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Original Article

A practical method to improve preoxygenation: Using the APL valve

Mahmut Arslan, Cengizhan Yavuz

Kahramanmaras Sutcu Imam University, Medical Faculty Department of Anesthesiology, Kahramanmaras, Turkey

Abstract

Aim: After induction of anesthesia hypoxemia may rapidly develop due to hypoventilation, apnea and decrease in functional residual capacity. Thus, preoxygenation should be administered to every patient before anesthesia induction since airway management may unexpectedly be difficult. Applying positive airway pressure is reported to improve preoxygenation. In this study, we aimed to investigate the effect of applying positive pressure via the adjustable pressure limiting valve (APL) on preoxygenation.

Material and Methods: 40 patients aged from 18 to 80 years to be operated under general anesthesia were included in this prospective randomized controlled study. The patients were randomly divided into two groups and preoxygenation was administered with anesthesia facemask in the supine position using two different techniques. In both techniques, the anesthesia circuit was flushed with O_2 flush for 30 seconds and then preoxygenation was performed with 100% oxygen and 12 L/min of fresh gas flow for 3 min in spontaneous breathing. In Group APL the APL valve was set at 5 cmH_2O pressure position. In Group SB, the APL valve was set at open (spontaneous) position.

Results: The percentage of patients with an FeO_2 of ≥ 90% at 3rd min was higher in Group APL than in Group SB (75% vs 40%, p=0.006). The mean FeO_2 value at 3rd min was statistically significantly higher in Group APL (89.6 vs 88.2, p=0.001). The degree of the difficulty of the technique was reported to be higher in Group APL.

Conclusion: In conclusion, we have shown that applying 5 cmH_2O positive pressure by APL valve improved preoxygenation compared with spontaneous breathing.

Keywords: Preoxygenation; airway management; adjustable pressure limiting valve

INTRODUCTION

After induction of anesthesia hypoxemia may rapidly develop due to hypoventilation, apnea and decrease in functional residual capacity. Although there are predictive methods for difficult airway, the sensitivity and specificity of these are not very high. Of the difficult intubation cases, 93% are unanticipated (1). It is recommended that preoxygenation be administered to each patient before anesthesia induction since airway management may unexpectedly be difficult after induction of anesthesia (2-4). Preoxygenation aims to replace the nitrogen in the lungs with oxygen by administering oxygen to the patient before anesthesia induction. Thus, the oxygen reserve is increased, preventing the patient from being desaturated until ventilation is secured after induction of anesthesia.

It has been reported that applying positive airway pressure improves preoxygenation (5-12). However, in those studies, advanced anesthesia devices or additional equipment have been used to provide PEEP or pressure support. The aim of this study was to investigate the effect of positive pressure created by using the airway pressure limiting valve (APL), which is a standard equipment of every anesthesia machine, on preoxygenation compared to that of standard spontaneous tidal volume breathing.

MATERIAL and METHODS

After obtaining the ethics committee approval Kahramanmaras Sutcu Imam University, School of Medicine, Clinical Research Ethics Committee: 2019/248) 40 patients aged from 18 to 80 years to be operated under general anesthesia were included in this randomized controlled study. Patients with a BMI of >35 and patients with cardiovascular or respiratory disease were excluded from the study. After standard monitoring was performed for the patients who were transferred to the operating

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Corresponding Author: Mahmut Arslan, Kahramanmaras University Medical Faculty Department of Anesthesiology, Kahramanmaras, Turkey, **E-mail:** mahmutarslan177@gmail.com

room, sedation was administered with 0.03 mg/kg of iv midazolam. The patients were randomly divided into two groups and preoxygenation was administered with anesthesia facemask in the supine position using two different techniques. Randomization for group allocation was performed using a computer generated random sequence generator program (random.org). Patients were randomly allocated to groups according to the order of presentation. In both techniques, the anesthesia circuit was flushed with O_2 flush for 30 seconds and then preoxygenation was performed with 100% oxygen and 12 L/min of fresh gas flow for 3 min in spontaneous breathing. In Group APL the APL valve was set at 5 cmH_2O pressure position. In Group SB, the APL valve was set at open (spontaneous) position.

During preoxygenation, expired O_2 fraction (FeO_2), SpO_2, end-tidal CO_2, tidal volume, respiration rate and minute ventilation were recorded every 10 seconds starting from the 30th second. Time to reach fraction a FeO_2 of 90% and FeO_2 values at 3rd min were recorded. The patients were asked to rate the difficulty of the technique between scores of 1-5 (VRS: verbal rating score): 1 = very easy; 2 = easy; 3 = moderate; 4 = difficult; 5 = very difficult.

The primary endpoint was determined as the percentage of patients with a FeO_2 of ≥ 90% at 3rd min. The secondary endpoints were time to reach a FeO_2 of 90%, FeO_2 at 3rd min and the VRS score.

In a preliminary study on 10 patients time to reach an FeO_2 of 90% was measured as 170±61 seconds in the spontaneous ventilation. A sample size of 17 patients in each group would be enough to demonstrate a difference of 60 s with a power of 80% and an alpha risk of 5%. To improve the power of the study 20 patients in each group were included in the study.

The data were analayzed with IBM SPSS version 22 (IBM SPSS for Windows, version 22; IBM Corporation, Armonk, New York, United States). Normal distribution of variables was examined by Shapiro-Wilk test. In the comparison of qualitative data chi-square test was used. Student's t-test was used to compare the quantitative data. VRS scores were compared by using the Mann Whitney test. The Kaplan-Meier method and Log-rank test were used for estimations reaching FeO_2 of 90% according to the methods. Statistical significance was set as $p<0.05$.

RESULTS

The study included 40 patients. There was no difference between the groups in terms of age, gender, weight, height and BMI. Baseline SpO_2 values in the two groups were similar (97.4±1.4% vs 97.5±1.3% , p=0.82). After 3 minutes of preoxygenation SpO_2 values reached 100 % in all patients in both groups. The percentage of patients with a FeO_2 of ≥ 90% at 3rd min was higher in Group APL than in Group SB (75% vs 40%, p=0.006). The Kaplan-Meier analysis results for the probability that FeO_2 reached 90% are shown in Figure 1. There was no difference between the two groups in terms of time to achieve a FeO_2 of 90%. The mean FeO_2 value at 3rd min was statistically significantly higher in Group APL. The degree of the difficulty of the technique was reported to be higher in Group APL. Minute ventilation and end tidal CO_2 values were similar (Table 2).

Table 1. Patient characteristics

Variable	Group APL (n=20)	Group SB (n=20)	P
Age (years)	39 (10)	42 (16)	0.38
Sex (F/M)	6/14	8/12	0.06
Weight (kg)	75 (12)	79 (9)	0.16
Height (cm)	166 (6)	168 (6)	0.28
BMI (kg/m^2)	27 (4)	28 (3)	0.29

Data are mean (standart deviation) and number as appropriate. BMI, Body mass index.

Table 2. Minute ventilation, end tidal CO2, FeO2 at 3rd minute, VRS and time to reach FeO2 of 90%

Variable	Group APL (n=20)	Group SB (n=20)	P
MV (L/min)	8.3 (2.9)	8.5 (3)	0.781
End tidal CO_2 (mmHg)	34.4 (4.2)	34.1 (3.6)	0.843
FeO2 (%) at 3rd minute	89.9 (1.5)	88.2 (1.6)	0.001*
Time to reach FeO_2 of 90% (second)	125 (35.3)	152 (29.6)	0.065
VRS	2 (2-4)	2 (2-2.5)	0.033*

Data are mean (standard deviation) and median (interquartile range) as appropriate. VRS, verbal rating score; FeO2, expired O2 fraction. *The difference is statistically significant.

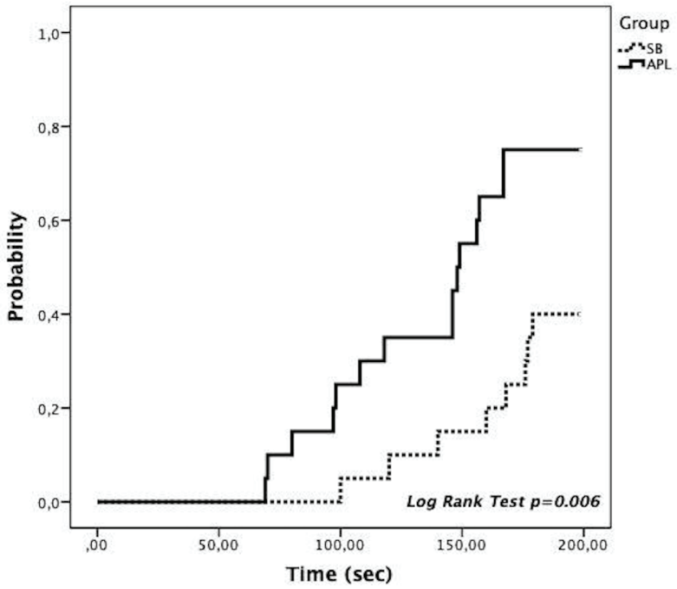

Figure 1. Kaplan-Meier analysis results for the probability that FeO2 reached 90%

DISCUSSION

This study demonstrated that the efficacy of preoxygenation can be improved without using any additional equipment by simply adjusting the APL valve to 5 cmH_2O pressure during spontaneous respiration.

Since oxygenation, endotracheal intubation and ventilation difficulty are unpredictable in general anesthesia procedures, preoxygenation is accepted as the standard of care (3,13). For an effective preoxygenation, leaks from the mask should be prevented, 100% oxygen should be used and rebreathing should not be allowed (14). In order to provide these, a well-fitting mask should be used and the fresh gas flow should be 10-12 L/min. The efficacy of preoxygenation can be evaluated with FeO_2; when FeO_2 reaches 90%, maximal preoxygenation is considered to be achieved (14). In our study, we used 100% oxygen, 12 L/min FGF and perfectly sealed face masks to improve preoxygenation.

In preoxygenation, tidal volume breathing for 3 min or 3-8 vital capacity breaths for 30 s-1 min are usually used (15). Compared with spontaneous breathing, positive pressure ventilation and PEEP provide to achieve preoxygenation targets in a shorter time and increase the proportion of patients reaching 90% FeO_2. Delay et al. reported that in obese patients, preoxygenation with pressure support at 8 cmH_2O and PEEP at 6 cmH2O decreased the time to reach maximal FeO_2 and increased the proportion of patients achieving 95% FeO_2 (9). In the study by Hanouz et al., patients were randomly allocated for preoxygenation with spontaneous breathing or positive pressure ventilation with or without PEEP (positive inspiratory pressure, 12 cmH_2O; PEEP, 6 cmH_2O) (6). At the 3rd min, 47%, 60%, and 74% of patients achieved a FeO_2 of 90% or more in the spontaneous breathing, positive pressure ventilation without PEEP, and with PEEP groups, respectively. Our results are in accordance with the above-mentioned studies; creating positive pressure by adjusting the APL valve increased the proportion of patients achieving a FeO_2 of 90% compared to that of spontaneous breathing. Application of positive pressure to awake patients can be uncomfortable, thus we used only 5 cmH_2O. Despite this relatively low pressure, the degree of difficulty assessed by using VRS was higher in Group APL than Group SB.

In this study we did not evaluate the safe apnea duration. This is the main limitation of the study. But there is a strong relationship between FeO_2 and safe apnea duration because it represents the O_2 wash-in inside the functional residual capacity.

CONCLUSION

In conclusion, this study has shown that applying positive pressure simply by adjusting the APL valve increased the success of preoxygenation. Since every anesthesia machine is equipped with an APL valve, this technique may be widely used to improve preoxygenation.

Competing interests: The authors declare that they have no conflict of interest.

Financial Disclosure: There is not any sources of financial assistance.

Ethical approval: This study was approved by the Kahramanmaras Sutcu Imam University School of Medicine Clinical Research Ethics Committee (2019/248) and conducted in compliance with the ethical principals according to the Declaration of Helsinki.

Mahmut Arslan, ORCID: 0000-0002-2820-1547

Cengizhan Yavuz, ORCID: 0000-0003-4627-7403

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