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Comparison of sevoflurane and isoflurane effects on cardiovascular and respiratory system during spontaneous ventilation in Angora goats

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Abstract: Seven healthy Angora goats were used to compare the effects of isoflurane and sevoflurane on the cardiovascular and respiratory systems during anesthesia periods. Once anesthesia was induced with propofol at 5.1 ± 0.9 mg/kg, it was maintained with isoflurane at 1%–3% in the first treatment period and sevoflurane at 2%–4% in the second treatment period after a 15-day interval. Heart rates measured immediately after anesthesia induction and 5 min later were found to be statistically significant between anesthetic groups ($P < 0.05$). Mean blood pressure in the isoflurane group decreased (75.7 ± 7.2 to 59.8 ± 9.8 mmHg) ($P < 0.05$) throughout the anesthesia period. It was determined that respiratory rate in sevoflurane treatment was lower than that in isoflurane treatment. In terms of time to stand up, sevoflurane-administered animals recovered significantly faster than animals intubated with isoflurane anesthesia (13.1 ± 4.4 and 25.0 ± 8.6 min) ($P < 0.05$). According to cardiopulmonary values, the respiratory rate was lower in the sevoflurane-applied animals compared to that of those receiving isoflurane anesthesia, although the difference was not statistically significant, and hypercapnia were not observed in either group. Consequently, it was determined that in the Angora goat, propofol-sevoflurane anesthesia exerts lower pressure on the cardiovascular system than isoflurane anesthesia. At the same time, recovery from sevoflurane anesthesia was shorter, and therefore it can be preferred to other anesthesia agents for routine anesthesia.

Key words: Sevoflurane, isoflurane, anesthesia, cardiovascular system, respiratory system, Angora goat

1. Introduction

Isoflurane and sevoflurane are noncombustible halogenated anesthetic agents. In addition to a faster anesthesia induction and shorter recovery time, isoflurane also provides good muscle relaxation. Sevoflurane is more preferable than isoflurane because it has lower irritation of the respiratory tract than isoflurane and it has some advantages such as easy induction and a fast recovery compared to isoflurane (1–3).

Propofol, a nonbarbiturate derivative, is a sedative and hypnotic drug that can be used in small animals for anesthesia and maintenance of sedation. Due to its shorter half-life and absence of accumulation in the body (4–6), it can be used safely in animals such as small ruminants (4,7). Information of the possible side effects of these types of anesthetics on small ruminants, however, is not present yet (8–12).

Goats are preferred as an animal model in experimental studies such as orthopedic, cardiovascular, respiratory, and cerebrovascular studies (13–15). Sevoflurane, isoflurane, and halothane are often used as anesthetic agents. However, anesthetic requirements have not been determined in the goat for these agents accurately. Therefore, the aim of this research was to compare the anesthetic effects of two different inhalation anesthetics that are used in the maintenance of anesthesia with propofol medication.

2. Materials and methods

The study was approved by the Animal Research Local Ethics Committee of Kırıkkale University (Decision No: 70/09). Seven healthy adult female Angora goats were used in this study. Prestudy screening included a physical examination and complete blood count to ensure animals were in good health. The same goats were used for both anesthesia groups within a 2-week interval. Once anesthesia was induced with propofol, it was maintained either with isoflurane or sevoflurane.

Feed and water were withheld from animals 18 h and 2 h prior to anesthesia respectively in order to prevent ruminal tympani during anesthesia. The medial auricular artery was catheterized (Wellcath-x plus 22G, Vellmed, Turkey) to measured systolic arterial pressure (SAP), diastolic arterial pressure (DAP), and mean arterial pressure (MAP). The caudal auricular vein was

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catheterized for anesthesia induction and additional dose if required. A single dose of 4 mg/kg propofol was administered for anesthesia induction (Propofol 1%, Fresenius Kabi, Sweden). Incremental doses of propofol to allow intubation were recorded. After anesthesia was induced with propofol, goats were reposed in sternal recumbency for intubation. Animals were repositioned in right lateral recumbency after intubation. In the first practice, goats were given isoflurane (Forane Likid, - ABBOT Laboratories Ltd., UK) at 1%–3% concentration. Fifteen days later in the second practice, the same goats were given sevoflurane (Sevorane Likid, - ABBOT Laboratories Ltd.) at 2%–4% concentration as 100% O_2 at 3 L/min. The depth of anesthesia was monitored by palpebral reflex and pressing of the tail and interdigital skin with Kocher forceps. Absence of the palpebral reflex and reaction to interdigital skin pressure with compressing of tail-end interdigital skin indicated enough anesthesia at the required depth.

Goats were kept for 1 h under stable anesthesia by providing spontaneous ventilation. Invasive blood pressure, heart rate, and body temperature were measured prior to and after propofol induction and at 5, 10, 15, 30, and 60 min of volatile anesthesia with a patient control monitor (Petaş KMA 800, Turkey). Blood oxygen saturation (SpO_2) was measured with pulse oximetry applied to the tongue. End-tidal CO_2 values were measured in the respiratory gas sample. Electrocardiographic monitorization was done during anesthesia. PHa, PaO_2, $PaCO_2$, $[HCO_3^-]$a, BEa, and O_2SA values were measured by blood gas analyzer (GASTAT Mini, Yokohama, Japan) by collecting the arterial blood samples into heparinized syringes before and after propofol and at 10, 30, and 60 min of volatile anesthesia.

At the end of 1 h of anesthesia, the vaporizer was closed and 100% O_2 was given into the system until the animals woke up. Extubation time of animals, time to head movement, time to getting into the sternal position, and time to standing up were recorded. Time of extubation was determined according to the starting of swallowing reflex and jaw movements.

Criteria that were presented by Lin et al. (16), Carroll et al. (13), and Prassinos et al. (17) were used to determine anesthesia induction, recovery after anesthesia, and regurgitation criteria.

Changes in pulse, blood pressure, SpO_2, $EtCO_2$, respiratory rate, body temperature, and blood gas values that were obtained during anesthesia was evaluated with analysis of variance (ANOVA). Whether there was a significant difference statistically or not between two different anesthetics was determined by Mann–Whitney U test after the test of normality. $P \leq 0.05$ was accepted as significant. SPSS 15.0 for Windows (SPSS Inc., Chicago, IL, USA) was used to evaluate the data.

3. Results

In the present study, it was found that a propofol dose of 4 mg/kg was not sufficient for intubation and general anesthesia. Additional doses of 2.5 ± 1.4 mg/kg per case (mean ± SD) of propofol were given. There were no significant changes in blood gas values during anesthesia in either anesthetic treatment ($P > 0.05$) (Table 1).

Table 1. Mean blood gas values of Angora goats challenged with sevoflurane and isoflurane anesthetic agents prior to, during, and after the challenging period (minutes).

Anesthetic agent	Parameter	Baseline	0	10	30	60	After anesthesia (60 min)
Isoflurane	pHa	7.5 (0.09)	7.3 (0.08)	7.3 (0.05)	7.3 (0.04)	7.3 (0.09)	7.4 (0.09)
	$paCO_2$ (mmHg)	37.8 (2.62)	42.1 (13.00)	40.3 (2.15)	39.9 (2.31)	39.6 (1.32)	40.0 (1.68)
	paO_2 (mmHg)	96.6 (2.24)	119.8 (73.63)	260.1 (72.64)	297.4 (78.34)	301.4 (66.65)	102.3 (11.19)
	$[HCO_3^-]$a (mmol/L)	33.7 (7.58)	30.5 (8.39)	27.4 (3.00)	28.3 (4.27)	29.5 (7.34)	34.2 (5.73)
	BEa (mmol/L)	12.5 (4.31)	5.5 (8.47)	2.0 (3.43)	1.8 (4.77)	3.5 (10.32)	10.9 (4.98)
Sevoflurane	pHa	7.4 (0.03)	7.3 (0.09)	7.2 (0.09)	7.2 (0.06)	7.3 (0.04)	7.4 (0.07)
	$paCO_2$ (mmHg)	39.5 (3.90)	39.4 (2.54)	41.8 (2.07)	40.5 (2.45)	40.6 (1.33)	41.5 (1.20)
	paO_2 (mmHg)	97.6 (9.65)	95.8 (33.43)	245.3 (137.37)	260.7 (115.79)	275.8 (93.38)	98.9 (0.69)
	$[HCO_3^-]$a (mmol/L)	30.8 (5.02)	29.1 (5.77)	25.6 (4.89)	27.9 (7.88)	28.0 (6.34)	26.6 (3.89)
	BEa (mmol/L)	8.6 (6.20)	4.2 (5.46)	–0.8 (5.31)	1.3 (7.35)	3.1 (5.59)	4.8 (3.11)

Data are expressed as mean ± SD (n=7). pHa, Arterial blood pH; $paCO_2$, arterial carbon dioxide partial pressure; paO_2, arterial oxygen partial pressure; $[HCO_3^-]$a, arterial bicarbonate concentration; BEa, arterial base excess.

Compared to values obtained prior to induction of anesthesia, changes in the heart rate during anesthesia were significant in both anesthetic treatment groups ($P < 0.05$). Significant decrease in heart rate lasted until 15 min of anesthesia (Table 2).

The SAP was significantly decreased throughout the anesthesia period in both volatile anesthetic treatments compared to the values obtained prior to induction of anesthesia ($P < 0.05$). The decrease reached the lowest level at 30 min of anesthesia in the sevoflurane treatment; however, the drop was sharper during the first 15 min of anesthesia in both treatments. Importantly, the decrease in sevoflurane-administered goats was higher and the difference between anesthetic groups was statistically significant at the 5-min measurement ($P < 0.05$). The decrease in blood pressure that reached the lowest level at 30 min of anesthesia seemed greater in the isoflurane-administered group. However, the difference was not significant, except for those mentioned above. After 30 min of anesthesia, blood pressure began to increase in the sevoflurane-administered group. However, the increase in blood pressure in isoflurane-administered goats started at 60 min, at which time volatile anesthesia was discontinued (Table 2).

In terms of quality of induction, quality of recovery, regurgitation, and hypersalivation, insignificant differences were obtained between isoflurane and sevoflurane anesthetic administration. The body temperature measured prior to anesthesia and during anesthesia was within physiological limits in both anesthetic treatment groups. However, body temperature decreased during anesthesia in both anesthetic treatment groups. The drop in the isoflurane group was slightly lower at 10, 30, and 60 min (Table 2). According to the data related to recovery from anesthesia, rapid awakening was seen in the sevoflurane-administered group (Table 3).

Table 2. Cardiovascular and cardiopulmonary values of Angora goats challenged with sevoflurane and isoflurane anesthetic agents during the challenging period (minutes).

Anesthetic agent	Parameter	Baseline	After propofol	0	5	10	15	30	60
Isoflurane	HR (bpm)	75.1 (8.8)	83.4 (9.6)*	89.3 (13.7)	86.8 (13.5)*[a]	85.2 (16.8)	86.8 (11.6)	89.8 (9.7)	86.2 (10.6)
	SAP (mmHg)	110.5 (13.4)	97.7 (7.7)	87.5 (10.6)*[a]	73.7 (16.5)*[a]	73.7 (9.2)	74.4 (10.5)*	81.4 (13.4)	79.2 (15.4) [a]
	DAP (mmHg)	66.1(10.4)	58.8 (3.6)	54.5 (3.4)	48.2 (5.6)	46.1 (4.3)	44.4 (3.9)	49.1 (8.4)	47.2 (10.0)*[a]
	MAP (mmHg)	83.4 (9.9)	75.7 (7.1)	65.4 (5.5)	55.4 (5.2)	56.3 (3.6)	57.4 (6.7)	63.3 (11.4)	59.8 (9.8)
	RR (breaths/min)	26.0 (6.4)	23.1 (7.0)	23.4 (7.0)	21.1 (4.2)	21.2 (2.6)	20.5 (5.7)	21.4 (4.2)	21.4 (6.7)
	SpO_2 (%)	99.5 (0.7)	99.4 (0.9)	99.0 (1.4)	99.0 (1.2)	99.1 (0.9)	98.7 (0.9)	99.0 (1.1)	98.1 (1.2)
	$EtCO_2$ (mmHg)	26.4 (2.3)	32.7 (2.3)	37.0 (3.6)	36.2 (2.9)	35.1 (3.6)	34.2 (2.2)	36.0 (2.2)	35.1 (1.3)
	Temp (°C)	39.4 (0.3)	39.3 (0.3)	39.2 (0.3)	39.1 (0.3)[a]	39.0 (0.3)[a]	38.9 (0.3)	38.7 (0.4)[a]	38.5 (0.3)[a]
Sevoflurane	HR (bpm)	87.1 (14.8)	102 (7.0)*	100.2 (12.7)	100.8 (12.8)[b]	97.2 (7.5)	94.7 (4.5)	90.1 (10.6)	87.2 (10.1)
	SAP (mmHg)	111.8 (19.2)	101.4 (17.1)	103.1 (17.1)[b]	98.4 (18.5)[b]	93.7 (22.1)	91.0 (17.8)	83.7 (15.4)*	97.8 (19.6) [b]
	DAP (mmHg)	67.0 (15.7)	62.7 (17.9)	67.8 (18.4)	63.4 (21.9)	59.7 (20.8)	57.1 (18.1)	53.7 (15.6)	66.0 (19.9)[b]
	MAP (mmHg)	87.5 (16.7)	79.8 (15.0)	82.5 (19.0)	75.3 (21.2)	74.7 (21.4)	72.4 (18.4)	66.3 (16.5)	79.1 (20.9)
	RR (breaths/min)	28,5 (5.8)	19.8(6.3)	16.8 (5.7)	18.0 (4.6)	18.1 (4.1)	19.1 (5.1)	19.1 (3.6)	19.2 (5.3)
	SpO_2 (%)	98.4 (0.7)	98.2 (0.9)	98.5 (1.1)	98.0 (0.8)	97.8 (1.2)	98.8 (1.4)	98.2 (0.9)	98.5 (1.1)
	$EtCO_2$ (mmHg)	26.5 (2.2)	32.7 (3.6)	36.0 (2.7)	38.0 (1.9)	37.7 (2.5)	36.7 (4.3)	34.7 (4.1)	36.0 (4.3)
	Temp (°C)	39.6 (0.2)	39.6 (0.3)	39.5 (0.3)	39.5 (0.3)[b]	39.4 (0.3)[b]	39.4 (0.3)	39.2 (0.2)[b]	39.1 (0.2)[b]

Data are expressed as mean ± SD (n=7). *: Significant difference from baseline ($P < 0.05$). [a,b]: Significant difference between isoflurane and sevoflurane anesthesia parameters in same column ($P < 0.05$). HR, Heart rate; SAP, systolic arterial pressure; DAP, diastolic arterial pressure; MAP, mean arterial pressure; RR, respiration rate; SpO_2, peripheral blood oxygen saturation; $EtCO_2$, end tidal carbon dioxide pressure; Temp, body temperature.

Table 3. Recovery data from sevoflurane and isoflurane anesthesia in Angora goats.

Variable	Anesthetic group	Mean (min) ± SD	P-value
Extubation (waking up and swallowing movements)	Isoflurane	8.43 ± 4.47	0.439
	Sevoflurane	6.43 ± 4.93	
First head movement	Isoflurane	12.43 ± 4.31	0.172*
	Sevoflurane	8.14 ± 4.53	
Thoracic recumbency	Isoflurane	16.43 ± 6.88	0.094
	Sevoflurane	10.29 ± 4.92	
Standing up	Isoflurane	25.00 ± 8.64	0.017*
	Sevoflurane	13.14 ± 4. 41	

Data are expressed as mean ± SD (n = 7).
*: Significant difference between the anesthesia agents ($P < 0.05$).

4. Discussion

Prior to anesthesia induction, it is commonly accepted that food and water are withdrawn from animals at 12–18 h and 2–6 h, respectively (6,8). This is done to prevent such complications as regurgitation, hypersalivation, tympani and apnea, which are among the most commonly observed complications in anesthesia application in small ruminants (6,8). In this study, food and water were withdrawn 18 h and 2 h prior to anesthesia, respectively. Therefore, no complications were observed. However, some other researchers did not limit access to water in goats prior to anesthesia and they did not observe severe complications (10,15,17–19).

In this study, propofol was preferred as an induction agent for volatile anesthesia in Angora goats. The most important advantage of propofol is that it contributes to quick recovery time, perception of the environment, and continuation of psychomotor skills. In addition, the incidence of postoperative complications such as vomiting is very low (9,20).

For the dosage of propofol in goats as an induction agent, there are various reports in the literature (17,21,22). The average dose of propofol has been 5.1 ± 0.9 mg/kg in goats to successfully induce anesthesia without any complications such as regurgitation and apnea (21). Muir (6) recommended a propofol dose of 4–6 mg/kg for small ruminants. Prassinos et al. (17) compared propofol in a comparative study with sodium thiopental and ketamine in terms of induction for anesthesia in goats. It was found that no anesthetic complications such as regurgitation and hypersalivation were experienced in propofol-administered goats. In addition, they reported that the recovery time was shorter in propofol-administered goats. In this study, 4 mg/kg propofol administration did not sufficiently induce anesthesia in Angora goats. Consequently, the dose of propofol was increased to 6.5 ± 1.4 mg/kg and that induced anesthesia sufficiently in Angora goats. Importantly, no incidence of anesthesia complications occurred. Higher doses may be attributed to breed differences.

Although pulmonary arterial pressure does not decrease, a dose-dependent decrease in the blood pressure can be observed during anesthesia in healthy animals. In healthy animals, sevoflurane did not stimulate the sympathetic nervous system in another study (23). When sevoflurane was compared with isoflurane, no differences were reported in the heart rate and systemic vascular resistance (6,24,25). However, Mohamadnia et al. (23) compared isoflurane, sevoflurane, and desflurane, and they reported that the decreases in the heart rate in sevoflurane-administered sheep were lower than those in others. In the present study, in sevoflurane-administered goats, the heart rate decreased during anesthesia until 60 min of anesthesia, at which time the volatile anesthesia administration was discontinued. On the other hand, in isoflurane-administered goats, the drop in the heart rate was not conspicuous and the heart rate was close to the initial values.

Studies have shown no differences between sevoflurane and isoflurane in terms of blood pressure values in goats during anesthesia (10,26,27). However, in the present study, some differences were determined. In this study, decrease at the beginning of the anesthesia, which we can most likely refer to propofol, was more dramatic with isoflurane compared to sevoflurane. In propofol-isoflurane anesthesia, the blood pressure dropped during the first 10 min of induction and began increasing up to

30 min of anesthesia (Table 2). We thought that propofol's effect at 15 min as seen in the drop in blood pressure was dramatic; during the first 15 min the differences may be relevant to the propofol dose that we used (6.5 ± 1.4 mg/kg). It was found that the blood pressure in sevoflurane-administered goats became closer to the initial values after 30 min of anesthesia, while the blood pressure continued to stay low until 60 min in isoflurane-administered goats. Thus, it was thought that maintenance of anesthesia with isoflurane in propofol-induced anesthesia in goats resulted in more suppression in blood pressure and consequently more dramatic effects on the cardiovascular system than sevoflurane. In this study, SpO_2 and $ETCO_2$ values were determined within tolerable limits, with only negligible changes in both anesthesia applications. Similar respiratory parameter data were also previously reported (10,18,23).

The respiratory rate was lower in sevoflurane-administered animals; however, the difference was not statistically significant ($P > 0.05$). The respiratory rate dropped in both groups of animals; however, we thought that suppression in respiratory system parameters was negligible with both isoflurane and sevoflurane. Additionally, both anesthetics did not significantly change blood gases concentrations.

The recovery from anesthesia without any complications has been one of the hallmarks of research in anesthesiology (16,26,28–30). In several studies agitation has been reported in people after anesthesia (29,30); however, Matthews et al. (31) reported no complications in various animal species such as horse. Likewise, we did not find such complications in Angora goats. In a comparative study conducted on goats, Alibhai (1) reported that the quickest recovery time was obtained with desflurane anesthesia compared to sevoflurane and isoflurane. The quickest time was obtained in sevoflurane in this research. Similarly, Hikasa et al. compared isoflurane, halothane, and sevoflurane (10) and they reported that sevoflurane-anesthetized goats had the quickest recovery time. This study agrees with those findings. The recovery time with propofol-sevoflurane was shorter compared to propofol-isoflurane anesthesia. In this study there was no complication with either anesthesia.

In conclusion, maintenance of anesthesia with sevoflurane in propofol-induced anesthesia in Angora goats resulted in less suppressive effects on the cardiovascular system with a shorter recovery time compared to isoflurane maintenance of anesthesia. Previously suggested dosages for induction of anesthesia may be reevaluated. Drugs and their doses approved by authorities for other animals or ruminants may be tested in Angora goats in further studies.

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