

COMPARISON OF THE HEMODYNAMIC EFFECTS OF SEVOFLURANE AND DESFLURANE USING A THORACIC ELECTRICAL BIOIMPEDANCE MONITOR

SEVOFLURAN VE DESFLURANIN HEMODİNAMİK ETKİLERİNİN TORASİK ELEKTRİKSEL BİYOEMPEDANS YÖNTEMİ İLE KARŞILAŞTIRILMASI

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ABSTRACT

Purpose: It is important to maintain cardiovascular stability and to avoid dangerous effects on the cardiovascular system during general anesthesia. Our aim is to compare the hemodynamic effects of sevoflurane and desflurane using a thoracic electrical bioimpedance (TEB) monitor. **Methods:** We randomized 40 patients, aged 20-60, ASA I-II group, into two groups. Anesthesia was induced with 7 mg/kg sodium thiopental, 1 µg/kg fentanyl and 0.1 mg/kg vecuronium bromide. After intubation, 2% sevoflurane and 6% desflurane were given with 50% N₂O and O₂ to Group I (n=20) and Group II (n=20), respectively. Before anesthesia 8 TEB and 5 ECG (DII and V5) electrodes were placed and the patients were monitored using a NCCOM3-R7 (BOMED CO, USA) TEB monitor, which was adjusted according to the Bernstein-Sramek equality. The heart rate (HR), mean arterial pressure (MAP), cardiac index (CI) and stroke index (SI) of the patients were measured before induction (t1), 5 min after intubation (t2), 5 min after surgical incision (t3), on the 10th min (t4), on the 20th min (t5) and 5 min after extubation (t6). The results were evaluated by Student's t-test, chi-square test and repeated measure ANOVA. **Results:** Patients in the two groups did not differ in physical characteristics or the basal values of hemodynamic parameters. HR values were decreased significantly at times t4 and t5 in the two groups (p<0.05). There was a significant decrease in MAP at t2, t3, t4 and t5 in both groups. CI and SI values were decreased significantly at t2, t3, t4, t5 and t6 compared to t1 in both groups (p<0.001). **Conclusion:** Desflurane has effects on the cardiovascular system similar to those of sevoflurane.

Key Words: Inhalational Anesthetics, Sevoflurane, Desflurane, Hemodynamic Effects.

ÖZET

Amaç: Genel anestezi sırasında kardiyovasküler stabilitenin devam ettirilmesi, kalp hızı, kan basıncı, kardiyak ritim ve bölgesel kan akımı üzerindeki zararlı etkilerden kaçınılması oldukça önemlidir. Çalışmamızda sevofluran ile desfluranın hemodinamik etkilerini torasik elektriksel biyoempedans yöntemi ile karşılaştırmayı amaçladık. **Metod:** Çalışmada 20-60 yaşları arasında ASA I-II 40 hasta rastgele olarak 20'şer kişilik 2 gruba ayrıldı. İndüksiyon 7 mg/kg sodyum tiyopental ve 0,1 mg/kg vekuronyum bromid ile yapıldı. İntübasyon sonrası 2% sevofluran ve 6% desfluran ile 50% N₂O ve % 50 O₂ ile sevofluran %2 veya desfluran %6 konsantrasyonlarda ile uygulandı. Hastalara 8 TEB elektrodu ve 5 EKG elektrodu takıldı. Bunlar Bernstein-Sramek eşitliğine göre düzenlenmiş NCCOM-3R7 (BOMED CO, ABD) TEB monitörüne bağlandı. Hastaların kalp hızı (KH), ortalama arter basıncı (OAB), kardiyak indeks ve hacim indeksi değerleri, indüksiyon öncesi (t1), entübasyondan 5 dakika sonra (t2), cerrahi insizyondan 5 dakika sonra (t3), takip eden 10. dakika. (t4) ve 20. dakikada (t5) son olarak da ekstübasyondan 5 dakika (t6) sonra kaydedildi. Sonuçlar Student's t testi, Ki-kare testi ve Tekrarlı Ölçümlerde İki Yönlü Varyans Analizi yöntemleri ile değerlendirildi. **Bulgular:** Hasta özellikleri ve hemodinamik parametrelerin başlangıç değerleri bakımından istatistiksel bir farka rastlanmamıştır. KH değerlerinde her iki grupta da t4 ve t5'de başlangıca göre düşüş olmuştur (p<0,05). OAB değerlerinde t2, t3, t4 ve t5'de her iki grupta da düşme olmuştur (p<0,05). Kardiyak indeks ve atım hacmi indeksi değerleri her iki grupta da başlangıca göre 2., 3., 4., 5. ve 6. zaman dilimlerinde düşmüştür (p<0,05). **Sonuç:** Sevofluran ve desfluranın kardiyovasküler sisteme etkilerinin benzer olduğu sonucuna vardık.

Anahtar Kelimeler: İnhalasyon Anestetikleri, Sevofluran, Desfluran, Hemodinamik Etkiler.

INTRODUCTION

Physiologic functions are affected during anesthesia and surgery to varying degrees. The main principle during anesthesia is to choose drugs and methods that cause minimal changes in patients' physiology. The organism responds to stress during anesthesia and surgery, resulting in negative effects on the cardiovascular system. In the preoperative period, the patients' pathologies should be diagnosed carefully and appropriate anesthetic management should be chosen to prevent undesirable effects.

The cardiovascular effects of volatile anesthetics are somewhat complex, but almost all produce dose-dependent decreases in systolic and diastolic function and decreases in stroke volume and blood pressure, and depress baroreflexes to varying degrees (1,2). Previous studies show that sevoflurane has minimal effects on the heart rate and decreases blood pressure dose-dependently, which is related to a decrease in systemic vascular resistance (3). Desflurane causes a transient increase in the heart rate, depending on the dose, which is related to the stimulation of the sympathetic system. This effect can be attenuated by administration of opioids, beta-1 antagonists and alpha-2 agonists. Desflurane causes a decrease in blood pressure, depending on concentration (4).

Cardiovascular complications are one of the most important causes of preoperative and postoperative morbidity and mortality. Although patients with a cardiac pathology have a higher risk, healthy patients also are exposed to cardiac complications—even cardiac arrest—during anesthesia (1). Therefore, in addition to electrocardiographic monitoring, hemodynamic monitoring should be performed, especially in high-risk patients (5,6). The thoracic electrical bioimpedance (TEB) monitor is a safe and noninvasive hemodynamic monitoring device by which hemodynamic changes can be easily followed. In previous studies, TEB and thermodilution methods were compared and TEB was found as reliable as the other methods (7,8). Therefore, in this study we aimed to compare the hemodynamic effects of desflurane and sevoflurane using a noninvasive method, i.e. TEB.

MATERIALS AND METHODS

With the approval of the ethics committee, 40 patients, aged 20-60, ASA I-II group, undergoing elective lower abdominal surgery, were included in the study. The exclusion criteria were uncontrolled diabetes mellitus; autoimmune, allergic, neuromuscular, peripheral vascular or neurologic disorders; smoking; pregnancy; steroid treatment; and operations shorter than 30 min or longer than 120 min. Patients were randomized into the sevoflurane group (Group I) or the desflurane group (Group II) consecutively. When patients were admitted to the operating room, intravenous cannulation with a 20G cannula was performed and an infusion of 0.9% NaCl at a rate of 5 ml/kg was started. Then 8 TEB and 5 ECG electrodes (D II and V5) were placed and the patients were monitored using a NCCOM3-R7 (BOMED CO, USA) TEB monitor, which was adjusted according to the Berstein-Sramek equality. Heart rate (HR), mean arterial pressure (MAP), cardiac index (CI) and stroke index (SI) were measured. MAP was recorded by an automated blood pressure cuff. Other measurements were obtained in slow mode by TEB. The data collectors were trained before the study.

Anesthesia was induced with 7 mg/kg thiopental sodium, 1 µg/kg fentanyl and 0.1 mg/kg vecuronium, and endotracheal intubation was performed. According to the groups, 2% sevoflurane or 6% desflurane in 50% N₂O and 50% O₂ was given at 3 l/min flow for the maintenance of anesthesia. Vecuronium bromide was repeated at a dose of 0.04 mg/kg as needed. No additional analgesic was given during surgery. Patients were extubated when they responded to verbal stimuli. Furthermore, 0.04 mg/kg neostigmine and 0.007 mg/kg atropine sulfate were given for antagonization of neuromuscular blockade. Parameters were measured before induction (t1), 5 min after intubation (t2), 5 min after surgical incision (t3), on the 10th min (t4) and on the 20th min (t5) of surgery and 5 min after extubation (t6).

For statistical analysis, Student's t-test (for demographic data of groups: comparison of age, height, weight and operation time between groups), chi-square test (for sex and type of surgery between groups) and repeated measure ANOVA (for comparison of HR, MAP, CI, SI

between groups and within groups according to time) were used. Data are expressed as means with standard deviations. In all instances statistical significance was accepted at $p < 0.05$.

RESULTS

No patient was excluded from the study because of an anesthetic or surgical complication. Demographic data of the patients and duration of surgery are shown in Table-1.

Patients in the two groups did not differ in physical characteristics or the basal values of hemodynamic parameters. Basal values were within the normal range according to mean

Table-1: Patient characteristics and duration of surgery according to the groups.

	Sevoflurane	Desflurane	p
Sex (F/M)	7/13	7/13	0.69
Age (year)	51.30 ± 14.23	48.82 ± 12.46	0.20
Weight (kg)	73.20 ± 10.07	65.52 ± 12.47	0.05
Height (cm)	164.45 ± 7.00	168.11 ± 10.22	0.20
Duration of surgery (min)	93.05 ± 22.83	85.94 ± 23.10	0.35

*Mean ± SD

Table-2: Intraoperative hemodynamic changes in the sevoflurane group.

Time	Heart rate (beats/min)	MAP (mm/Hg)	CI (L/min/m ²)	SI (mL/m ²)
t1	79.70 ± 14.49	108.30 ± 14.02	3.55 ± 0.19	45.80 ± 12.83
t2	77.35 ± 12.83	97.80 ± 12.88	2.67 ± 0.15	35.95 ± 14.47
t3	74.10 ± 13.69	94.10 ± 13.04	2.58 ± 0.15	34.75 ± 12.74
t4	70.30 ± 14.87	95.00 ± 16.49	2.65 ± 0.18	38.70 ± 12.20
t5	71.50 ± 14.64	91.15 ± 14.04	2.62 ± 0.19	37.15 ± 11.25
t6	79.55 ± 16.38	106.90 ± 16.02	3.00 ± 0.23	37.90 ± 9.40

*Mean ± SD

**MAP: Mean Arterial Pressure, CI: Cardiac Index, SI: Stroke Index

Table-3: Intraoperative hemodynamic changes in the desflurane group.

Time	Heart rate (beats/min)	MAP (mm/Hg)	CI (L/min/m ²)	SI (mL/m ²)
t1	77.52 ± 15.66	99.00 ± 13.41	4.00 ± 0.21	52.52 ± 13.37
t2	85.29 ± 15.70	93.82 ± 12.53	3.12 ± 0.17	37.29 ± 9.47
t3	81.76 ± 14.13	92.82 ± 12.63	3.00 ± 0.16	37.05 ± 8.30
t4	76.76 ± 13.49	93.76 ± 15.39	3.01 ± 0.19	40.05 ± 9.75
t5	72.35 ± 13.69	99.64 ± 14.84	3.14 ± 0.20	43.94 ± 10.20
t6	84.82 ± 14.85	100.05 ± 12.10	3.73 ± 0.25	46.05 ± 14.04

*Mean±SD

**MAP: Mean Arterial Pressure, CI: Cardiac Index, SI: Stroke Index

patient age.

Hemodynamic changes during surgery in the sevoflurane and desflurane groups are shown in Table-2 and Table-3, respectively. When the sevoflurane and desflurane groups were compared, there was no significant difference between the heart rates of the groups ($p=0.2$). Comparing heart rate values within the sevoflurane and desflurane groups, they were significantly decreased at t4 ($p < 0.05$) and t5 ($p < 0.05$) compared to t1 in both groups. The mean heart rate values of both groups changed in a similar way during surgery within the groups (Fig. 1).

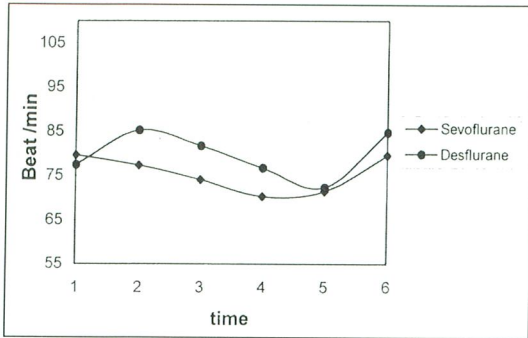


Fig. 1: Intraoperative heart rate changes in the groups.

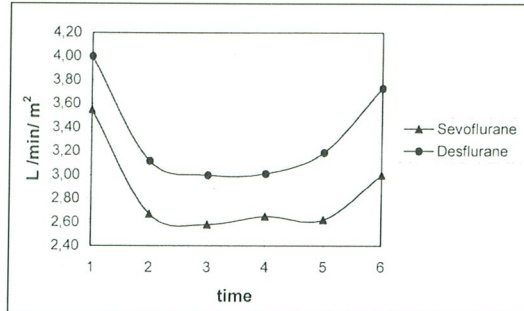


Fig. 3: Intraoperative CI changes in the groups.

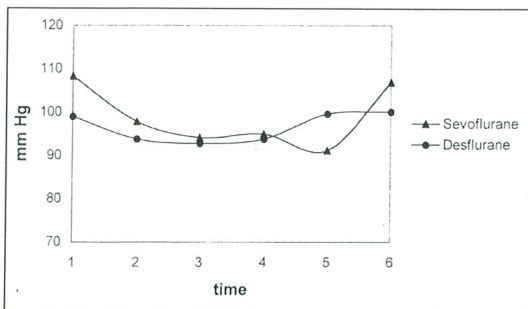


Fig. 2: Intraoperative MAP changes in the groups.

When MAP values were compared, there was no significant difference between the two groups. There were significant decreases in MAP at t2, t3, t4 and t5 compared to t1 within both groups and MAP values increased to the same level at t6 (Fig. 2). CI values were significantly different between the sevoflurane and desflurane groups ($p < 0.05$). CI values decreased significantly at t2, t3, t4, t5 and t6 when compared with t1 within both groups ($p < 0.05$) (Fig. 3). CI values decreased similarly in both groups. When SI values were compared, there was no significant difference between the two groups. SI values decreased significantly at t2, t3, t4, t5 and t6 when compared with t1 within both groups ($p < 0.05$) (Fig. 4).

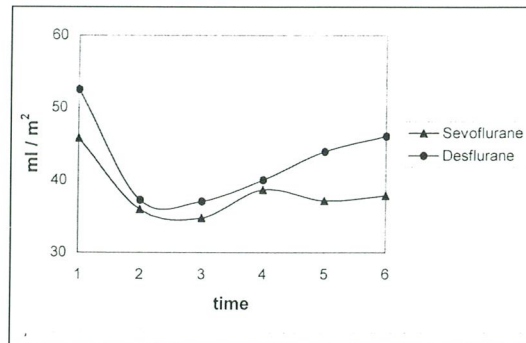


Fig. 4: Intraoperative SI changes in the groups.

DISCUSSION

Thoracic electrical bioimpedance is a safe and comfortable method for patients and is easily applied by the user. Because of offering continuous data, including several parameters, and its non-invasive and economic application, it is appropriate for cardiac output measurement. A TEB monitor is minimally affected by outer effects like electrocautery, respiration and patient movement and provides beneficial data (2,9).

All potent volatile anesthetics have similar cardiovascular effects. It has been reported that sevoflurane has minimal effects on the heart rate (10,11). This effect is thought to be related to not depressing myocardial contractility by increasing O₂ consumption and not decreasing myocardial

perfusion (12). In the first human study, in 1981, nonpremedicated volunteers were given 2-3% sevoflurane for longer than 1 hour. During this period, the heart rate showed no difference from basal values (10). A few years later, Monokar et al. showed a stable heart rate in healthy swine during sevoflurane anesthesia (13). Weiskopf et al. reported that the heart rate did not change with 0.83 MAC desflurane but increased progressively with an increase in desflurane concentration (14). Wajima et al. studied the effects of sevoflurane and isoflurane with and without 67% N₂O on heart rate, systolic and diastolic blood pressures and end-tidal CO₂ concentration and they reported that even if nitrous oxide was added to sevoflurane or isoflurane, an increase in heart rate could not be avoided after rapid increases in concentrations of sevoflurane and isoflurane (15). The heart rate is affected by several factors such as preoperative state, premedication, method of induction, endotracheal intubation and maintenance of anesthesia. In our study anesthesia was induced in the same way in the two groups, volatile anesthetic concentrations remained the same and we did not observe any significant difference between the heart rates of the groups. Leung et al. observed a decrease in heart rate values 10 min after intubation compared with basal values in desflurane and isoflurane groups (16). In our study—in accordance with Leung's study—heart rate values 10 and 20 minutes after surgical incision decreased in both groups. Picker et al. studied the effects of halothane, isoflurane, enflurane, sevoflurane and desflurane on heart rate and heart rate variability as a measure of cardiac vagal activity in dogs, and explained the differences between the agents in the degree of increase in heart rate by differences in their vagolytic action (17).

Blood pressure changes caused by volatile anesthetics are a sign of their effects on cardiac output and vascular resistance. Two major components of blood pressure, heart rate and the smooth muscle of blood vessels, are affected indirectly by anesthetics. All potent anesthetics change these factors in a dose-dependent manner (18). Sevoflurane decreases blood pressure by decreasing systemic vascular resistance, depending on dose. Although sevoflurane depresses myocardial contractility and causes cardiovascular collapse under deep anesthesia, it

preserves the cardiac index under clinical concentrations. The effect of myocardial contractility depression by sevoflurane is a result of the blockage of calcium flow (12).

An experimental study with mongrel dogs showed that sevoflurane decreased blood pressure more than isoflurane with increasing concentrations (19). No significant difference was observed between the blood pressure decreasing effects of sevoflurane and isoflurane in chronically anesthetized dogs in different studies (20,21).

In a retrospective study in chronically anesthetized swine, the decrease in MAP under sevoflurane anesthesia was greater than that under halothane and isoflurane at equipotent concentrations (13).

In spontaneously breathing rats, sevoflurane decreased blood pressure less than halothane. It is thought that sevoflurane preserved cardiac output better than halothane (22).

Studies performed on volunteers and pediatric patients with sevoflurane were not consistent with each other. In a study including patients aged 0 (newborn) to 12 years, decreases in systolic blood pressure were smaller as age increased under 1 MAC sevoflurane anesthesia (23).

Thomson et al. compared isoflurane and desflurane in patients undergoing coronary artery bypass surgery. In both groups MAP was significantly decreased after induction and returned to basal values during sternotomy in the isoflurane group (24).

Leung et al. did not observe any decrease in systolic blood pressure (SBP) in isoflurane and desflurane groups before endotracheal intubation, but SBP decreased progressively after endotracheal intubation in both groups. There was no difference between vasopressor (ephedrine or norepinephrine) consumption in the two groups (16). In our study, in agreement with their study, MAP was decreased significantly 5 min after intubation, 5 min after surgical incision and in the following 10 min in both the sevoflurane and desflurane groups. While MAP decreased in the sevoflurane group, it remained the same in the desflurane group 20 min after surgical incision.

In spontaneously breathing rats, blood pressure and cardiac output were decreased less by 1 MAC sevoflurane than by 1 MAC halothane (22). In a study performed on newborn swine, it was observed that sevoflurane decreased blood pressure and the cardiac index less than halothane and isoflurane at equipotent doses (25).

Cahalan et al. determined cardiovascular effects of 0.91, 1.34 and 1.74 MAC desflurane/nitrous oxide anesthesia and desflurane anesthesia in 12 healthy volunteers, and they observed that desflurane/nitrous oxide together caused less circulatory depression than desflurane alone. They also observed that desflurane/nitrous oxide anesthesia caused a dose-dependent decrease in systemic blood pressure, cardiac index, stroke index, systemic vascular resistance and left ventricle stroke work index (26). In our study, in correlation with their study, decreases were recorded in the cardiac index at measurement times in both groups.

Another beneficial parameter for assessing cardiac performance is stroke volume. The stroke index is a calculated by stroke volume/body surface area and is used to compare patients of different heights and weights.

Kawana et al. compared the hemodynamic effects of 1 MAC and 2 MAC sevoflurane and halothane by TEB monitor in pediatric patients. Both sevoflurane and halothane depressed the stroke index in a dose-dependent manner (27).

Malan et al. assessed cardiac output by thermodilution methods in healthy volunteers and observed that both sevoflurane and isoflurane decreased the cardiac index and systemic vascular resistance, and the cardiovascular effects of the two agents were found to be similar (28).

Weiskopf et al. reported that desflurane decreased the stroke index but cardiovascular depression did not progress during prolonged desflurane anesthesia (14). In our study the stroke index decreased at t2, t3, t4, t5 and t6 in both the sevoflurane and desflurane groups.

In conclusion, both sevoflurane and desflurane decrease hemodynamic parameters in a similar pattern and the TEB monitor is a non-invasive and easy method for monitoring hemodynamic measurements and can safely be

used in surgical patients.

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