Background: Hypothermia is a common physiological condition that occurs during surgical operations. The goal of this experiment is to measure the temperature of the fluids flowing through heated breathing circuits with respect to changes in infusion speed.

Methods: The infusion pump was connected to the intravenous inlet of a heated breathing circuit with two 50 cm extension lines connected to the outlet. Fluids were injected through the heated breathing circuit at 100, 200, 300, 400, 500, 600, and 700 ml/h, with measurement of the fluid temperature immediately after transit (OP 20), 70 cm after transit (OP 70), and 120 cm after transit (OP 120).

Results: The mean fluid temperatures at OP 20, OP 70, and OP 120 were 40.7 ± 4.8°C, 35.1 ± 3.22°C, and 31.7 ± 2.5°C, respectively.

Conclusions: The heated breathing circuit was effective to heat the fluid. After passing out the heated breathing circuit, the temperature of the fluid continuously reduced. A length of 70 cm can be used to efficiently supply heated fluid to the patient. From this experiment, it is expected that supplying heated fluid to a patient using the heated breathing circuit will help maintain the patient's body temperature. (Anesth Pain Med 2017; 12: 28-31)

Key Words: Anesthesia, Closed-circuit, Fluids, Temperature.

INTRODUCTION

Hypothermia is a common physiological condition that occurs during surgical operations owing to the ambient temperature of the location in which the surgery is performed, infusion of cold blood or other fluids, exposure of the abdomen, body cavities, or other surgical sites, and fluctuations in nervous system control of temperature resulting from anesthesia. Hypothermia has the advantage of reducing metabolic rate and increasing neurological protective effects, but it is generally considered that complications of hypothermia, including coagulopathy, metabolic acidosis, and interference with immune responses, outweigh its benefits [1]. Under the influence of hypothermia, the effects of neuromuscular agents are prolonged, and as a result, the recovery period is prolonged as well [2,3]. There are many devices that can be used to prevent hypothermia, such as circulating water mattresses, forced air warming, resistive heating blankets, and others. Fluid-heating devices are one of these options, and heated breathing circuits are widely used to provide heated and moisturized air to patients in order to prevent decrease in body temperature or the drying of mucous membranes. Recently, heated breathing circuits were re-formed to heat the fluid by inserting the intravenous line (Fig. 1). While maintaining the function as a heated circuit, if it is possible to warm fluid, it is considered more clinically practicable. The fluid warmers in use today are limited in their ability to supply fluids at a consistent temperature with constantly fluctuating flow rate [4]. Heating of the fluid through the heated breathing circuit may also have the same problem. The heated breathing circuit has no temperature control or fluid-temperature measuring device. The goal of this experiment is to measure the temperature of the fluids supplied through heated breathing circuits with respect to changes in infusion speed.

MATERIALS AND METHODS

As this experiment only required measuring the temperature of fluids heated by heated breathing circuits, it did not require...
the participation of patients. First, the heated breathing circuits (Mega Acer Kit®, Ace Medical, Korea) were connected to the ventilator with the fresh gas flow set to 4 L/min, tidal volume to 500 ml, and the respiratory rate to 12 beats/min. The experiment was started after the set point of the heated breathing circuits was set to 41°C and the temperature measured by the heated breathing monitor reached 40°C. The length of the heated breathing circuit’s heating coil was 110 cm. A volume of 50 ml of normal saline stored at room temperature (25°C) was injected into a syringe and connected to an infusion pump (Terufusion® Syringe Pumps, Terumo, Japan). The infusion pump was then connected to the IV inlet with two 50 cm extension lines (3-Way Extension Line, Sewoon Medical, Korea) connected to the outlet; 2 ml of fluid was needed to fill each extension line. Fluids were injected through the heated circuit at 100, 200, 300, 400, 500, 600, and 700 ml/h, with measurement of the fluid temperature immediately after transit (outlet point [OP] 20), 70 cm after transit (OP 70), and 120 cm after transit (OP 120). These experiments were repeated three times. The temperature of the operating room was maintained at 23°C. The temperature of the fluid received into a 3-ml plastic container surrounded by Styrofoam was measured three times. Temperatures were recorded with a digital thermometer (SK-1110, SATO, Japan) when there was no change for 30 s.

### RESULTS

When the fluid was injected at a rate of 100 ml/h without any extensions (OP 20), the measured temperature was 40.6 ± 0.0°C. The temperature with a 70 cm extension (OP 70) was 29.9 ± 0.1°C, and the temperature with a 120 cm extension (OP 120) was 26.8 ± 0.0°C. The measurements taken when the fluid was injected at 200 ml/h were 47.8 ± 0.1°C, 37.3 ± 0.1°C, and 31.3 ± 0.0°C, respectively. The measurements at 300 ml/h were 45.1 ± 0.1°C, 39.2 ± 0.0°C, and 34.1 ± 0.0°C, respectively. The measurements at 400 ml/h were 41.7 ± 0.1°C, 37.4 ± 0.1°C, 34.2 ± 0.1°C, respectively. The measurements at 500 ml/h were 39.0 ± 0.1°C, 35.4 ± 0.1°C, and 32.1 ± 0.1°C, respectively. The measurements at 600 ml/h were 37.1 ± 0.1°C, 35.1 ± 0.1°C, and 32.4 ± 0.1°C, respectively. Finally, the measurements at 700 ml/h were 33.5 ± 0.1°C, 32.3 ± 0.0°C, and 30.8 ± 0.1°C (Table 1, Fig. 2), respectively.

### Table 1. Changes in Fluid Temperature according to the Infusion Rate

| Infusion rate | OP 20       | OP 70       | OP 120      |
|---------------|-------------|-------------|-------------|
| 100 ml/h      | 40.6 ± 0.0  | 29.9 ± 0.1  | 26.8 ± 0.0  |
| 200 ml/h      | 47.8 ± 0.1  | 37.3 ± 0.1  | 31.3 ± 0.0  |
| 300 ml/h      | 45.1 ± 0.1  | 39.2 ± 0.0  | 34.1 ± 0.0  |
| 400 ml/h      | 41.7 ± 0.1  | 37.4 ± 0.1  | 34.2 ± 0.1  |
| 500 ml/h      | 39.0 ± 0.1  | 35.4 ± 0.1  | 32.1 ± 0.1  |
| 600 ml/h      | 37.1 ± 0.1  | 34.5 ± 0.1  | 32.4 ± 0.1  |
| 700 ml/h      | 33.5 ± 0.1  | 32.3 ± 0.0  | 30.8 ± 0.1  |
| Mean          | 40.7 ± 4.8  | 35.1 ± 3.2  | 31.7 ± 2.5  |

Values are expressed mean ± SD and degrees Celsius. OP 20: the fluid temperature immediately after transit, OP 70: 70 cm after transit, OP 120: 120 cm after transit.
DISCUSSION

Comparing the measured temperatures at OP 20, the highest temperature was 47.8°C at a rate of 200 ml/h. The temperature measured at a rate of 100 ml/h was 40.6°C. The internal temperature of the heating coil in heated breathing circuit rises above 60°C [5]. During the transit from exit point of the heated circuit to OP 20, the temperature of the fluid continuously decreased to the distance was 20 cm (Fig. 1). The larger heat loss occurred at the rate of 100 ml/h owing to the slower flow rate than 200 ml/h. The constant heat loss that occurred up to 700 ml/h shows that the fluid was not heated sufficiently because of the reduction of heating time within the heated breathing circuit.

Comparing the measured temperatures at OP 70, the highest recorded temperature was 39.2°C at a rate of 300 ml/h. When compared to the recorded results for OP 20, the difference between the recorded temperatures was as low as 1°C and as high as 11°C. The greatest difference occurred at the lowest speed of 100 ml/h, while the smallest difference occurred at the highest speed of 700 ml/h. This is believed to be a result of increased external heat loss due to the prolonged time needed to reach the 70 cm measurement point.

The highest recorded temperature in the case of OP 120 was 34.2°C. Similar to the results for OP 70, lower rates of temperature decrease were observed at higher transfer speeds, with decreased heat loss assumed at those rates.

The heated fluids are maintained below 45°C for safety during injection, but the fluid temperature rose to a maximum of 47.8°C when using no extension line in this experiment [6]. The injection of fluids at these temperatures may result in patients experiencing burns and blood degeneration; however, without using any extension line, it cannot be connected to the venous catheter of a patient in a clinical situation. There were no measured temperatures over 40°C in cases of using at least one extension line in this experiment. However, considering the graph of temperature change (Fig. 2), the recorded temperature at the 70 cm measurement point at a rate of 300 ml/h was 39.2°C, and as such, caution is needed because of the possibility that the fluid temperature may rise above 40°C at similar rates. To prevent burning damage while using heated breathing circuits, injection speeds must be maintained at at least 500 ml/h or more than one extension lines should be used.

In supplying a patient with fluid during surgery, the maintenance volume and the allowable blood loss are calculated; the maintenance fluids are generally set at a rate of 8–12 ml/kg/h for major abdominal surgeries [7]. If a patient weighing 60 kg undergoes an abdominal surgery lasting longer than 4 h, more than 2,400 ml of maintenance fluids is injected and the patient’s body temperature can decrease by more than 0.6°C through the use of room temperature crystalloid fluid alone [8]. As such, to prevent further decreases in body temperature, fluids heated to temperatures higher than 30°C should be used in long-term surgeries, and maintenance fluids may be heated through heated breathing circuits. Jung et al. [9] recently reported that the Mega Acer Kit® was effective for preventing hypothermia during spinal surgery. Kim et al. [10] have shown that the use of fluid warmer or forced-air warmer devices effectively preserves the core body temperature after tourniquet deflation at the total knee arthroplasty.

The purpose of this experiment was to measure the actual temperature of the fluids supplied through heated breathing circuits with respect to changes in infusion speed. It was measured using a single heated breathing circuit in the same operating room. Therefore, additional experiments may be necessary to confirm whether other products have the same fluid warming ability. Owing to the rate limitations of the infusion pump, flow rates in excess of 700 ml/h were not tested. However, it was thought that using a specialized fluid warming device would be more feasible if a higher flow rate were required. In this experiment, normal saline at 25°C was used at room temperature of 23°C. If higher-temperature fluid was used or the room temperature was higher, the fluid-heating function of the heated breathing circuit would have been more effective. The wall thickness of the 50 cm...
extension lines used for this experiment was 1.2 mm (Fig. 3). If thicker-walled extension lines had been used, the fluid temperature would have been better-maintained.

Further experiments to examine the effects of operating room temperature, fluid temperature, and the differences of extension line wall thickness may be necessary.

In conclusion, the heated breathing circuit was effective to heat the fluid. After passing out the heated breathing circuit, the temperature of the fluid continuously reduced. A length of 70 cm can be used to efficiently supply the heated fluid to the patient. From this experiment, it is expected that supplying heated fluid to a patient using the heated breathing circuit will help maintain the patient’s body temperature.

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