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The Effect of Water-Filtered Infrared-A (wIRA) on Body Core and Body Surface Temperatures in Anesthetized Rabbits Maintained with Isoflurane

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Abstract The purpose of this study was to evaluate body temperature changes in rabbits anesthetized using water-filtered infrared-A (wIRA). Ten rabbits were used for this study. For the experimental group (wIRA group; wG, n = 5), the experimental equipment was used and irradiated using wIRA. The control group (CG, n = 5) did not have any warming device. There were no significant differences in heart rate, respiration rate, and end tidal CO_2 ($EtCO_2$) between wG and CG. After 80 min, the core body temperature of wG rabbits was significantly higher than that of CG rabbits. The surface body temperature was significantly higher while receiving wIRA support at all time points after 5 min. In conclusion, in rabbits under inhalation anesthesia, the surface body temperature was better maintained than the core body temperature when using wIRA.

Key words wIRA, rabbit, body temperature, surface, core.

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Introduction

In dogs and cats, hypothermia occurs when the body temperature is lower than 37°C (19); this is a major perioperative complication in veterinary medicine (1). In rabbits, a body temperature lower than 38.5°C indicates hypothermia (29). Hypothermia often occurs during anesthesia because of decreased metabolic rate, drug-related vasodilation, and muscle inactivity (27). Intraoperatively, hypothermia may occur during thoracotomy or lavage using unheated fluid during laparotomy (2). The side effects of hypothermia during anesthesia may include decreased cardiovascular function, decreased metabolism and excretion of anesthetic drugs, and increased vulnerability to infections (10). Moreover, recovery may be delayed and shivering may occur after awakening (26).

Methods for raising body temperature are divided into two categories, i.e., warming of the body surface and warming of the core parts (1). The traditional method to prevent hypothermia is to raise the body surface temperature, i.e., active surface rewarming (1,22), using circulating warm water blankets, warm packs, and forced air-warming blankets (1,3,22). This method can effectively raise the surface body temperature but does not adequately increase the core temperature. In addition, water blankets and warm packs can cause low-temperature burns (4). The process of raising the core body temperature is called active core rewarming and involves warmed and humidified inhaled air and warm intravenous fluid therapy during surgery (1,2).

Water-filtered infrared-A (wIRA) has the characteristic of raising whole-body temperature without raising surface body temperature, and in human medicine, wIRA is also used for wound healing (7). Certain wavelengths (780-1400 nm) pass through water and reach the skin, and water absorbs or reduces unwanted wavelengths in the infrared region (12). The radiation through the water filter has a similar effect as the sun's heat radiation; therefore, the body surface is not burned, and high temperatures (38-42°C) can be delivered to the deep tissues (20). wIRA has two effects, thermal and non-thermal. In the thermal effect, heat energy is transferred to the tissue to increase body temperature, blood flow to the surrounding tissues, and metabolism (13). The non-thermal effect stimulates wound healing and affects cytochrome C oxidase and skin growth factors to activate cellular responses (12). Owing to these properties, wIRA is used to treat burns, skin cancer, and even breast cancer (21).

To our knowledge, there are no reports of clinical studies on anesthesia on changes in body temperature using wIRA. The objective of this study was to evaluate the thermal effect of core body temperature compared with surface body temperature during anesthesia using wIRA. The purpose of this study was to investigate the effect of wIRA on hypothermia induced by inhalation anesthesia. We hypothesized that the surface body temperature and core body temperature will be higher in the wIRA group compared to the control group.

Materials and Methods

Experimental animals

Ten New Zealand White male rabbits (weight, 2.5-3.0 kg; mean ± SD age, 1.2 ± 0.2 years, n = 10) were used after approval by the Institutional Animal Care and Use Committee of Kyungpook National University (approval number: KNU2022-0006). The following conditions were used: room temperature, 20-25°C; air humidity, 50-60%; light/dark cycle, 12 h; stabilization period, seven days. Water and food were supplied during the experimental periods.

Preparation of irradiation with wIRA

All rabbits were fasted a day before anesthesia. For the experimental group (wIRA group; wG, n = 5), an experimental equipment (RBp 3000; Ray-bio, Korea) with a wavelength of 400-1,100 nm was used and irradiation was done from 30 cm distance. The control group (CG, n = 5) was not exposed to any warming device. Alfaxalone (3 mg $kg^{-}1$, IV Alfaxan®; Jurox, Australia) was administered after a 24 gauge catheter was inserted into the marginal vein of each rabbit's ear, for induction. After induction, V-gel (size R3, V-gel®; Docsinnovent, UK) was intubated, and respiratory anesthesia was induced. Then, after intubation, the rabbit was placed in the ventral-dorsal position (VD) using a W-plate, and an eye lubricant was applied. Isoflurane concentration was maintained at 2%, and anesthesia was induced for 2 h. N/S solution was administered intravenously at a rate of 5 mL $kg^{-}1$ h^{-1}. After anesthesia, the abdominal hair was clipped from the sternum to the umbilicus using a clipper. The room temperature was maintained at 25°C.

Physical evaluation and data collection

For physical evaluation, core body temperature, surface body temperature, heart rate (HR), respiration rate (RR), end tidal CO_2 ($EtCO_2$), and hemoglobin oxygen saturation (SpO_2) were measured. The core temperature was measured using an esophageal thermometer (M1024251, GE Healthcare, US) and the surface temperature was measured using a skin infrared thermometer (BNT 400; Braun, Germany). The remaining indicators were measured by monitoring the patients (CARESCAPE™ B650; GE Healthcare, US). Data were collected at five-minute (min) intervals for 20 min, and continued at ten-minute intervals for 2 h.

Statistical analysis

After normality testing using the Shapiro-Wilk test, data for the control and wIRA groups were compared using a t-test. Core and superficial temperatures were compared using two-way ANOVA. Statistical analyses were performed using SPSS 25.0 (IBM SPSS Inc., Armonk, New York, US). $p < 0.05$ was considered significant.

Results

There were no significant differences in HR, RR, and $EtCO_2$ between animals of wG and CG (Table 1). Core body temperature was not significantly different between animals of wG and CG (Fig. 1) until 120 min ($p = 0.05$).

There was no significant difference in the surface body temperature at base (0 min) (Fig. 2). However, after 5 min, the surface body temperature was significantly higher while receiving wIRA support at all times (5, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120 min; $p < 0.05$).

Discussion

The main finding of this study was that maintaining the surface body temperature was a much better strategy than maintaining the core body temperature. In other study showed that wIRA raises the core body temperature without affecting the surface body temperature (12); however, the opposite was found in this study. According to recent research results, it has been reported that changes in skin and subcutis temperature are affected by irradiance, exposure time, and tissue depth, and temperature maxima were between 4 and 7 mm (30). According to another study, superficial temperature was significantly increased from 39°C to 43°C when wIRA was used, and core body temperature increased with time (21). An interesting fact is that the fat composition of pigs (saturated fats: 69%, unsaturated fats: 31%) and rabbits (saturated fats: 30%, unsaturated fats: 70%) differs (7). Hence, using wIRA, the core body temperature would increase in pigs owing to their lower heat distribution and heat loss (21,30). Although there have been no studies on body temperature maintenance in rabbits, differences in fat composition between the two animals may have affected the results; therefore, further studies are required.

There were side effects such as burning sensation, hyperpigmentation, and blister formation when applying local hyperthermia (44°C for 30 min) (14). However, no skin side effects were observed when wIRA was applied in another study (8). In addition, wIRA is well accepted by patients without side effects even when used chronically and acutely (33). In addition, wIRA was well accepted by patient with no side effects when used chronically and acutely (33). In this study, skin was irradiated with wIRA for 2 h, and there were no significant side effects.

In this study, anesthesia was induced with alfaxalone and maintained with isoflurane. Alfaxalone is a steroid anesthetic

Table 1. Results of changes in HR, RR, $EtCO_2$ during 120 min of anesthesia

Time (min)	Control group (CG)			wIRA group (wG)		
	HR (beats/min)	RR (breaths/min)	$EtCO_2$ (mmHg)	HR (beats/min)	RR (breaths/min)	$EtCO_2$ (mmHg)
0 (base)	214.4 ± 54.6	17.8 ± 10.0	42.0 ± 5.6	222.2 ± 7.3	26.6 ± 12.3	42.8 ± 12.2
5	238.4 ± 17.7	27.0 ± 7.1	40.0 ± 5.3	227.0 ± 13.7	27.4 ± 10.3	42.4 ± 10.9
10	230.4 ± 21.3	24.0 ± 9.4	40.8 ± 4.6	221.2 ± 9.5	26.6 ± 11.1	42.6 ± 9.5
15	219.2 ± 22.9	24.0 ± 9.4	41.4 ± 4.6	221.8 ± 6.4	29.0 ± 7.4	43.0 ± 9.5
20	225.0 ± 22.0	28.2 ± 9.2	41.6 ± 4.5	213.6 ± 10.9	29.8 ± 6.2	43.4 ± 9.6
30	218.2 ± 27.9	24.8 ± 5.9	43.2 ± 6.8	216.4 ± 16.3	27.8 ± 8.7	43.0 ± 9.0
40	210.6 ± 29.2	27.4 ± 3.6	44.2 ± 9.7	204.8 ± 15.9	30.6 ± 4.6	43.8 ± 8.5
50	193.4 ± 25.7	24.8 ± 9.0	46.2 ± 11.3	189.0 ± 10.1	29.2 ± 4.6	45.6 ± 8.5
60	154.5 ± 70.6	29.4 ± 3.9	46.0 ± 10.4	192.4 ± 13.5	30.0 ± 3.3	45.0 ± 8.4
70	182.4 ± 24.3	28.8 ± 4.6	45.6 ± 7.9	185.4 ± 17.7	30.2 ± 2.5	43.6 ± 7.6
80	175.4 ± 22.0	29.0 ± 4.8	46.8 ± 8.8	179.8 ± 18.5	28.8 ± 4.3	44.4 ± 8.9
90	166.4 ± 20.4	26.4 ± 4.3	47.8 ± 9.7	173.0 ± 26.1	30.0 ± 4.4	44.0 ± 6.7
100	158.4 ± 24.2	26.0 ± 3.9	50.0 ± 12.1	162.0 ± 25.2	29.0 ± 5.1	45.2 ± 6.7
110	161.2 ± 26.6	22.0 ± 5.2	48.0 ± 16.8	167.2 ± 18.7	29.0 ± 4.7	44.6 ± 7.0
120	160.6 ± 26.1	37.0 ± 15.7	45.6 ± 14.3	170.2 ± 21.4	27.6 ± 3.2	44.6 ± 6.8

Data are presented as mean ± standard deviation.
HR, heart rate; RR, respiratory rate; $EtCO_2$, end-tidal CO_2.

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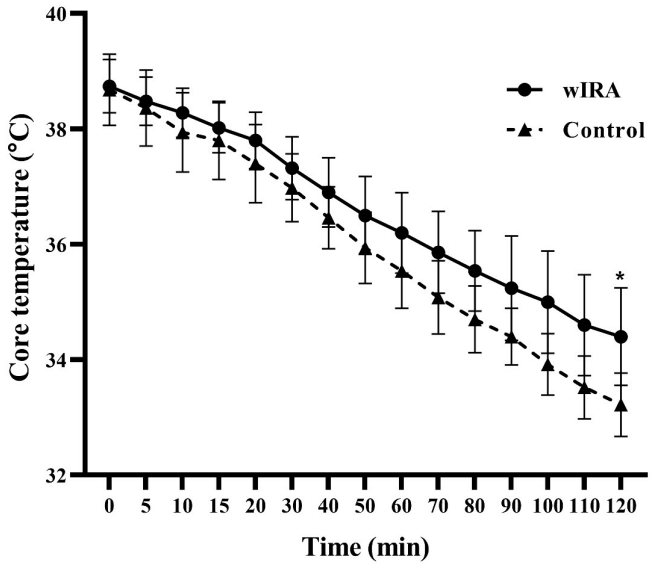

Fig. 1. Change in core temperature in rabbits during anesthesia. Data are presented as mean ± standard deviation. *p < 0.05.

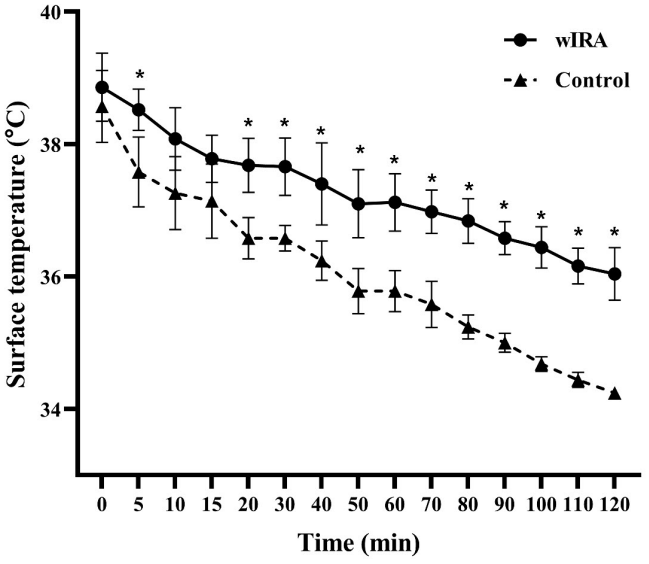

Fig. 2. Change in surface temperature in rabbits during anesthesia. Data are presented as mean ± standard deviation. *p < 0.05.

agent with dose-dependent effects on the cardiovascular and respiratory systems (27). In the cardiovascular system, it decreases blood pressure and increases HR. In the respiratory system, it decreases the respiratory rate, tidal volume, and PaO_2 (18). Isoflurane causes severe respiratory depression and decreases arterial blood pressure, HR, and systemic vascular resistance in a dose-dependent manner (27,34). Inhalation anesthetic agents change body temperature by decreasing thermogenesis or increasing heat loss. In some studies, owing to decreased vascular resistance, the muscle blood flow increased from the deep to the skin, resulting in increased heat loss (23). These results indicate that alfaxalone and isoflurane may have had an effect on body temperature changes. In our study, we investigated whether wIRA was effective at maintaining the surface body temperature following anesthesia-induced hypothermia without any effect on the maintenance of core temperature.

The normal body temperature of rabbits fluctuates between 38.5 and 39.5°C (29). In this study, body temperature decreased significantly with time after anesthesia in rabbits. These results were similar to those obtained in dogs and cats, with hypothermia occurring during surgical anesthesia in 83.6% of the dogs and moderate hypothermia in 66% of the cats (24,25). As a physiological effect of hypothermia, central nervous system depression (reduction of intracranial pressure), cardiovascular abnormalities (decreased cardiac output and blood pressure, bradycardia), delay in metabolic rate, respiratory depression, and immune system depression may occur as complications (5,19). In this study, wIRA was used to maintain the core body temperature, but no significant results were obtained. There are several reasons for this. In small animals, the smaller the body weight, the larger the body surface area, and these factors tend to induce hypothermia during anesthesia (28). During general anesthesia, environmental factors also include cold O_2 from ventilation, intravenous fluid supply, ambient temperature, and heat loss through the shaved body area, which may lower the body temperature (4). Due to the above factors, it is assumed that it is difficult to maintain body temperature in rabbits when wIRA is applied under general anesthesia.

The rabbit's normal HR was 198-330 bpm (16), and the vital results showed that it gradually decreased over time and became lower than the normal range after 50 min for both CG and wG. In some studies, mild hypothermia in humans and pigs decreased the HR but increased the overall hemodynamic parameters of myocardial contractility (9,31). In addition, a study in rabbits also reported that hypothermia significantly reduced the HR but resulted in good left ventricular pressure (17). In our study, as the anesthesia time increased, body temperature and HR decreased.

Furthermore, blood pressure was measured using oscillometric techniques, but continuous and accurate results were not obtained. Oscillometric techniques are methods of measuring blood pressure by detecting pulse beats (32). If the pulse rate is measured incorrectly, the blood pressure result is insignificant (6). Further, when the size of the peripheral artery is small, the pulse may not be sufficiently detected (11). In this study, blood pressure using the oscillometric method

were measured and excluded because rabbits had a fast HR, small peripheral arteries, and hair in the measurement area, so accurate results could not be obtained. When hypothermia occurs, norepinephrine is attached to the α1-receptor for compensation. However, if hypothermia is severe or prolonged, this response is reduced, and as a result, the responsiveness to catecholamines and vasoconstriction is decreased, resulting in hypotension (19). Moreover, baroreceptor function decreases in hypothermia, which leads to abnormalities in blood pressure control and HR control in response to volume changes (15). If the cardiovascular system function declines, tissue perfusion will be reduced, which can lead to hypoperfusion or organ dysfunction after anesthesia. In this study, blood pressure measurement was attempted; however, continuous and accurate results were not obtained, and the correlation between hypothermia and the cardiovascular system could not be determined.

This study has several limitations. First, blood pressure was measured using the oscillometric method at the beginning of the study, but blood pressure was discontinued because continuous and accurate results were not obtained. Therefore, a decrease in the core body temperature due to hypoperfusion cannot be ignored. Finally, the number of rabbits (10 rabbits) used in the study was small, which is an obvious statistical limitation.

In conclusion, in rabbits under inhalation anesthesia, although wIRA had a mild effect on maintaining body temperature, the surface body temperature was maintained better than the core body temperature. As these results may differ depending on the effect of anesthetic drugs or inhalation anesthesia, the effectiveness of wIRA can be evaluated later by conducting the same study using conscious rabbits.

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Conflicts of Interest

The authors have no conflicting interests.

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