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Evaluation of Pressure of Arterial Oxygen by Age in Supine Position during General Anesthesia

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Abstract

Background: The concentration of supplemental O_2 should be measured during general anesthesia to determine whether patients' pressure of arterial oxygen (PaO_2) is correct. Nevertheless, we do not know standard value of PaO_2 by age in supine position during general anesthesia. In this study, we evaluated the PaO_2 by age at 33% or 40% O_2 concentration. Materials and Methods: We retrospectively reviewed the anesthetic charts of 660 patients who were received general anesthesia from January 2001 to December 2013. Patients were divided into two groups by concentration of fraction of inspiratory oxygen: group at 33% or 40%. Second, patients aged 16 - 85 years were classified into 7 groups by age with each group covering one decade. Results: The PaO_2 was 185.1 ± 19.2 mmHg (33%) and 209.8 ± 19.8 mmHg (40%) at age 16 - 25 years, 178.7 ± 23.6 mmHg (33%) and 202.7 ± 26.0 mmHg (40%) at age 26 - 35 years, 165.8 ± 30.6 mmHg (33%) and 188.9 ± 22.2 (40%) mmHg at age 36 - 45 years, 154.1 ± 22.8 mmHg (33%) and 181.8 ± 19.2 (40%) mmHg at age 46 - 55 years, 153.7 ± 21.7 mmHg (33%) and 177.5 ± 18.1 mmHg (40%) at age 56 - 65 years, 152.2 ± 24.5 mmHg and 171.0 ± 22.1 mmHg at age 66 - 75 years, and 154.6 ± 24.3 mmHg and 174.1 ± 20.2 mmHg at age 76 - 85 years. Conclusion: The PaO_2 tended to decrease with age at both 33% and 40% O_2 concentration.

Keywords

Pressure of Arterial Oxygen, Supine Position, Age, General Anesthesia

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1. Introduction

In patients in the supine position, general anesthesia induces atelectasis formation, a reduction in lung volume, and respiratory mechanical impairment that may be associated with gas exchange abnormalities [1]. An increase in the intra-abdominal pressure and consequent cephalad displacement of the diaphragm caused by the anesthetic procedure account for the occurrence of atelectasis in the most dependent lung regions and are associated with oxygenation impairment after anesthetic induction [2] [3]. Anesthesia may thus produce more adverse effects on respiratory function in patients in supine position.

The concentration of supplemental O_2 should be measured during general anesthesia to determine whether patients' pressure of arterial oxygen (PaO_2) is correct. However, the standard PaO_2 value undergoing oral and maxillofacial surgery in the supine position during general anesthesia is unknown.

In this study, the PaO_2 was evaluated with respect to F_IO_2 and age in patients undergoing oral and maxillofacial surgery during general anesthesia. Because there have been very few previous reports evaluating PaO_2 with respect to F_IO_2 and age in this clinical situation, we do not know the standard value of PaO_2 in this patient population. Therefore, this study was designed to obtain the standard value of PaO_2 according to F_IO_2 and age in patients in supine position during general anesthesia.

2. Materials and Methods

This retrospective study was approved by the Committee on Clinical Investigation for human research at Iwate Medical University.

We evaluated 660 patients aged ≥ 16 years who underwent general anesthesia in the supine position between January 2001 and December 2013. The anesthetic charts of these 660 patients, all classified as American Society of Anesthesiologists physical status I or II (with the exception of patients with conditions such as asthma, respiratory disease, obesity [body mass index of ≥25 kg/m^2], and smoking), were retrospectively reviewed to investigate age, height, weight, % forced vital capacity (%FVC), % forced expiratory volume in 1 second ($FEV_{1.0}$%), and PaO_2. First, patients were divided into two groups by concentration of fraction of inspiratory oxygen (F_IO_2): group at 33% F_IO_2 and group at 40% F_IO_2. Second, patients aged 16 - 85 years were classified into 7 groups by age with each group covering one decade: in group at 33% F_IO_2, group A (aged 16 - 25 years), group B (26 - 35 years), group C (36 - 45 years), group D (46 - 55 years), group E (56 - 65 years), group F (66 - 75 years), and group G (76 - 85 years), in group at 40% F_IO_2, group H (aged 16 - 25 years), group I (26 - 35 years), group J (36 - 45 years), group K (46 - 55 years), group L (56 - 65 years), group M (66 - 75 years), and group N (76 - 85 years).

Anesthesia was induced with intravenous (IV) propofol (1 - 2 mg/kg of ideal body weight) or thiopental sodium (3 - 5 mg/kg of ideal body weight). Muscle relaxation was provided with vecuronium bromide (0.1 mg/kg of ideal body weight) or rocuronium bromide (0.8 mg/kg of ideal body weight). After tracheal intubation, anesthesia was maintained in almost all patients with sevoflurane (1% - 2%) and nitrous oxide gas if necessary, and patients were mechanically ventilated. We usually used RAE cuffed tracheal tubes (Cuffed Murphy Eye®; Covidien, Mallinckrodt, Ireland) for oral and Parker Flex-Tip® PFHV tubes (Parker Medical, Highlands Ranch) for nasal intubation. The ventilatory settings were as follows: tidal volume, 8 - 10 ml/kg of ideal body weight; respiratory rate, 10 - 12 breaths/minute; peak airway pressure, below 20 cm H_2O; PEEP, 0 cm H_2O; and inspiratory oxygen concentration, 33% or 40%. After 30 to 60 minutes of stabilization following the start of the operation, a blood sample was drawn from the radial artery or the dorsalis pedis artery and analyzed for blood gases.

Values are presented as mean ± standard deviation. Statistical analysis was performed using SPSS, version 11.0 (SPSS, Inc., Chicago, IL, USA). Statistical analysis employed one-way analysis of variance followed by multiple-comparison testing using the Scheffe test for comparisons among groups. The relationship between PaO_2 and age was investigated by Pearson's correlation coefficient test. Correlation coefficients were obtained using simple regression analysis (Excel software, 2003; Microsoft, Redmond, WA, USA). Differences were considered statistically significant at a P value of < 0.05.

3. Results

Patients' characteristics and laboratory data are presented in **Table 1** and **Table 2**.

Regarding groups A - G there were significant differences in age (among all seven groups), height (group G compared with groups A, B, C, D and E; group F compared with groups A, B and C; group E compared with

Table 1. Patient profiles and laboratory data by age. Comparison among groups according to patient age (from 16 to 85 years in one decade increments) at 33% of O_2 concentration.

Group	A (16 - 25 years)	B (26 - 35 years)	C (36 - 45 years)	D (46 - 55 years)
Number	105	58	49	47
Age (yrs)	20.6 ± 2.8	29.5 ± 2.9*	41.0 ± 2.6$^{*,\#}$	51.7 ± 2.7$^{*,\#,\S}$
Height (cm)	166.0 ± 8.7	167.3 ± 8.0	165.1 ± 7.8	160.9 ± 8.9$^{\#}$
Weight (kg)	57.7 ± 9.5	59.4 ± 9.9	60.5 ± 10.1	58.6 ± 10.4
%FVC (%)	105.8 ± 16.8	114.3 ± 14.6	110.5 ± 19.0	109.3 ± 14.9
$FEV_{1.0}$% (%)	90.6 ± 10.1	85.6 ± 6.1	83.1 ± 5.8*	81.0 ± 6.4$^{*,\#}$
PaO_2 (mmHg)	185.1 ± 19.2	178.7 ± 23.6	165.8 ± 30.6*	154.1 ± 22.8$^{*,\#}$

Group	E (56 - 65 years)	F (66 - 75 years)	G (76 - 85 years)
Number	45	67	46
Age (yrs)	60.5 ± 2.4$^{*,\#,\S,\dagger}$	69.0 ± 3.1$^{*,\#,\S,\dagger,\ddagger}$	78.2 ± 2.7$^{*,\#,\S,\dagger,\ddagger,\text{‡}}$
Height (cm)	159.6 ± 7.7$^{\#,\S}$	157.5 ± 9.0$^{*,\#,\S}$	162.6 ± 8.2$^{*,\#,\S,\dagger,\ddagger}$
Weight (kg)	54.8 ± 7.6	54.7 ± 7.9	48.5 ± 9.4$^{*,\#,\S}$
%FVC (%)	113.1 ± 15.5	111.0 ± 17.1	98.4 ± 20.2$^{\#,\ddagger,\text{‡}}$
$FEV_{1.0}$% (%)	80.1 ± 6.0$^{*,\#}$	78.4 ± 4.3$^{*,\#}$	77.9 ± 6.0$^{*,\#}$
PaO_2 (mmHg)	153.7 ± 21.7$^{*,\#}$	152.2 ± 24.5$^{*,\#}$	154.6 ± 24.3$^{*,\#}$

$^{*}p < 0.05$ vs group A, $^{\#}p < 0.05$ vs group B, $^{\S}p < 0.05$ vs group C; $^{\dagger}p < 0.05$ vs group D, $^{\ddagger}p<0.05$ vs group E, $^{\text{‡}}p < 0.05$ vs group F.

Table 2. Patient profiles and laboratory data by age. Comparison among groups according to patient age (from 16 to 85 years in one decade increments) at 40% of O_2 concentration.

Group	H (16 - 25 years)	I (26 - 35 years)	J (36 - 45 years)	K (46 - 55 years)
Number	41	33	36	33
Age (yrs)	19.7 ± 3.0	30.3 ± 2.8*	40.7 ± 2.9$^{*,\#}$	50.7 ± 2.8$^{*,\#,\S}$
Height (cm)	165.1 ± 9.7	164.3 ± 9.4	165.0 ± 8.9	162.8 ± 8.7
Weight (kg)	59.4 ± 10.5	57.1 ± 9.4	60.8 ± 11.3	58.3 ± 7.2
%FVC (%)	107.3 ± 14.1	114.7 ± 16.4	114.0 ± 17.1	120.6 ± 11.2*
$FEV_{1.0}$% (%)	90.3 ± 10.7	87.5 ± 5.4	83.9 ± 6.4	81.5 ± 4.1*
PaO_2 (mmHg)	209.8 ± 19.8	202.7 ± 26.0	188.9 ± 22.2*	181.8 ± 19.2*

Group	L (56 - 65 years)	M (66 - 75 years)	N (76 - 85 years)
Number	32	38	30
Age (yrs)	61.4 ± 2.4$^{*,\#,\S,\dagger}$	70.1 ± 3.0$^{*,\#,\S,\dagger,\ddagger}$	79.9 ± 3.2$^{*,\#,\S,\dagger,\ddagger,\text{‡}}$
Height (cm)	158.0 ± 7.6	155.5 ± 8.9$^{*,\#,\S}$	152.0 ± 8.0$^{*,\#,\S,\dagger,\ddagger}$
Weight (kg)	55.3 ± 9.1	52.5 ± 10.0	49.3 ± 6.8*,§
%FVC (%)	118.4 ± 15.0*	111.4 ± 16.7	106.7 ± 20.6*,†,‡
$FEV_{1.0}$% (%)	80.2 ± 2.9$^{*,\#}$	79.2 ± 5.2$^{*,\#}$	82.0 ± 14.8
PaO_2 (mmHg)	177.5 ± 18.1*	171.0 ± 22.1$^{*,\#}$	174.1 ± 20.2$^{*,\#}$

$^{*}p < 0.05$ vs group H, $^{\#}p < 0.05$ vs group I, $^{\S}p < 0.05$ vs group J; $^{\dagger}p < 0.05$ vs group K, $^{\ddagger}p < 0.05$ vs group L, $^{\text{‡}}p < 0.05$ vs group M.

groups A and C; and group D compared with group B), weight (group G compared with groups A, B and C), %FVC (group G compared with groups A, E and F), $FEV_{1.0}$% (groups D, E, F, G compared with groups A

and B and group C compared with group A), and PaO_2 (groups D, E, F, G compared with groups A and B and group C compared with group A). The PaO_2 was 185.1 ± 19.2 mmHg at age 16 - 25 years, 178.7 ± 23.6 mmHg at age 26 - 35 years, 165.8 ± 30.6 mmHg at age 36 - 45 years, 154.1 ± 22.8 mmHg at age 46-55 years, 153.7 ± 21.7 mmHg at age 56 - 65 years, 152.2 ± 24.5 mmHg at age 66 - 75 years, and 154.6 ± 24.3 mmHg at age 76 - 85 years (**Table 1**).

Regarding groups H-N there were significant differences in age (among all seven groups), height (group N compared with groups H, I, J, K and L; and group M compared with groups H, I and J), weight (group N compared with groups A, B and C), %FVC (group N compared with group K and L, and groups K and L compared with group A), $FEV_{1.0}$% (groups L and M compared with groups H and I and group K compared with group H), and PaO_2 (groups M and N compared with groups A and B and groups J, K, L compared with group H). The PaO_2 was 209.8 ± 19.8 mmHg at age 16 - 25 years, 202.7 ± 26.0 mmHg at age 26 - 35 years, 188.9 ± 22.2 mmHg at age 36 - 45 years, 181.8 ± 19.2 mmHg at age 46 - 55 years, 177.5 ± 18.1 mmHg at age 56 - 65 years, 171.0 ± 22.1 mmHg at age 66 - 75 years, and 174.1 ± 20.2 mmHg at age 76 - 85 years (**Table 2**). There was also a negative correlation between PaO_2 and age ($r = 0.500$, slop = −0.6288, $P < 0.05$ and $R^2 = 0.2505$) in group at 33% F_IO_2, and there was a negative correlation between the two ($r = 0.424$, slop = −0.6024, $P < 0.05$ and $R^2 = 0.18$) in group at 40% F_IO_2 (**Figure 1**).

There is also a negative correlation between PaO_2 and age ($r = 0.500$, slop = −0.6288, $P < 0.05$ and $R^2 = 0.2505$) in group at 33% F_IO_2, and a negative correlation between the two ($r = 0.424$, slop = −0.6024, $P < 0.05$ and $R^2 = 0.18$) in group at 40% F_IO_2.

4. Discussion

In the present study, we found out two important issues. The value of PaO_2 according to F_IO_2 at 33% or 40% inhalation is obtained in supine position during general anesthesia. The PaO_2 tends to decrease with increasing age for patients anesthetized in the supine position.

First, the value of PaO_2 according to F_IO_2 at 33% or 40% inhalation was obtained in supine position during general anesthesia. In this study, when the value of PaO_2 is compared with group at 33% and group at 40% O_2 concentration, it is suggested that the value of PaO_2 in all age at 33% O_2 concentration plus almost 20 mmHg is the value of PaO_2 at 40% O_2 in all age. Generally, the ideal standard value of PaO_2 at 33% O_2 concentration is almost 185 mmHg at 40% concentration is almost 230 mmHg. In this study the value of PaO_2 was almost same value as or lower than the ideal standard value but was thought to be within the clinically acceptable range in all groups. And in group at 33% O_2 concentration, the value of PaO_2 decreases by almost 10 mmHg with age from 16 - 25 years to 46 - 65 years and that of group at age 46 - 55 years, group at age 56 - 65 years, group at age 66 - 75 years and group at age 76 - 85 years are almost same value. In both group at 33% and group at 40% O_2 concentration, the value of PaO_2 in group 66 - 75 years is lowest among seven groups. Nevertheless, we do not have

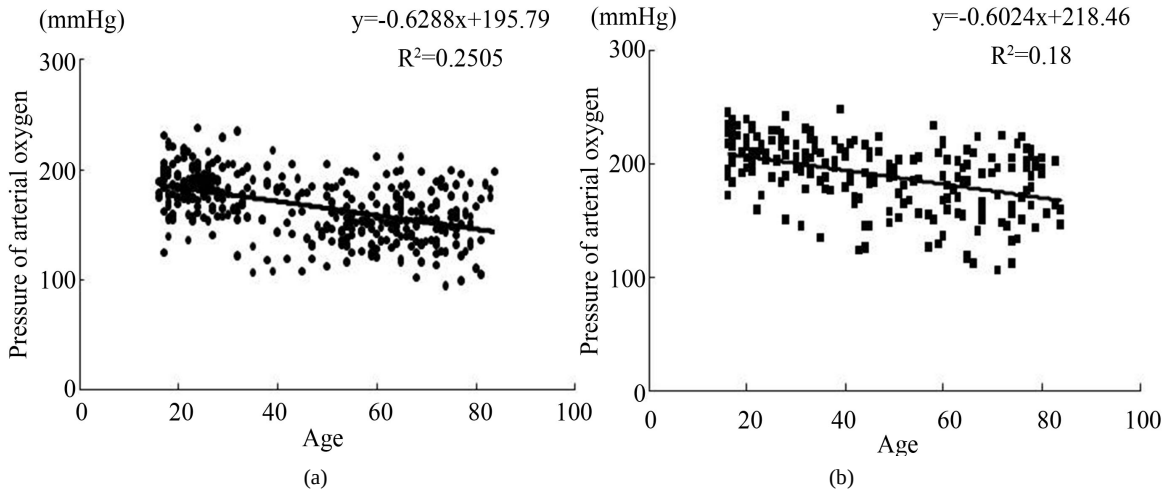

Figure 1. Relationship between pressure of arterial oxygen and age. (a) Fraction of inspiratory oxygen at 33% inhalation; (b) Fraction of inspiratory oxygen at 40% inhalation.

enough data to judge why the value of PaO_2 in group 66-75 years is lowest. Become aware of the value of PaO_2 by age also suggests that we could know whether patients' PaO_2 is low or not and determine the concentration of supplemental O_2. In addition, general anesthesia is more safely performed.

Second, the PaO_2 tends to decrease with increasing age for patients anesthetized in the supine position. There was also a negative correlation between PaO_2 and age in group at 33% and 40% F_IO_2. Pulmonary gas exchange is impaired during general anesthesia [4] [5]. It is also generally held that the gas exchange impairment in anaesthetized subjects increases with age [5] [6]. During inhalation anesthesia with mechanical ventilation, atelectasis and shunt developed, however, atelectasis and shunt did not increase significantly with age, shunt influenced PaO_2 most, low ventilation/perfusion ratios being a secondary factor which, was increasingly important with increasing age, thus explaining the well-known age-dependent deterioration of arterial oxygenation during anesthesia [5]. And the major cause of impaired oxygenation of the blood was shunt, an effect of prompt atelectasis formation in dependent lung regions and was ventilation/perfusion (V/Q) mismatch, and the magnitude of shunt and size of atelectasis were independent of the age of the patient, whereas V/Q mismatch increased with age, explaining the age dependent impairment of oxygenation [7]. Negative correlations were found between PaO_2 and age in both group at 33% F_IO_2 ($r = 0.500$, $P < 0.05$) and group at 40% F_IO_2 ($r = 0.424$, $P < 0.05$). The regression lines using PaO_2 as outcome variable (y) and age as predictor variable (x) were $y = -0.6288x + 195.79$ (group at 33% F_IO_2) and $y = -0.6024x + 218.46$ (group at 33% F_IO_2). We believe that these data can help to predict the outcome of the PaO_2 value by age in the supine position during general anesthesia.

5. Conclusion

The standard value of PaO_2 according to F_IO_2 at 33% or 40% inhalation was obtained and the PaO_2 tended to decrease with age in supine position during general anesthesia. Become aware of the value of PaO_2 by age at 33% or 40% O_2 concentration and also suggests that we could know whether patients' PaO_2 is low or not and determine the concentration of supplemental O_2. In addition, general anesthesia is more safely performed.

Conflict of Interests

The authors declare that they received no financial support and have no conflict of interests.

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Abbreviations

PaO_2: Pressure of arterial oxygen
F_IO_2: Fraction of inspiratory oxygen
%FVC: % forced vital capacity
$FEV_{1.0}$%: % forced expiratory volume in 1 second