

Evaluation of Partial Pressure of Arterial Oxygen in Obese Patients in Supine Position during General Anesthesia

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Abstract

Background: Anesthetists should measure the concentration of supplemental oxygen to determine whether patients' partial pressure of arterial oxygen (PaO₂) is correct during general anesthesia. However, the standard PaO₂ value in obese patients in the supine position is unknown. We evaluated the PaO₂ with respect to the Broca-Katsura obesity index. **Materials and Methods:** From January 2001 to December 2013, we evaluated 472 patients aged ≥16 years old that underwent general anesthesia in the supine position. The anesthetic charts of 472 patients with an American Society of Anesthesiologists physical status of I or II were retrospectively reviewed to investigate the PaO₂. **Results:** In patients aged 16 to <65 years old, the PaO₂ was 165.7 ± 25.6 mmHg at a Broca-Katsura index of <20%, 141.8 ± 26.9 mmHg at a Broca-Katsura index of 20% to <40%, 132.7 ± 22.7 mmHg at a Broca-Katsura index of 40% to <60%, and 111.7 ± 34.6 mmHg at a Broca-Katsura index of ≥60%. In patients aged 65 to <84 years old, the PaO₂ was 152.1 ± 23.8 mmHg at a Broca-Katsura index of <20%, 130.6 ± 26.7 mmHg at a Broca-Katsura index of 20% to <40%, and 127.5 ± 11.3 mmHg at a Broca-Katsura index of 40% to <60%. **Conclusion:** With an increasing Broca-Katsura index, the PaO₂ tended to decrease with age from 16 to <65 years old and 65 to <84 years old. Additionally, the PaO₂ tended to decrease with age from 16 to <65 years at a Broca-Katsura index of 20% to <40%.

Keywords

Arterial Partial Pressure of Oxygen, Broca-Katsura Index, General Anesthesia, Obesity, Supine

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Position

1. Introduction

Anesthetic management is reportedly associated with a higher incidence of critical incidents during anesthesia in obese than in nonobese patients [1]. During general anesthesia, obese patients are more likely to develop rapid oxygen desaturation during periods of apnea [2] and exhibit lower tissue oxygen levels at a given partial pressure of arterial oxygen (PaO₂) than that of nonobese patients [3]. Additionally, 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 [4]. 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 [5] [6]. Anesthesia may thus produce more adverse effects on respiratory function in obese than in nonobese patients [7]. The concentration of supplemental O₂ should be measured during general anesthesia to determine whether patients' PaO₂ value is correct. However, the standard PaO₂ value in obese patients and those undergoing oral and maxillofacial surgery in the supine position during general anesthesia is unknown.

The Broca-Katsura index is an index of obesity [8]-[10]. The modified Broca index is used for Japanese patients. This index is occasionally used to determine whether a patient is obese during the preoperative anesthetic evaluation. Very few studies have evaluated the PaO₂ with respect to the Broca-Katsura index during general anesthesia. In this study, we evaluated the PaO₂ with respect to the Broca-Katsura index in obese patients in the 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.

From January 2001 to December 2013, we evaluated 472 patients aged ≥ 16 years that underwent general anesthesia for oral and maxillofacial surgery and dental procedures in our department. None of the patients had a history of smoking or respiratory or cardiopulmonary disease. All patients had an American Society of Anesthesiologists physical status of I or II. Their anesthetic charts were retrospectively reviewed for age, height, weight, percent forced vital capacity (%FVC), percent forced expiratory volume in 1 s (%FEV_{1.0}), and PaO₂. First, the patients were divided into two groups by age: 16 to <65 years and ≥ 65 years. Next, each group was divided according to the Broca-Katsura index. The Broca-Katsura index was used to determine whether a patient was obese and was calculated as follows:

$$\text{Broca-Katsura index (\%)} = \{[\text{weight in kg} - (\text{height in cm} - 100)] \times 0.9\} / (\text{height in cm} - 100) \times 0.9.$$

Patients aged ≥ 16 to <65 years were divided into four groups [9]: Group A (normal weight; Broca-Katsura index of <20%), Group B (mild obesity; Broca-Katsura index of 20% to <40%), Group C (moderate obesity; Broca-Katsura index of 40% to <60%), and Group D (severe obesity; Broca-Katsura index of $\geq 60\%$). Patients aged ≥ 65 years were divided into three groups: Group E (normal weight; Broca-Katsura index of <20%), Group F (mild obesity; Broca-Katsura index of 20% to <40%), and Group D (moderate obesity; Broca-Katsura index of 40% to <60%). Finally, Group B (mild obesity; Broca-Katsura index of 20% to <40%) was divided into five groups according to age: Group H (16 to <26 years old), Group I (26 to <36 years old), Group J (36 to <46 years old), Group K (46 to <56 years old), and Group L (56 to <65 years old).

Anesthesia was induced with intravenous propofol (1 - 2 mg/kg of ideal body weight) or thiopental sodium (3 - 5 mg/kg of ideal body weight). Muscle relaxation was provided by 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 mechanical ventilation. Nitrous oxide gas was administered if necessary. The ventilatory settings were as follows: tidal volume, 8 - 10 mL/kg of ideal body weight; respiratory rate, 10 - 12 breaths/min; peak airway pressure, <20 cm H₂O; positive end-expiratory pressure, 0 cm H₂O; and inspiratory oxygen concentration, 33%. After the patient had been stable for 30 - 60 min

from the start of the operation, blood was drawn from the radial artery or dorsalis pedis artery and analyzed for blood gas concentrations.

Values are presented as mean \pm standard deviation. Statistical analysis was performed using SPSS, version 11.0 (SPSS, Inc., Chicago, IL, USA). Statistical analysis was performed by one-way analysis of variance followed by multiple-comparison testing among groups using the Sheffe test. Differences were considered statistically significant at a p value of <0.05 .

3. Results

All patients' characteristics and laboratory data according to age and Broca-Katsura index are presented in **Table 1(a)** and **Table 1(b)**. In patients aged 16 to <65 years, there were no significant differences in age, height, %FVC, or %FEV_{1.0} among the four groups. However, there were significant differences in the body weight of Group D compared with Groups A and B, Group C compared with Groups A and B, and Group B compared with Groups A, C, and D. Furthermore, there were significant differences in the PaO₂ of Group A compared with Groups B, C, and D. The PaO₂ decreased as the Broca-Katsura index increased (**Table 1, Figure 1**). In patients aged 65 to <84 years, there were no significant differences in age, %FVC, or %FEV_{1.0} among the four groups. However, there were significant differences in the height of Group G compared with Groups E and F, in the body weight of Group E compared with Groups F and G, and in the PaO₂ of Group E compared with Groups F and G (**Table 1**).

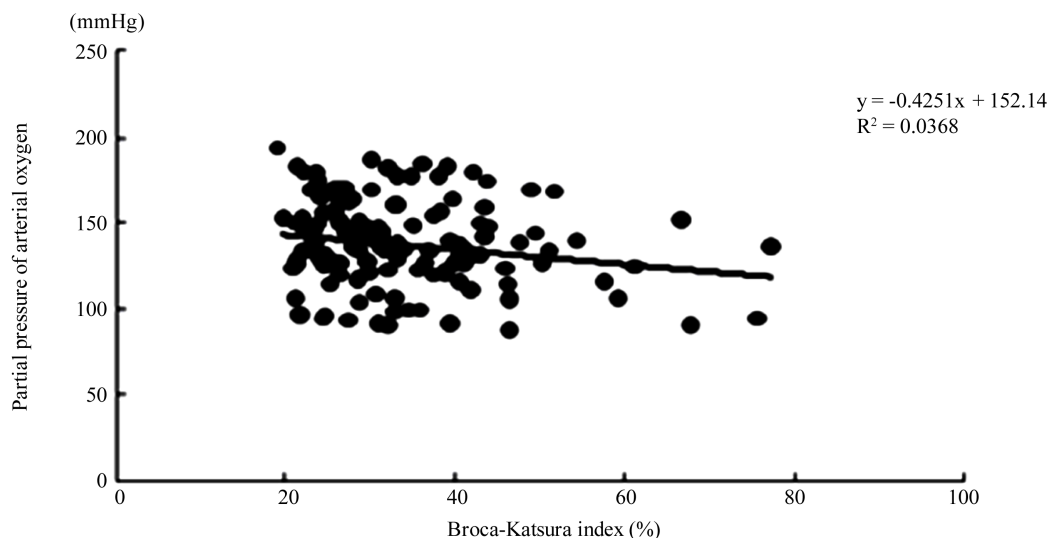
Table 1. (a) Patients' characteristics and laboratory data according to the Broca-Katsura index and age (16 to <65 years old); (b) Patients' characteristics and laboratory data according to the Broca-Katsura index and age (65 to <84 years old).

(a)				
Broca-Katsura index (%)	0 - 20	20 - 40	40 - 60	60 -
O ₂ concentration (%)	33	33	33	33
Group	A	B	C	D
Number (M:F)	208 (121:87)	109 (63:46)	27 (15:12)	5 (5:0)
Age (yrs)	43.1 \pm 14.8	45.6 \pm 13.7	41.6 \pm 14.3	41.1 \pm 16.0
Height (cm)	163.7 \pm 8.8	160.2 \pm 8.9	159.6 \pm 19.2	156.4 \pm 13.4
Weight (kg)	58.5 \pm 9.9	69.9 \pm 10.2 ^{*,#,\$}	78.2 \pm 12.5 ^{*,*}	86.6 \pm 23.1 ^{*,*}
%FVC (%)	112.5 \pm 15.6	109.8 \pm 15.8	108.8 \pm 16.0	112.8 \pm 6.8
FEV _{1.0} % (%)	82.4 \pm 5.9	82.1 \pm 6.0	83.1 \pm 4.0	86.2 \pm 2.4
PaO ₂ (mmHg)	165.7 \pm 25.6	141.8 \pm 26.9 [*]	132.7 \pm 22.2 [*]	111.7 \pm 34.6 [*]

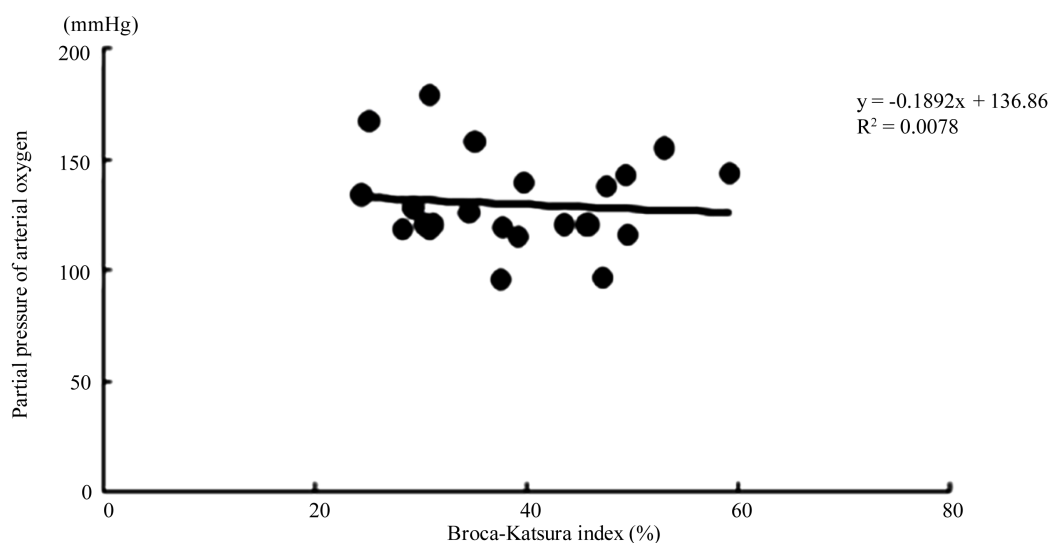
Data are presented as mean \pm standard deviation. ^{*} $p < 0.05$ vs. Group A; ^{*} $p < 0.05$ vs. Group B; [#] $p < 0.05$ vs. Group C; ^{\$} $p < 0.05$ vs. Group D

(b)			
Broca-Katsura index (%)	0 - 20	20 - 40	40 - 60
O ₂ concentration (%)	33	33	33
Group	E	F	G
Number (M:F)	101 (58:43)	13(8:5)	9 (4:5)
Age (yrs)	74.1 \pm 5.1	73.9 \pm 5.6	75.4 \pm 6.5
Height (cm)	154.7 \pm 8.5	151.6 \pm 8.2	149.0 \pm 9.7 ^{†,‡}
Weight (kg)	51.3 \pm 7.7	60.9 \pm 9.2 [†]	66.0 \pm 12.7 [†]
%FVC (%)	104.9 \pm 20.2	102.3 \pm 13.1	97.3 \pm 13.1
FEV _{1.0} % (%)	78.1 \pm 5.1	81.4 \pm 8.7 [†]	79.1 \pm 7.8
PaO ₂ (mmHg)	152.1 \pm 23.8	130.6 \pm 26.7 [†]	127.5 \pm 11.3 [†]

Data are presented as mean \pm standard deviation. [†] $p < 0.05$ vs. Group E; [‡] $p < 0.05$ vs. Group F



(a): Broca-Katsura index at 20 to <80 in group aged 16 to <65 years



(b): Broca-Katsura index at 20 to <60 in group aged 65 to <84 years

Figure 1. PaO_2 in the two main age groups according to the Broca-Katsura index at a 33% oxygen concentration. (a) Age of 16 to <65 years old. The mean PaO_2 was 165.7 ± 25.6 mmHg at a Broca-Katsura index of <20%, 141.8 ± 26.9 mmHg at a Broca-Katsura index of 20% to <40%, 132.7 ± 22.7 mmHg at a Broca-Katsura index of 40% to <60%, and 111.7 ± 34.6 mmHg at a Broca-Katsura index of $\geq 60\%$. (b) Age of ≥ 65 years old. The mean PaO_2 was 152.1 ± 23.8 mmHg at a Broca-Katsura index of <20%, 130.6 ± 26.7 mmHg at a Broca-Katsura index of 20% to <40%, and 127.5 ± 11.3 mmHg at a Broca-Katsura index of 40% to <60%. These results demonstrate that the PaO_2 tends to decrease with an increasing Broca-Katsura index in patients aged 16 to <65 years and ≥ 65 years.

The characteristics and laboratory data of patients aged 16 to <65 years with a Broca-Katsura index of 20% - 40% are presented in [Table 2](#). There were no significant differences in the %FVC or %FEV_{1.0} among the five groups. However, there were significant differences in age among the five groups; in the height of Group L compared with Groups H, I, J, and K, of Group K compared with Groups H and J, and of Group I compared with Group H; in the body weight of Group L compared with Groups H, I, J, and K and of Group K compared with Groups H and J; and in the PaO_2 of Group L compared with Groups H and I, of Group K compared with

Table 2. Characteristics and laboratory data of patients aged 16 to <65 years old with a Broca-Katsura index of 20% to ≤40%.

	aged 16 to <26 years	aged 26 to <36 years	aged 36 to <46 years	aged 46 to <56 years	aged 56 to <65 years
Group	H	I	J	K	L
Number (M:F)	19 (8:10)	11 (7:4)	21 (13:8)	35 (21:14)	23 (15:8)
Age (yrs)	19.9 ± 3.7	31.4 ± 2.6*	41.2 ± 2.7*,*	51.1 ± 3.1*,*,#	59.5 ± 2.7*,*,#,§
Height (cm)	165.8 ± 6.8	163.2 ± 5.9*	164.7 ± 7.0	159.1 ± 8.6*,#	154.4 ± 8.4*,*,#,§
Weight (kg)	77.2 ± 8.2	72.5 ± 7.7	75.1 ± 7.5	68.0 ± 9.7*,#	63.7 ± 9.3*,*,#,§
%FVC (%)	114.3 ± 19.4	113.0 ± 18.9	113.0 ± 12.9	113.2 ± 11.5	102.5 ± 16.6
FEV _{1.0} (%)	82.7 ± 6.5	85.1 ± 4.3	82.4 ± 4.5	80.9 ± 5.4	84.0 ± 6.4
PaO ₂ (mmHg)	165.0 ± 22.3	156.4 ± 18.9	139.3 ± 27.1*	131.7 ± 22.6*,*	130.9 ± 21.0*,*

Data are presented as mean ± standard deviation. * $p < 0.05$ vs. Group H; * $p < 0.05$ vs. Group I; # $p < 0.05$ vs. Group J; § $p < 0.05$ vs. Group K.

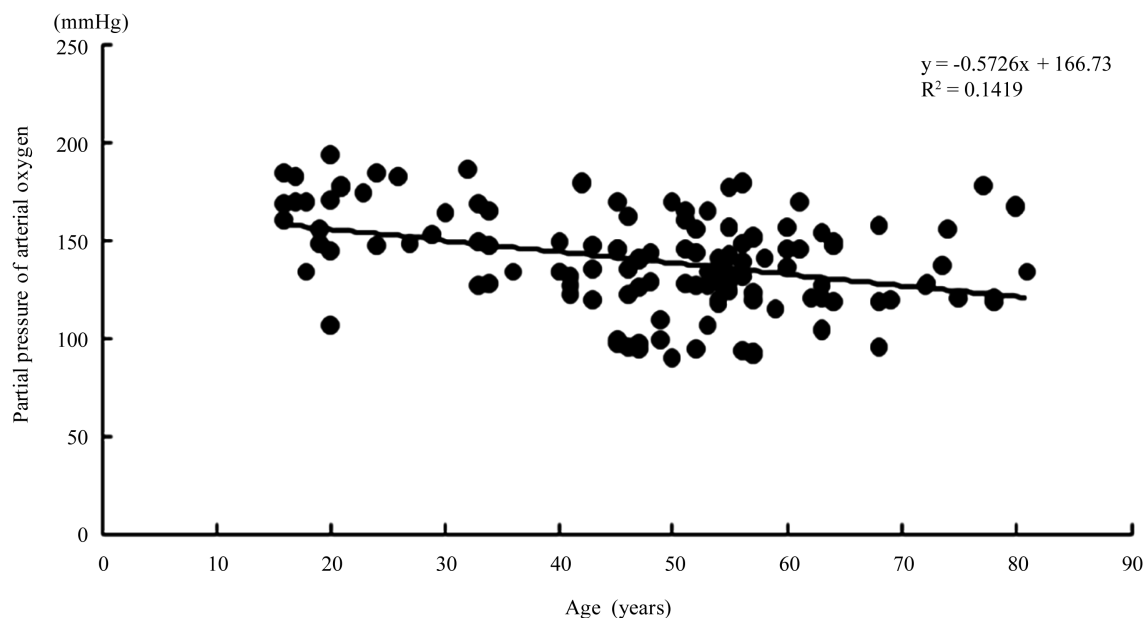
Groups H and I, and of Group J compared with Group H (Table 2). The mean of PaO₂ tended to increase with increasing age in patients aged 16 to <65 years and with a Broca-Katsura index of 20% - 40%.

In group at age of 16 to <65 years with a Broca-Katsura index of 20% to <80% (Figure 1(a)), the correlation between PaO₂ and Broca-Katsura index (20% to <80%); PaO₂ linearly decreased with increasing Broca-Katsura index ($R = 0.191$; $p < 0.05$) (Figure 1(a)), and there was a not correlation between the two. In group at age of 65 to <84 years with Broca-Katsura index at 20% to <60% (Figure 1(b)), the correlation between PaO₂ and Broca-Katsura index (20% to <60%); PaO₂ linearly decreased with increasing Broca-Katsura index ($R = 0.0881$; $p < 0.05$), and there was a not correlation between the two. In groups with Broca-Katsura index at 20% to <40% (Figure 2(a)), the correlation between PaO₂ and age; PaO₂ linearly decreased with increasing age ($R = 0.3761$; $p < 0.05$), and there was a slight correlation between the two. And in groups with Broca-Katsura index at 40% to <60% (Figure 2(b)), the correlation between PaO₂ and age; PaO₂ linearly decreased with increasing age ($R = 0.3481$; $p < 0.05$), and there was a slight correlation between the two.

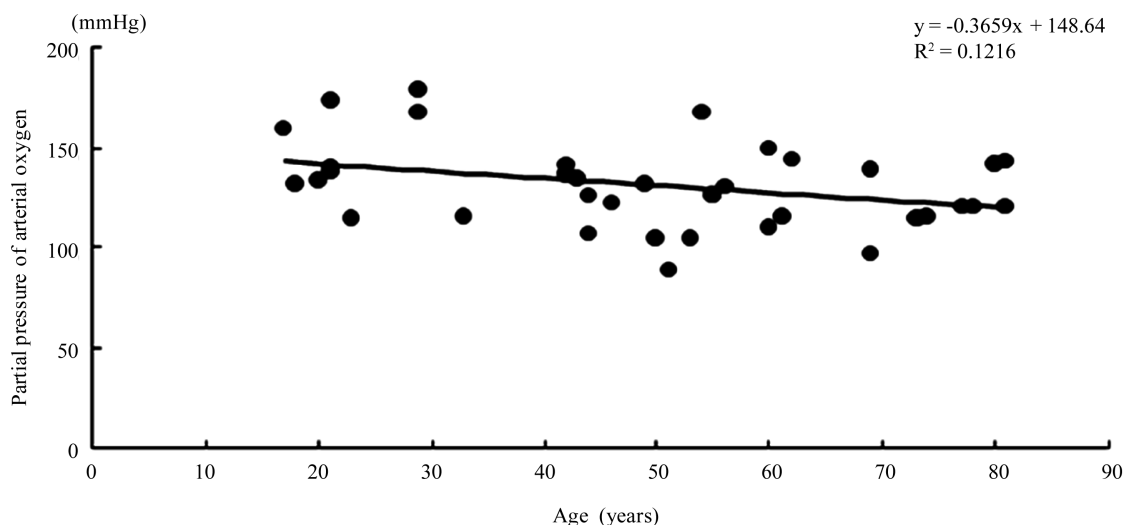
4. Discussion

In this study, we found out two important issues. The standard PaO₂ in obese patients in the supine position during general anesthesia is determined with respect to the Broca-Katsura index. The mean PaO₂ tends to decrease with an increasing Broca-Katsura index in patients aged 16 to <65 years and 65 to <84 years.

First, the standard PaO₂ in obese patients in the supine position during general anesthesia is determined with respect to the Broca-Katsura index. In the supine position, it is thought that impaired arterial oxygenation during general anesthesia is mainly attributable to the development of intrapulmonary shunting (atelectasis) and deterioration in the ventilation-perfusion relationship [6] [11] [12]. Loss of respiratory muscle tone associated with anesthetic induction and muscle paralysis presumably decrease the transverse chest area and force the diaphragm to move cephalad, leading to reduction in the functional residual capacity (FRC) and compression of dependent lung tissue (compression atelectasis) [13] [14]. Additionally, general anesthesia in the supine position induces atelectasis formation, a reduction in lung volume, and mechanical respiratory impairment that may be associated with gas exchange abnormalities [3]. Physiological pulmonary derangements in obese adults include decreases in the FRC, FVC, and FEV_{1.0} [15]. A linear relationship between increases in the body mass index (BMI) and decreases in the FRC [16]. Increases in abdominal mass and intra-abdominal pressure are expected with increases in the BMI [17]. The gravitational intra-abdominal pressure gradient likely increases with an increased load especially in the most dependent lung regions, resulting in cephalad displacement of the diaphragm and reduction in the passive movements of its dependent portions [18] [19]. Oxygenation decreased with an increasing BMI and that the main cause of this decrease was likely related to the reduction in FRC. Although the mechanisms of FRC reduction and atelectasis formation during general anesthesia are not understood, it is thought that the major causes of the decrease in oxygenation with an increasing Broca-Katsura index in the present study are likely related to reduction in the FRC and atelectasis formation induced by general anesthesia. We believe that these data can help to predict the outcome of the PaO₂ value in obese patients in the supine position during general anesthesia.



(a): Broca-Katsura index at 20 to <40



(b): Broca-Katsura index at 40 to <60

Figure 2. PaO₂ in the various age groups according to a Broca-Katsura index of 20% to <40% at a 33% oxygen concentration. The mean PaO₂ was 165.0 ± 22.3 mmHg in patients aged 16 to <26 years, 156.4 ± 18.9 mmHg in patients aged 26 to <36 years, 139.7 ± 27.1 mmHg in patients aged 36 to <46 years, 131.7 ± 22.6 mmHg in patients aged 46 to <56 years, and 130.9 ± 21.0 mmHg in patients aged 56 to <65 years. The PaO₂ tended to decrease with age in patients aged 16 to <65 years with a Broca-Katsura index of 20% to <40%.

Second, the mean PaO₂ tends to decrease with an increasing Broca-Katsura index in patients aged 16 to <65 years and 65 to <84 years. In this study, when the mean PaO₂ was evaluated by Broca-Katsura index, the mean PaO₂ tended to decrease with an increasing Broca-Katsura index and there were significant differences among groups (Table 1, Table 2). But there was not a correlation between PaO₂ and Broca-Katsura index (20% to <80%) in group at age of 16 to <65 or Broca-Katsura index at 20% to <60% in group at age of 65 to <84 since the correlation between PaO₂ and Broca-Katsura index was low ($R < 0.200$). The PaO₂ might linearly decrease with increasing age with Broca-Katsura index at 20% to <40% or at 40% to <60% since there was a slight correlation between PaO₂ and age (Figure 2(a), Figure 2(b)). Nevertheless, we believe that these data can help to

predict the outcome of the PaO₂ value in obese patients in the supine position during general anesthesia.

5. Conclusion

The standard PaO₂ in obese patients in the supine position during general anesthesia is determined with respect to the Broca-Katsura index and the mean PaO₂ tends to decrease with an increasing Broca-Katsura index in patients aged 16 to <65 years old and 65 to <84 years old. Though there was not a correlation between PaO₂ and Broca-Katsura index, there was a slight correlation between PaO₂ and age. We believe that the data provide reliable information on the value of PaO₂ and are clinically useful for management of anesthesia.

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Conflicts of Interest

Kenichi Satoh, Mami Chikuda, Ayako Ohashi, Miho Kumagai, Akiyoshi Kuji, and Shigeharu Joh have no conflicts of interest.

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Abbreviations

%FVC: % forced vital capacity;

FEV_{1.0} %: forced expiratory volume 1.0 second %;

PaO₂: arterial partial pressure of oxygen.