The Relationship of Sevoflurane Consumption with Metabolic Age and Basal Metabolic Rate- A Prospective Observational Study

Sevofluran Tüketiminin Metabolik Yaş ve Bazal Metabolizma Hızı ile İlişkisi- Prospektif Gözlemsel Bir Çalışma

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Objective: Sevoflurane is usually administered according to the minimum alveolar concentration. Age is an important variable affecting the minimum alveolar concentration and it should be kept in mind that two individuals of the same chronologic age may have different metabolic ages. The purpose of this study is to evaluate the relationship between metabolic age, chronological age and sevoflurane consumption in patients with sufficient depth of anesthesia.

Materials and Methods: This prospective observational study included 79 ASA I–II patients aged 18–65 years undergoing elective rhinoplasty or septoplasty. Preoperative bioelectrical impedance analysis (Tanita BC-418 MA, Japan) was used to determine chronological and metabolic age along with other metabolic parameters. General anesthesia was standardized with propofol, fentanyl, rocuronium, and sevoflurane titrated to a BIS of 40–60. Patients were grouped using the percentage age-difference formula: Group A, <–6.6%; Group B, –6.6% to 11.7%; Group C, >11.7%, and total sevoflurane consumption was recorded.

Results: The study included 79 patients, 29.1% of whom were women. The mean chronologic and metabolic ages of the patients were 31.29 ± 11.9 and 30.42 ± 12.89 years, respectively. A significant difference was seen between chronologic and metabolic age and total sevoflurane consumption (p=0.006; p=0.007) and a weak negative correlation was observed (r= -0.304; r=-0.301). When the sevoflurane consumption amounts of the groups were compared, a notable difference was observed among the three groups (p<0.001). Sevoflurane consumption was higher in patients whose metabolic age was younger than chronologic age compared to other groups..

Conclusion: Metabolic age was associated with sevoflurane consumption, and the amount of sevoflurane consumed decreased in patients whose metabolic age was older than chronological age.

Keywords: Sevoflurane, Sevoflurane Consumption, Metabolic Age, Body Composition Analysis.

Amaç: Anestezi idamesinde yaygın kullanılan inhaler ajanlardan sevofluran genellikle minimum alveolar konsantrasyona (MAK) göre uygulanmaktadır. MAK için yaş önemli bir değişkendir. Aynı kronolojik yaştaki iki birey farklı metabolik yaşa sahip olabilir. Çalışmamızda sevofluran ile yeterli anestezi derinliği sağlanan hastalarda metabolik yaş ve kronolojik yaş ile sevofluran tüketimi arasındaki ilişkiyi değerlendirmeyi amaçladık.

Gereç ve Yöntem: Bu prospektif gözlemsel çalışmaya, elektif rinoplasti veya septoplasti geçiren 18-65 yaş arası 79 ASA I-II hasta dahil edildi. Ameliyat öncesi biyoelektrik empedans analizi (Tanita BC-418 MA, Japonya), diğer metabolik parametrelerle birlikte kronolojik ve metabolik yaşı belirlemek için kullanıldı. Genel anestezi, BIS 40-60'a titre edilen propofol, fentanil, rokuronyum ve sevofluran ile standardize edildi. Hastalar yaş farkı yüzdesi formülüne göre gruplandırıldı: Grup A, <–%6,6; Grup B, -%6,6 ila %11,7; Grup C, >%11,7 ve toplam sevofluran tüketimi kaydedildi.

Bulgular: 79 hastanın %29.1'i kadındı. Hastaların kronolojik yaş ortalaması 31.29 ± 11.9, metabolik yaş ortalaması 30,42 ± 12,89 idi. Kronolojik yaş ve metabolik yaş ile total sevofluran tüketimi arasında istatistiksel olarak anlamlı fark saptandı (p=0,006; p=0,007), ve negatif yönde zayıf korelasyon gözlendi (r= -0,304; r= -0,301). Grupların sevofluran tüketim miktarları karşılaştırıldığında üç grup arasında belirgin fark gözlendi (p<0,001). Metabolik yaşı kronolojik yaşından küçük olan hastalarda sevofluran tüketimi diğer gruplara göre daha yüksekti.

Sonuç: Metabolik yaşın sevofluran tüketimi ile ilişkili olduğu ve metabolik yaşı kronolojik yaşından büyük olan hastalarda sevofluran tüketim miktarı azaldı.

Anahtar Kelimeler: Sevofluran, Sevofluran Tüketim Miktarı, Metabolik Yaş, Vücut Kompozisyon Analizi.

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INTRODUCTION

Sevoflurane is a frequently utilized inhalation agent in anesthesia practice, administered primarily according to the minimum alveolar concentration (MAC) for both induction and maintenance. Age is a crucial factor influencing MAC, which decreases by approximately 6% per decade with advancing age. Although chronological age is a considerable risk factor for adverse clinical outcomes, individuals with the identical chronological age can exhibit varying states of biological aging (Stachnik et al., 2006).

Metabolic age indicates the age defined by body mass index, weight, body fluid and fat conditions. Several factors, including age, race, gender, physical activity, pregnancy, medical conditions, and diet, play a role in influencing body balance (Pietrobelli et al., 2004). Various body composition analysis methods can provide access to many values such as metabolic age and basal metabolic rate (BMR). Bioelectrical impedance analysis (BIA) is a dependable technique for evaluating body composition, along with medical statistical methods, to identify patterns based on age, sex and other relevant parameters. In addition, this method is easy, fast, inexpensive and non-invasive. The Tanita BC-418 MA works with the BIA method and was shown to be a reliable tool when compared to the dual-energy X-ray absorptiometry in 2004. After this year, Tanita BC-418 MA has been used safely in body composition analysis in many studies (Tannir et al., 2022; Leuciuc et al., 2021).

Reducing the consumption of inhalation agents is one of the focal points of this study. This is because these agents remain in the atmosphere for an extended period with minimal in vivo metabolism, leading to significant environmental impacts such as climate change and global warming (Colak & Toprak, 2021). Additionally, it increases the costs of healthcare services. Strategies aimed at reducing the usage of inhalation anesthetics are being investigated to decrease these costs (Alnemri et al., 2022).

In our study, we planned to evaluate the relationship between metabolic age, chronological age and the amount of sevoflurane consumption in patients where adequate depth of anesthesia was achieved with sevoflurane. Through this, our goal was to reduce hospital costs and prevent environmental pollution by minimizing sevoflurane consumption.

MATERIALS AND METHODS

Study design and population

Our study is a prospective observational study covering 6 months. The study was directed in conformity with the Declaration of Helsinki-2013. Ethical approval has been acquired from the Malatya Medical Center Clinical Research Institutional Review Board (protocol no:2022/92) recruitment start date of September 10, 2022, and recruitment end date of March 3, 2023. From the included patients, informed consent was obtained preoperatively (Clinical Trials ID: NCT06018597).

In the power analysis, it was calculated that a minimum of 76 patients is required to detect a significant difference with a type 1 error rate (alpha) of 0.05, a statistical power (beta) of 0.8, and an effect size of 0.10 in our study. This is about the relation between sevoflurane consumption and metabolic age, as well as basal metabolic rate.

A total of 85 cases, aged between 18 and 65, planning for rhinoplasty or septoplasty, classified as ASA I-II, and surgical duration between 1-3 hours, were included in the study. Patients with BMI less than 16.5 kg/m² or greater than 35 kg/m², classified as ASA III or ASA IV, having a history of allergic reactions to anesthesia or the medications planned for use in the study, at high risk of malignant hyperthermia, and presenting with hypoxia, hypothermia, hyperthermia, electrolyte imbalance, severe hypotension, anemia, liver or kidney damage, neurological or psychiatric diseases, or cardiovascular or

respiratory system disorders, were excluded, resulting in the evaluation of 79 patients (Figure 1).

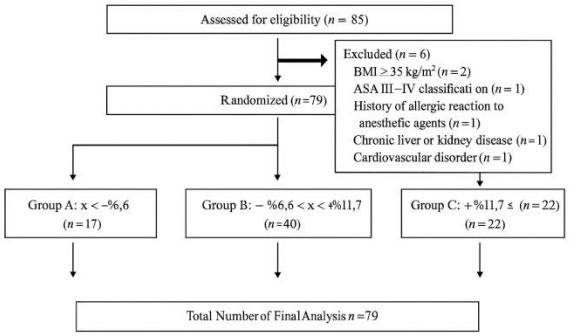

Figure 1. CONSORT flow diagram of study

Anthropometric measurements

All patients participating in the study were instructed to fast overnight, avoid from alcohol and exhausting physical activity for 24 hours, as part of the preoperative evaluation. On the day of surgery, anthropometric measurements were taken 2 hours before surgery. Body composition analysis and metabolic age measurements were conducted using the BIA method with Tanita BC-418 MA (Tokyo, Japan).

The weight of volunteer patients was measured using a digitalscaleintegratedintotheTanita BC-418 MA bioimpedance analyser, rounded to the closest 0.1 kg. An anthropometer was used to measure height, rounded off to the closest 0.1 cm.

Anthropometric metrics were recorded usage a single-frequency bioimpedance analyser Tanita BC-418 MA operating at 50 kHz with eight-point contact electrodes. The system comprises a platform with stainless steel foot pads and two hand grips with stainless steel contact points. The platform consists of four pairs of contacts, with two contacts for each foot and one pair of contacts for each hand grip. Measurements were taken while the patient was standing barefoot, wearing light clothing, and with arms slightly bent. The recorded measurements include weight, Body Mass Index (BMI), ideal body weight, body fat percentage, fat mass, lean body weight, muscle mass, BMR, metabolic age, and degree of obesity. The measurements were performed using the same device and following the instructions for use.

Anesthesia Management

Patients admitted to the surgery room without premedication received routine monitoring, including, heart rate, cuff-based blood pressure monitoring, electrocardiogram, Bispectral Index (BIS), Train of Four (TOF), and fingertip oxygen saturation. The Aspect A 2000 monitor (Aspect Medical Systems, Newton) was used for bispectral Index monitoring. In this study, the total amounts of consumed sevoflurane and MAC values were tracked using the Draeger Primus anesthesia machine (Dräger, Lübeck, Germany). After routine monitoring, peripheral venous access was established in patients using an 18-gauge catheter, and induction was initiated with lidocaine (Aritmal® 2%) at 0.5 mg/kg, propofol (®Lipuro 1%) at 2,5 mg/kg, and fentanyl (Talinat® 0.5mg/10ml) at 1-2 µg/kg. Following the achievement of anesthesia depth, the ulnar nerve at the wrist was stimulated every 15 seconds with square wave stimuli of 0.2 ms duration and 50 mA intensity, given in a TOF mode. Subsequently, a dose of 0.6 mg/kg rocuronium (Esmeron®) was administered to the patients. TOF-Watch SX with the four-stimulus method was used to measure neuromuscular agent effectiveness, and intubation was performed orally when the TOF value reached 0.

Controlled ventilation was maintained in volume-controlled mode with a tidal volume of 6-8 ml/kg, respiratory rate of 10-14/min, EtCO2 value between 35-45 mmHg. Following intubation, for anesthesia maintenance until the BIS reached 40-60, patients were initially administered a mixture

of sevoflurane and 50% oxygen at a flow rate of 4 L/min, and the time to reach the target was recorded. The fresh gas flow was then reduced to 1 L/min, the sevoflurane dose was adjusted to sustain a BIS of 40-60 throughout the case. For intraoperative analgesia, all patients received a infusion of remifentanil at a rate of 0.05 µg/kg/min. For postoperative analgesia, intravenous paracetamol (10 mg/kg) and tramadol (1 mg/kg) were administered. At the end of the surgery, all anesthetic agents were discontinued. After achieving a TOF value of 75% and ensuring spontaneous breathing, neuromuscular blockade was reversed with 50 µg/kg neostigmine and 20 µg/kg atropine. Extubation was performed when the TOF value reached 90%.

The below parameters have been saved at the beginning of surgery and during perioperative monitoring: peripheral oxygen saturation (SpO2), systolic arterial pressure (SAP), diastolic arterial pressure (DAP), mean arterial pressure (MAP), heart rate (HR), BIS, MAC and end-tidal carbondioxide (EtCO2) values.

The operation duration, anesthesia duration, extubation duration, time to eye opening, total sevoflurane consumption, oxygen consumption, and air consumption were recorded during the case. In the recovery unit, consciousness, activity, respiration, circulation, and SpO2 status were measured according to the Modified Aldrete Sedation Score (MASS) at the10th, 20th, and 30th minutes. This score was documented along with the Ramsey sedation scale score evaluated at the same time points. Cases with MASS scores ≥9 were transferred to the service.

Statistical analysis and ethical aspects

The data analysis was conducted using IBM© SPSS© Statistics (version 25 for Windows, IBM Corporation, Armonk, New York, USA). For the normality analysis, the Shapiro-Wilk test, histogram distribution, and skewness-kurtosis parameters were employed. Descriptive statistics were utilized, including mean ± standard deviation for normally distributed variables, median (min–max) for non-normally distributed variables, and frequencies with percentages for nominal variables.

In the statistical analyses, one-way analysis of variance (ANOVA) was used for data demonstrating a normal distribution, while the Kruskal-Wallis test was employed for data not showing a normal distribution. Following significant one-way ANOVA results for homogeneously distributed variables (according to Levene's homogeneity test), Tukey's test was applied. Fornon-homogeneous variables, Tamhane's post hoc tests were conducted. For non-parametric variables, after a significant Kruskal-Wallis test, the Mann-Whitney U test with Bonferroni correction was applied.

In the analysis of continuous variables, the Pearson correlation test was used for parametric variables, and the Spearman correlation test was used for non-parametric variables. ROC (Receiver Operating Characteristic) analysis was conducted to determine the cut-off value for continuous variables, and sensitivity and specificity values were determined.

A p-value less than 0.05 was considered statistically significant.

In the study, the percentage age difference formula was used to standardize the association with the amount of sevoflurane usage in elderly and young patients among the chronological and metabolic ages of the patients.

Percentage Age Difference= (Chronological age - Metabolic age)/Chronological age

This formula showed us that the distinction among the patient's chronological age and metabolic age is the percentage of the patient's age. Subsequent calculations were

based on the percentage value of the distiction among chronological age and metabolic age.

RESULTS

A total of 79 patients were included in this study, consisting of 23 females (29.1%) and 56 males (70.9%). The mean chronological age of the patients was 31.29 ± 11.9 years, the mean metabolic age was 30.42 ± 12.89 years, and the average BMR was 1617.52 ± 260.7 cal. The mean sevoflurane consumption rate was 0.19 ± 0.04 ml/min (Table 1).

Table 1. Patient characteristics and sevoflurane consumption of the patients

		Mean	Standard Deviation	Minimum - Maximum
Chronological Age		31.29	11.90	18-62
Metabolic Age		30 .42	12.89	14-63
Gender	Female n(%)	23 (29.1)		
	Male n(%)	56 (70.9)		
Weight (kg)		68.92	13 .92	36.90-105.70
Length (cm)		171.09	7 .99	148-188
BMI (kg/m^2)		23.51	4 .37	13.90-32.00
BMR (cal)		1617.52	260.70	1038-2369
Sevoflurane Consumption (ml/min)		0.19	0.04	0.09-0.30

Values are presented as mean ± SD or number (%).BMR: Basal metabolic rate, BMI: Body Mass Index.

As detailed in the Methods section, percentage age difference values were calculated and used for the analysis.

According to the percentage age difference value, two separate ROC analyses were performed in positive (+) and negative (-) directions and two separate significance values were determined. A positive percentage age difference indicates patients whose chronological age is older than their metabolic age, and a negative percentage age difference indicates patients whose metabolicage is older than their calendar age.

Upon examining the ROC analysis with a positive orientation, we observed that the area under the curve (AUC) was 0.737 when the cut-off value of the percentage age difference was 11.7% (p=0.0012). The sensitivity and specificity of this cut-off value were 63% and 88%, respectively. Upon examining the ROC analysis with a negative orientation, it was observed that the area under the curve (AUC) was 0.701 when the cut off value of the percentage age difference was -6.6% (p=0.029). The sensitivity and specificity of this cut-off value was 68% and 75%, respectively (Table 2, Figure 2).

Patients were divided into three groups based on these positive and negative cut-off values obtained by ROC analysis:

Group A: x < (-%6,6): Those with a Percent Age Difference less than -6.6%

Group B: (-%6,6) < x < (+%11,7): Those with a Percent Age Difference between -6.6% and 11.7%

Group C: (+%11,7) < x: Those with a Percent Age Difference greater than 11.7%.

Table 2. Two Separate Positive and Negative ROC Analysis by Percentage Age Difference

Percent Age Difference Cut-off	AUC	p	%95 Confidence Interval		Sensitivity	Specificity
			Lower Limit	Upper Limit		
Positively %11.7	0.737	**0.0012**	0.590	0.854	63	88
Negatively -6.6%	0.701	**0.029**	0.520	0.845	68	75

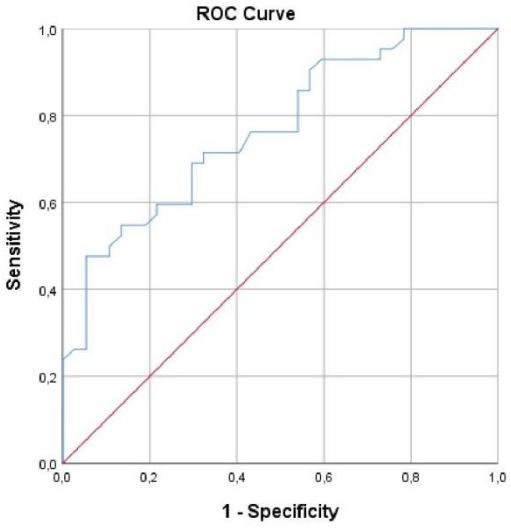

Figure 2. ROC Analysis Plot between Percent Age Difference and Sevoflurane Consumption Calculated According to Metabolic Age

In two-way comparisons, Group A was found to be higher than Groups B and C in terms of weight, BMI, fat mass and obesity degree ($p<0.001$). When comparing the groups in terms of fat-free mass and muscle mass, no statistically significant differences were observed among these three groups (fat-free mass $p = 0.258$; muscle mass $p = 0.340$). Similarly, no statistically significant difference was observed among the groups when comparing the patients' BMI ($p = 0.118$). However, a statistically considerable difference was noted among the groups when evaluating the BMR per kilogram of weight (BMI/weight) score ($p <0.001$). In bidirectional comparisons, the difference between Group A and Group B, as well as between Group A and Group C, was significant (Table 3).

When the groups were compared in terms of sevoflurane consumption rate per minute, a remarkable difference was found among these three groups (Grup A: 0.164 +0.05ml/min, Grup B: 0.199±0.07 ml/min, Grup C: 0.297±0.06 ml/min) ($p <0.001$). In pairwise comparisons, the difference between Group A and Group C as well as the difference among Group B and Group C was found to be significant. The amount of sevoflurane consumed in Group C was more than in the other groups (Table 3).

Table 3. Comparison of metabolic parameters according to groups

	Group A (n=17)	Group B (n=40)	Group C (n=22)	p
Weight (kg)	81.31±17.21$^{\alpha,\beta}$	66.71±11.89$^{\alpha}$	63.40±8.14$^{\beta}$	**<0.001**
Length (cm)	169.06±9.40	170.78±7.47	173.23±7.60	0.258
BMI (kg/m^2)	28.21±4.38$^{\alpha,\beta}$	22.88±3.87$^{\alpha}$	21.02±1.89$^{\alpha,\beta}$	**<0.001**
Ideal Weight (kg)	64.96 ±7.06	66.16±7.02	66.62±5.51	0.733
Free-Fat Mass (kg)	57.84±12.99	55.96± 8.32	53.25±7.13	0.258
Muscle Mass (kg)	54 .41±12.34	51.29±7.91	50.40±6.92	0.340
Fat Mass (kg)	23.45±6.30$^{\alpha,\beta}$	12.73±6.80$^{\alpha}$	10.05±2.75$^{\beta}$	**<0.001**
Oil Content (%)	28.47±6.25$^{\alpha,\beta}$	18.29±8.24$^{\alpha}$	16.35±4.21$^{\beta}$	**<0.001**
Degree of Obesity	24.09±18.82$^{\alpha,\beta}$	0.88±14.29$^{\alpha}$	-4.74 ± 8.15$^{\beta}$	**<0.001**
BMR (cal)	1731.88±378.6	1593.85±222.61	1572.2±193.3	0.118
BMR/Weight (cal/kg)	21.47±2.29$^{\alpha,\beta}$	24.16±2.26$^{\alpha}$	24.87±1.81$^{\beta}$	**<0.001**
Oxygen Consumption (l)	138.00±49.34	128.38 ± 42.63	140.18 ±34.34	0.515
Air Consumption (l)	68.12 ±29.56	66.30±24.77$^{\alpha}$	84.95±26.39$^{\alpha,\beta}$	**0.027**
Sevoflurane Consumption (ml/min)	0.164±0.05^{a}	0.199±0.07$^{\beta}$	0.297±0.06$^{\alpha,\beta}$	**<0.001**

Values are presented as mean ± SD or number (%).
BMR: Basal metabolic rate, BMI: Body Mass Index
$^{\alpha,\beta}$The same upper letters indicate the groups with a significant difference. $p<0.05$ is statistically significant.

When hemodynamic data were investigated, no statistically remarkable difference was seen between the groups in repeated measurements at all time points ($p >0.05$). Similarly, the recorded MAC and BIS values were comparable between all groups at all time points. In the postoperative evaluation, duration of anesthesia, length of surgery, extubation time, postoperative Ramsey score and MASS groups were statistically similar ($p > 0.05$) (Table 4).

Table 4. Comparison of the recovery parameters of the groups

	Group A (n=17)	Group B (n=40)	Group C (n=22)	p
Extubation Time (min)	8.412±2.76	8.06 ±2.76	8.27±2.62	0.895
Eye Opening Time (min)	10.94±3.07	10.38±2.95	11.36±3.24	0.465
MASS 9 Time (min)	12.65±3.22	12.35 ±3.43	13.00±3.38	0.767
Time of Anaesthesia (min)	123.53±36.17	116.25±37.94$^{\alpha}$	143.18±30.61$^{\alpha,}$	**0.021**
Surgical Time (min)	108.53±36.17	101.25±37.94$^{\alpha}$	128.18±30.61$^{\alpha,}$	**0.021**

Values are presented as mean ± SD or number (%).
$^{\alpha, \beta}$The same upper letters indicate the groups with a significant difference. $p<0.05$ is statistically significant.

DISCUSSION

In our study, a significant difference was observed between the amount of sevoflurane consumed during surgery and both chronological and metabolic age ($p = 0.006$, $p = 0.007$), showing a weak negative correlation ($r = –0.304$, $r = –0.301$). When sevoflurane consumption was compared between groups, a statistically remarkable difference was found ($p < 0.001$). Sevoflurane consumption was higher in Group C patients, whose metabolic age was younger than chronological age. Furthermore, it was observed that factors such as weight, BMI, fat mass, and degree of obesity were inversely associated with sevoflurane consumption. To our knowledge, there is no similar study in the literature evaluating the relationship between metabolic age, chronological age, and sevoflurane consumption.

Although all cases in our study were managed with low-flow anesthesia (1 L/min), which is known to decrease volatile anesthetic use, this condition was standardized for all participants. Therefore, the observed differences in sevoflurane consumption cannot be attributed to the anesthesia technique itself, but rather to physiological variations related to metabolic age. It can be suggested that patients with a younger metabolic profile have higher tissue perfusion and oxygen utilization, resulting in greater distribution of volatile anesthetics and higher consumption. Conversely, patients with a higher metabolic age relative to their chronological age may exhibit decreased metabolic activity and tissue uptake, leading to lower anesthetic requirements despite equivalent BIS values (40–60). These findings indicate that metabolic age may independently influence anesthetic pharmacodynamics under identical anesthetic and monitoring conditions.

Monitoring the depth of anesthesia is crucial to prevent complications such as excessive sedation, delayed emergence, and hemodynamic instability (Monk et al., 2005). While the depth of inhalational anesthesia is typically monitored by MAC tracking (Pandit et al., 2013), MAC values are known to decline with increasing age (Griffiths et al., 2014). The use of BIS has become common practice for maintaining adequate anesthetic depth and facilitating recovery (Aho et al., 2015; Morimoto et al., 2006; Poon et al., 2020; Hagihira et al., 2004). However, Georgevici et al. (2021) showed that a constant MAC value does not always correspond to a stable depth of sedation, emphasizing the need for continuous EEG or BIS monitoring. Punjasawadwong et al. (2014) found that BIS monitoring during anesthesia reduced the requirement for volatile agents by 65%. In studies by Kanazawa et al. (2016; 2017) and Matsuura et al. (2009), it was demonstrated that alveolar concentrations of desflurane and sevoflurane required to maintain a BIS of 50 decrease with advancing age, even at equivalent MAC levels. Similarly, in our study, despite maintaining BIS values between 40–60, sevoflurane consumption varied significantly across metabolic age groups, supporting the hypothesis that physiological rather than chronological aging may play a role in anesthetic demand.

Chronological age reflects the passage of time but does not necessarily correspond to biological function, as individuals of identical chronological age may exhibit different physiological and metabolic profiles (D'Agostino et al., 2008). Bioelectrical impedance analysis (BIA) is a simple, inexpensive, and non-invasive tool for assessing body composition, providing information about fat mass, muscle mass, and metabolic age (Kyle et al., 2004). In our study, BIA was used to determine metabolic age, BMR, and other anthropometric parameters. Previous studies have confirmed the reliability of segmental BIA in estimating body composition compared to DEXA (Pietrobelli et al., 2004).

Recent research has drawn attention to the clinical significance of metabolic age. Yabuta et al. (2016) demonstrated that individuals with identical chronological ages can exhibit different physiological aging rates due to genetic and lifestyle factors. Similarly, Gunn et al. (2009) and Elguezabal-Rodelo et al. (2021) showed that metabolic age better reflects cardiovascular and metabolic risk than chronological age. Donma & Donma (2019) reported a mean chronological age of 43.2 ± 16.0 years and metabolic age of 46.3 ± 16.3 years in 287 participants, while Gerald & Eclaire (2020) observed a –5 to –8 year difference between chronological and metabolic age in 2.1 million people. Mehrdad et al. (2021) found corresponding mean values of 43.0 ± 8.7 years and 41.1 ± 12.5 years. In our study, the mean chronological and metabolic ages were 31.29 ± 11.90 and 30.42 ± 12.89 years, respectively. The lower average values in our cohort likely reflect the exclusion of patients with BMI < 16.5 kg/m² or > 35 kg/m².

Low-flow (1 L/min) and minimal-flow (0.5 L/min) anesthesia techniques substantially reduce anesthetic waste (Odin & Feiss, 2005). Modern anesthesia machines enable continuous end-tidal gas monitoring, ensuring the safety of low-flow anesthesia (Lerou & Booij, 2001). Therefore, the observed variations in sevoflurane consumption in our study cannot be attributed to differences in flow rates but rather to metabolic differences. BIS-guided anesthesia management has been shown to reduce volatile anesthetic use and cost (Tyagi et al., 2014; Nair et al., 2013; Miller et al., 2016). Consistent with these reports, our findings support that metabolic age differences may contribute to variations in anesthetic consumption even under standardized BIS-guided, low-flow conditions.

The practical implication of our results is that preoperative assessment of metabolic age may help predict anesthetic requirements more accurately than chronological age alone. Incorporating metabolic age estimation into preoperative evaluation could guide anesthesiologists in adjusting vaporizer settings and volatile agent delivery more precisely. This individualized approach may optimize anesthetic dosing, minimize drug wastage, and improve recovery quality, particularly in patients with atypical metabolic profiles or body compositions.

Strengths and Limitations

The study has some restrictions. These consist of the single-center nature of the study and the comparatively low average chronological age of our patient group, which is associated with the selected surgeries. We believe that an increase in the average chronological age would yield more significant findings. Similarly, our study included patients with a specific range of BMI. Our results indicate an association between BMI and metabolic age. Further research should investigate whether maintaining a wider range of BMI could provide more meaningful results.

CONCLUSION

In conclusion, patients with a metabolic age higher than their chronological age consumed less sevoflurane under BIS-guided low-flow anesthesia. Considering the metabolic age of patients during anesthesia maintenance may

help optimize sevoflurane usage. However, the differences in key parameters such as BMI between the groups, the relatively small sample size, and the predominance of younger patients may limit the generalizability of these findings. Therefore, further studies with larger and more diverse populations are needed to validate the applicability of this approach.

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Conflict of interest: The authors have no conflicts of interest to declare.

Ethics approval and consent to participate: Ethical approval for this study was obtained from Malatya Medical Center clinical research ethics committee on 3.03.2023. Decision number: 2022/92

The study was conducted in line with the principles of the "Helsinki Declaration."

Availability of Data and Materials: The datasets from the current study can be obtained on request from the corresponding author.

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