physical Status (ASA PS), history of smoking and hemoglobin level were comparable among the three study groups (Table 1).

Duration of safe apnea period was significantly longer in Group H (405.9 ± 106.69 s) compared to Group S and Group C. Although the duration of safe apnea period was longer in Group S (319.65 ± 71.54 s) compared to Group C (296.9 ± 99.01 s), it was statistically insignificant (Table 2).

The pH, PaO_2 and $PaCO_2$ at the start of preoxygenation, after preoxygenation and at primary end point were comparable among the three groups (Table 3). The $PaCO_2$ level was slightly higher in Group H at primary end point compared to Group S and Group C but the difference was statistically insignificant.

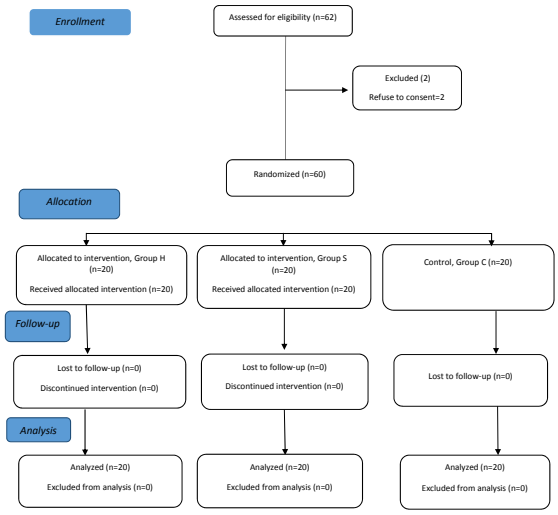

Figure 1. Flow diagram of the study

Table 1. Patient characteristics.

Parameter	Group C (n=20)	Group S (n=20)	Group H (n=20)
Age (years)	34±12.8	32.2±10.2	28.4±6.9
Gender (male/female)	8/12	9/11	8/12
BMI (kg/m^2)	21.4±2.1	21.6±2.2	21.1±1.8
History of smoking (Y/N)	4/16	4/16	3/17
ASA-PS (I/II)	14/6	16/4	18/2
Hemoglobin (g/dL)	13.1±1.4	12.7±2.1	12.9±1.7

Values are presented as mean (±SD) or n. ASA-PS=American Society of Anesthesiologists Physical Status, BMI=body mass index, Y/N=yes/no

Table 2. Comparison of duration of safe apnea period.

Groups	Time (in sec)	P-value
Group C (n=20)	296.90±99.01	
Group S (n=20)	319.65±71.54	0.724*
Group H (n=20)	405.90±106.69	0.001†
		0.014‡

Values are presented as mean (± SD),
*Group S vs. Control group,
†Group H vs. Control group,
‡Group H vs. CPAP group

During induction standardized dose of IV propofol was adequate in all the patients and events of coughing were not noted. No adverse hemodynamic instability was observed during the study period except transient ventricular premature complexes (VPCs) in two patients, one in Group C and one in Group H, which did not require any treatment. None of the patients mentioned about intraoperative awareness.

DISCUSSION

The main finding of our study is that combining CPAP and 25° head up tilt prolongs safe apnea period remarkably.

Table 3. Comparison of arterial blood gas values at different time points.

	Group C (n=20)	Group S (n=20)	Group H (n=20)	P value
Baseline				
pH	7.40 ± 0.01	7.40 ± 0.02	7.39 ± 0.02	0.369
PaO_2 (mmHg)	85.97 ± 13.92	88.37 ± 11.92	91.90 ± 10.71	0.313
$PaCO_2$ (mmHg)	46.91 ± 6.15	44.60 ± 7.71	44.92 ± 5.80	0.493
After preoxygenation				
pH	7.40 ± 0.02	7.39 ± 0.02	7.38 ± 0.03	0.259
PaO_2 (mmHg)	274.85 ± 44.90	289.95 ± 49.26	286.75 ± 62.02	0.635
$PaCO_2$ (mmHg)	44.86 ± 5.59	44.61 ± 6.85	47.29 ± 7.65	0.387
At desaturation (SpO_2 92%)				
pH	7.28 ± 0.03	7.28 ± 0.02	7.27 ± 0.03	0.159
PaO_2 (mmHg)	62.17 ± 5.55	64.40 ± 6.58	65.92 ± 9.47	0.279
$PaCO_2$ (mmHg)	60.90 ± 6.04	59.96 ± 7.47	64.18 ± 7.87	0.157

Values are presented as mean (± SD)

There was almost two minutes prolongation of safe apnea period with combination of 25° head up tilt and application of a 5 cmH_2O CPAP when compared to conventional three min tidal volume preoxygenation in supine position. However, addition of 5 cmH_2O CPAP to conventional three min tidal volume preoxygenation in supine position only marginally increased (less than half min) the safe apnea period.

Induction of general anaesthesia is associated with development of intrapulmonary shunt due to formation of atelectasis. Atelectasis appears within minutes of induction of anaesthesia in 85-90% of non-obese patients.[7] Therefore, prevention of atelectasis formation leads to prolongation of safe apnea period and margin of safety. Atelectasis formation can be prevented by application of CPAP/ PEEP during induction of anaesthesia.[15] FRC is found to decrease when changing position from standing to sitting and it decreases further in supine position in healthy person.[16] So, performing preoxygenation in head-up tilt position will lead to less decrease in FRC compared to supine and increases lung store of oxygen. These are the probable reasons for increase in duration of safe apnea period in our study.

Some previous studies have compared the effects of head-up (ranging from 20° to 90°) on the duration of safe apnea period in comparison with conventional preoxygenation. Lane et al. found preoxygenation in a 20 degree head-up position took 386 seconds to desaturate to 95% versus 283 seconds in the control (supine) group.[3] Recently, Venkateswaran et al. confirmed these results, with the 20-degree head-up group taking 452 seconds to desaturate versus 364 seconds for the supine group, a finding very close to ours.[4] Altermatt et al. examined specifically preoxygenation in obese patients (body mass index > 35).[5] They found the patients preoxygenated in a sitting position took 214 seconds to desaturate versus 162 seconds for patients preoxygenated while lying flat. Dixon et al. showed similar benefits in patients with body mass index greater than 40 who were preoxygenated in the 25-degree head-up position (time for desaturation to 92% was 201 ± 55 seconds in head-up vs. 155 ± 69 seconds in supine).[2] Expectedly, these studies involving obese patients had relatively shorter desaturation time compared to our findings in non-obese patients. Similarly, Baraka et al. found increase in time to desaturation after preoxygenation in 45 degree head-up position compared to supine in non-pregnant ladies.[6] But interestingly, no benefit was found in case of pregnant ladies with the change in preoxygenation position which is most likely due to impairment of diaphragmatic excursion by gravid uterus.

The duration of safe apnea period was significantly longer with the 25° head-up position plus CPAP as compared to application of a same amount of CPAP in supine position in the present study. Venkateswaran et al. in their study found no significant difference in the duration of non-hypoxic apnea period between PEEP and head-up tilt group.[4] Variation in the study design probably explains the difference between their and our findings. It can be expected when combining head-up position with CPAP may have additive effect for prolongation of safe apnea period.

In our study application of CPAP during three min tidal volume preoxygenation resulted in prolongation of safe apnea period by 23 seconds compared to conventional preoxygenation technique. Cressey et al. found a non-statistically significant increase of 37 seconds in the time to desaturate to 90% when 7.5 cm H_2O CPAP was applied during pre-oxygenation to morbidly obese women.[13] Though this prolongation of safe apnea period proved statistically insignificant it can be beneficial during difficult airway management scenario.

There are many studies that compared the effects of application of PEEP of 6-10 cmH_2O with conventional preoxygenation.[12,14] In those studies the authors have found statistically significant increase in duration of safe apnea period with application of PEEP compared to conventional technique. This can be explained by one notable difference of methodology compared to ours is that patients in PEEP group received PEEP with intermittent positive pressure ventilation with the mask following induction and paralysis. Along with that the PEEP applied was greater than in our study. However, in our study we didn't apply intermittent positive-pressure ventilation (IPPV) or PEEP after induction of anaesthesia. This difference in methodology may explain why our results were different from those of other such studies.[12,14]

There are no studies mentioning any specific level of CPAP/ PEEP is comfortable to the patients. Application of higher level of CPAP/ PEEP can be associated with adverse hemodynamic effects along with discomfort during preoxygenation. Hence, we decided to use only 5 cm H_2O CPAP which was well tolerated by all the patients and we did not encounter any significant hemodynamic disturbances.

It is expected that anaesthetic induction maintaining the 25° head-up tilt can exacerbate the hypotensive effects. So, to counteract those effects we lowered the head-up patients to supine position immediately following desaturation in addition to preloading with fluid. Event of hypotension following induction was not observed in any of our patients. Theoretically preoxygenation in head-up position is believed to increase risk of aspiration if regurgitation occurs, though the risk of regurgitation as such is lower with the head-up position.[3] Intubation in head-up may be technically difficult because of unconventional position, but in our study we did not encounter any difficulty since we use footstep to facilitate intubation. Besides, in the study done by Lee et al. they found 25° head-up to be associated with better positioning of the head for optimal intubation and better access to the airway by gravitational retraction of the breast tissue in female patients.[17]

In our study ABG was analyzed at different time points as SpO_2 value cannot be relied on completely to find accurate saturation of patient's Hb. In ABG analysis the minimum pH observed was 7.20 and the maximum $PaCO_2$ noted was 77.7 mmHg at the time of desaturation. Both of these values were clinically acceptable and immediately corrected after resumption of ventilation with oxygen. In our study no anaesthetic agents were delivered after intubation till desaturation which might predispose patients to the risk of awareness. Due to unavailability of target controlled infusion devices and Bispectral Index (BIS) for monitoring depth of anaesthesia to prevent awareness, we decided to administer two milligrams of midazolam intravenously to all our patients. There was no report of any intraoperative awareness, in postoperative follow-up.

Hypoxia is defined as fall of saturation below 90%, but from oxy-hemoglobin dissociation curve we can conclude that there will be rapid fall of saturation when the SpO_2 value falls below 90%. So, in our study we took 92% as cut-off point for fall of saturation considering safety of patients. There were no major adverse events in any of the patients studied except in two patients who developed occasional VPCs for which no intervention was needed. In our study the value of $PaCO_2$ was higher at time of desaturation in head-up with CPAP group (64.18 ± 7.87) compared to CPAP only (59.96 ± 7.47) and control group (60.90 ± 6.04) though it did not reach to the level of statistical significance. Venkateswaran et al. in their study also found higher value of $PaCO_2$ in head-up group compared to control group and the difference was statistically significant.[4] Longer duration of safe apnea period and consequent longer duration of lack of alveolar ventilation in head-up group is the most probable reason for this finding.

The main limitation of our study is that the investigator observing the outcome could not be blinded. Although, standardized anaesthetic induction technique and observer-independent criteria for defining the duration of safe apnea were used to limit possibility of bias. In our study the breathing rate of patients were not monitored so, the exact time of development of apnea by the patients couldn't be noted. So, to standardize safe apnea period was defined as time from loss of consciousness to fall of saturation to 92%. Since, the study was done in non-obese patients we cannot extrapolate the finding in obese patients. There is need of further research to find benefit of combining head-up and CPAP during preoxygenation in obese patients.

CONCLUSION

Preoxygenation in 25° head-up position with 5 cmH_2O CPAP provides significantly longer duration of safe apnea period compared to application of CPAP during preoxygenation in supine position or conventional preoxygenation technique in non-obese patients. Application of CPAP also prolongs the duration but not to the level of statistical significance.

REFERENCES

1. Tanoubi I, Drolet P, Donati F. Optimizing preoxygenation in adults. *Can J Anesth.* 2009;56:449–66.
2. Dixon BJ, Dixon JB, Carden JR, Burn AJ, Schachter LM, Playfair JM, et al. Preoxygenation is more effective in the 25 degrees head-up position than in the supine position in severely obese patients: a randomized controlled study. *Anesthesiology.* 2005;102(6):1110–15.
3. Lane S, Saunders D, Schofield A, Padmanabhan R, Hildreth A, Laws D. A prospective, randomised controlled trial comparing the efficacy of pre-oxygenation in the 20 degrees head-up vs supine position. Anaesthesia. 2005;60:1064–7.
4. Venkateswaran R, Goneppanavar U, Frenny AP. Preoxygenation with 20 degree head-up tilt provides longer duration of non-hypoxic apnea than conventional preoxygenation in non-obese healthy adults. *J Anesth*. 2011;25:189–94.
5. Altermatt FR, Munoz HR, Delfino AE, Cortinez LI. Pre-oxygenation in the obese patient: effects of position on tolerance to apnoea. *Br J Anaesth*. 2005;95(5):706–9.
6. Baraka AS, Hanna MT, Jabbour SI, Nawfal MF, Sibai AN, Yazbeck VG, et al. Preoxygenation of pregnant and nonpregnant women in the head-up versus supine position. *Anesth Analg.* 1992;75(5):757–9.
7. Lundquist H, Hedenstierna G, Strandberg A,Tokics L, Brismar B. CT-assessment of dependent lung densities in man during general anaesthesia. *Acta Radiol.* 1995;36(6):626–32.
8. Magnusson L, Spahn DR. New concepts of atelectasis during general anaesthesia. *Br J Anaesth*. 2003;91:61–72.
9. Davis DP, Hwang JQ, Dunford JV. Rate of decline in oxygen saturation at various pulse oximetry values with prehospital rapid sequence intubation. *Prehosp Emerg Care.* 2008;12(1):46–51.

10. El-Khatib MF, Kanazi G, Baraka AS. Noninvasive bilevel positive airway pressure for preoxygenation of the critically ill morbidly obese patient. *Can J Anaesth.* 2007;54(9):744–7.

11. Baillard C, Fosse JP, Sebbane M, Chanques G, Vincent F, Courouble P, et al. Noninvasive ventilation improves preoxygenation before intubation of hypoxic patients. *Am J Respir Crit Care Med.* 2006;174(2):171–7.

12. Herriger A, Frascarolo P, Spahn DR, Magnusson L. The effect of positive airway pressure during pre-oxygenation and induction of anaesthesia upon duration of non-hypoxic apnoea. *Anaesthesia.* 2004;59:243–7.

13. Cressey DM, Berthoud MC, Reilly CS. Effectiveness of continuous positive airway pressure to enhance pre-oxygenation in morbidly obese women. *Anaesthesia.* 2001;56:670–89.

14. Gander S, Frascarolo P, Suter M, Spahn DR, Magnusson L. Positive end-expiratory pressure during induction of general anesthesia increases duration of nonhypoxic apnea in morbidly obese patients. *Anesth Analg.* 2005;100:580–84.

15. Rusca M, Proietti S, Schnyder P, Frascarolo P, Hedenstierna G, Spahn DR, et al. Prevention of Atelectasis Formation During Induction of General Anesthesia. *Anesth Analg*. 2003;97:1835–9.

16. Katz S, Arish N, Rokach A, Zaltzman Y, Marcus E. The effect of body position on pulmonary function: a systematic review. *BMC Pulmonary Medicine.* 2018;18:1–16.

17. Lee BJ, Kang JM, Kim DO. Laryngeal exposure during laryngoscopy is better in the 25 degree back-up position than in the supine position. *Br J Anaesth.* 2007;99(4):581–6.