**Warmed Irrigation Fluid Does Not Decrease Perioperative Hypothermia During Arthroscopic Shoulder Surgery**

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**Purpose:** To compare the clinical efficacy of warmed irrigation fluid and room-temperature fluid in decreasing perioperative hypothermia during arthroscopic rotator cuff surgery. **Methods:** In this prospective, randomized, comparative study, warmed (36°C) arthroscopic irrigation fluid (group W, n = 36) or room-temperature irrigation fluid (group RT, n = 36) was used without intraoperative warming devices during arthroscopic shoulder surgery in 72 patients. The serial core body temperature and the last and lowest core body temperatures were measured by use of an esophageal stethoscope with a thermometer and a digital tympanic thermometer at 15-minute intervals during the operation and recovery period, respectively. When patients arrived in the postanesthesia care unit (PACU) after surgery, they were warmed immediately and monitored thereafter for body temperature and development of hypothermia-related adverse effects such as postoperative shivering and cardiac events. We evaluated the changes in the patients’ weight and prothrombin time on postoperative day 1 and the hemoglobin level and visual analog scale pain score immediately after the operation and on postoperative day 1. **Results:** The 2 groups did not differ in demographic and surgical data and incidence of intraoperative hypothermia (33 of 36 [91.6%] in group RT and 34 of 36 [94.4%] in group W, P = .276). The core body temperatures decreased throughout the surgery and increased linearly in the PACU, without any intergroup differences (P > .05). All patients were normothermic within 1 hour of arrival in the PACU. The 2 groups did not differ in postoperative weight change, prothrombin time, hemoglobin level, or postoperative visual analog scale pain score (all P > .05). Postoperative shivering occurred in 3 patients and 1 patient in group RT and group W, respectively. No cardiac events occurred in either group. **Conclusions:** Warmed irrigation fluid was not superior to room-temperature irrigation fluid in reducing the occurrence of perioperative hypothermia during arthroscopic shoulder surgery. **Level of Evidence:** Level I, randomized controlled trial.

Mild hypothermia (34°C to 36°C) occurs commonly during any surgery for reasons such as heat redistribution, low ambient temperature of the operating room, intravenous fluid volume, use of antimicrobial skin preparations, and blood loss. The known deleterious clinical effects of hypothermia, which is defined by a core body temperature of less than 36°C, are postoperative shivering; cardiac morbidity, which impairs oxygen delivery to the tissue; delay in recovery from anesthesia; blood loss; coagulopathy; and wound infection.

With the increase in the popularity of arthroscopic shoulder surgery, concerns regarding perioperative hypothermia have emerged because the shoulder joint is located quite close to the core body structure and a large amount of irrigation fluid is used in this surgery to ensure sufficient visibility during the surgery. Nevertheless, few clinical studies have been conducted on perioperative hypothermia during arthroscopic shoulder surgery. Board and Srinivasan recommended that irrigation fluid should be warmed to 36°C because it influences the core body temperature. Similarly, Kim et al. reported that hypothermia occurred more often with room-temperature irrigation fluid than with warmed irrigation fluid during arthroscopic shoulder surgery. However, in our clinical experience, we have noted that room-temperature irrigation fluid does not...
cause hypothermia or shivering severe enough to cause cardiac morbidity or discomfort during arthroscopic rotator cuff surgery.

Therefore this prospective, randomized, comparative study was designed to compare the clinical efficacy of warmed irrigation fluid and room-temperature fluid in decreasing perioperative hypothermia during arthroscopic rotator cuff surgery. We hypothesized that the use of warmed irrigation solution during arthroscopic shoulder surgery would not decrease the occurrence of perioperative hypothermia to a level lower than that encountered with room-temperature irrigation solution.

**Methods**

**Patients**

Seventy-two adult patients with American Society of Anesthesiologists physical status 1 or 2 who were scheduled for arthroscopic shoulder surgery were prospectively enrolled in this study. Institutional review board approval of the protocol was acquired before the initiation of the study, and all patients provided written informed consent. We excluded patients with large to massive rotator cuff tears, isolated subscapularis tears, or previous operations on the same shoulder, as well as patients requiring external warming devices before or during surgery. Patients were randomly allocated to receive warmed arthroscopic irrigation fluid (group W, n = 36) or room-temperature irrigation fluid (group RT, n = 36) by use of a random number table generated by the permuted block randomization method (www.randomizer.org). The cardiology department was consulted to perform preoperative cardiac evaluations, including echocardiography, for patients aged older than 65 years or those with hypertension. The patients in group RT included 2 with atrial fibrillation, 2 with mitral regurgitation, 1 with paroxysmal supraventricular tachycardia, 4 with grade 1 diastolic dysfunction, and 21 with hypertension controlled with medication. In group W, 1 patient each had atrial fibrillation and mitral regurgitation, 4 had grade 1 diastolic dysfunction, and 19 had hypertension controlled with medication.

**Surgical Environment and Anesthesia**

The operating room temperature was automatically regulated to maintain a temperature of 20°C. External warming devices such as a warming blanket or forced-air warming device were not used before or during the operation. All intravenous fluids were administered at room temperature. Each patient was provided with the same number of blankets or other forms of cover during the surgery. If the use of external warming devices became necessary for the patient’s comfort or safety before and throughout the surgery, the patient was excluded from the study.

Normal saline solution in a 3-L bag, mixed with 1 mg/mL of epinephrine, was used as the irrigation fluid. The patients in group RT received room-temperature irrigation fluid, whereas those in group W received irrigation fluid pre-warmed to 36°C by an electrical warmer (Delitas; KT Ltd Co, Seoul, South Korea) placed in the operating room. Throughout the operation, the irrigation fluid was delivered to the arthroscope at a pressure of 60 mm Hg by a pressure-controlled pump (10K; Linvatec, Largo, FL). The temperature of the irrigation fluid in the warmer was monitored continuously by use of a digital thermometer placed in a bag of solution.

Monitoring of the electrocardiogram; peripheral arterial oxygen saturation; noninvasive, automatic blood pressure; and respiratory rate was started before induction of anesthesia. For all patients in this study, the core body temperature was recorded with a tympanic thermometer on arrival to the operating room. No agents for regional anesthetic blockade or pain control were used. General anesthesia was induced with intravenous administration of lidocaine (30 mg), propofol (2 mg/kg), and rocuronium (0.8 mg/kg). After induction of general anesthesia, an esophageal stethoscope with a temperature sensor (DeRoyal, Powell, TN) was inserted to monitor the core body temperature and breathing and heart sounds because the patient’s chest was covered with a drape during the operation. We recorded the core body temperature at 15-minute intervals during the operation and the last and lowest core body temperatures during the operation. Anesthesia was maintained with 1.5 to 2 vol% sevoflurane and target-controlled infusion of remifentanil (Ultiva; Glaxo-Wellcome, München, Germany) at an effect-site concentration of 1 to 3 ng/mL by an infusion pump and 50% nitrous oxide—oxygen mixture. Lactated Ringer solution (5 mL/min) at room temperature was infused for the maintenance of blood volume. Vital signs were recorded every 5 minutes throughout the operation and every 15 minutes during the recovery period by an anesthesia nurse who was unaware of our study.

**Surgical Procedures and Postanesthesia Care Unit Management**

All the arthroscopic surgeries were performed by the same surgeon. After the induction of general anesthesia, patients were positioned in the lateral decubitus position. Subsequent surgical procedures were performed in the glenohumeral and subacromial space. Subacromial decompression with acromioplasty was performed in all patients to remove the inflamed bursal tissue and to create a flat acromion. Distal clavicle resection was performed in patients who had symptomatic acromioclavicular joint arthritis (Table 1). Biceps tenotomy or tenodesis was performed for a symptomatic biceps tear involving greater than 50% of the tendon and for a symptomatic degenerative SLAP lesion according to the age and activity level of
Irrigation fluid in arthroscopic cuff surgery. The patient warming system; Tyco Healthcare Group LP, Pleasanton, CA) were used for rapid recovery to normothermia if the patient’s core body temperature was below 36°C. A digital tympanic thermometer (Braun ThermoScan 5; Kaz Europe SA, Lausanne, Switzerland) was used to measure the core body temperature at 15-minute intervals in the PACU. The patients were monitored for adverse effects such as postoperative shivering, nausea, vomiting, headache, dizziness, and cardiac events. Patients were discharged from the PACU when vital signs returned to the normal range and after resolution of adverse effects, if any.

The patients’ weight and prothrombin time (PT) were evaluated preoperatively and on postoperative day 1 to check for the absorption of irrigation fluid and the development of coagulopathy due to hypothermia. In addition, the hemoglobin level and visual analog scale (VAS) pain score were evaluated preoperatively, immediately after the operation, and on postoperative day 1. The patients were also monitored for wound infection and other related complications until 2 weeks after surgery.

### Statistical Analysis

The sample size was calculated based on the results of previous similar studies. Seventy-two patients were required to detect a temperature difference of 0.9°C with a type I (α) error of .05 and a type II (β) error of .1 (90% power), considering 20% possible data loss. Continuous data (core body temperature, VAS pain score, hemoglobin level, PT, and body weight) were compared by use of an independent *t* test, and the incidences of hypothermia, postoperative shivering, cardiac events, and adverse effects were compared by use of the $\chi^2$ test or Fisher exact test. The relation between core body temperature and other variables was evaluated with the Pearson correlation coefficient. All statistical analyses were performed with SPSS software (version 12.0; SPSS, Chicago, IL); $P < .05$ was taken as the level of statistical significance.

### Results

Our clinical study was completed in all patients in both groups, and all their data were included in the statistical analysis. The demographic, anesthesia, and surgical data were similar for the 2 groups (Table 1). The 2 groups did not differ in initial core body temperature (36.5°C ± 0.3°C in group RT and 36.4°C ± 0.5°C in group W, $P = .744$). The target temperatures of irrigation fluid were maintained throughout the operation in each group.

The core body temperatures decreased throughout the operation and linearly increased by warming in the PACU, and there were no intergroup differences in these temperature changes (Fig 1). The incidence of hypothermia during the operation in group RT (33 of 36,
91.6%) and group W (33 of 36, 94.4%) was not different ($P = .276$) (Table 2). In addition, no intergroup differences were noted in the last and lowest core body temperatures, VAS pain score, difference in PT, decrease in hemoglobin level, and weight gain (Table 2). A negative correlation was noted between the last core body temperature and body weight gain in group RT ($r = -0.374$, $P = .038$). The body mass index showed a positive correlation with the last core body temperature in both group RT ($r = 0.313$, $P = .043$) and group W ($r = 0.397$, $P = .016$). However, other variables such as age, decrease in hemoglobin level, amount of fluid used, duration of anesthesia, and operative time did not show any relation with the core body temperature in both groups (all $P > .05$). At 30 minutes after arrival in the PACU, the number of patients reaching normothermia was higher in group W (24 of 36, 66%) than in group RT (14 of 36, 42%) ($P = .033$). Normothermia was restored in all patients in both groups within 60 minutes of arrival in the PACU (Table 3).

In the case of 1 patient in group W, ST elevation was noted, which was normalized by nitroglycerin infusion during the operation. Two patients in group W had bradycardia, but it was resolved during warming in the PACU. Nausea, vomiting, headache, and wound infections were not recorded in any patient in the 2 groups.

### Discussion

This study aimed to compare the effect of warmed irrigation fluid and room-temperature irrigation fluid on the prevention of perioperative hypothermia in patients undergoing arthroscopic rotator cuff surgery. Our results showed that with both types of fluids, the core body temperatures decreased in a similar manner throughout surgery, without any intergroup differences.

Reports indicate that 50% to 70% of surgical patients have hypothermia, mainly because of anesthesia-induced impairment of thermoregulatory control and exposure to the cool operating room environment. The main mechanism underlying the development of hypothermia during general anesthesia is heat redistribution, which is defined as the shift of the internal heat from core body structures to the peripheral limbs. Besides heat redistribution, another important contributor to hypothermia is heat loss from the skin by convection and radiation. Parodi et al. showed that the prolonged surgery time contributes toward the development of hypothermia during hip arthroscopic surgery; thus a reduction in the operative time and appropriate skin coverage are important for preventing hypothermia.

Mild perioperative hypothermia (34°C to 36°C) should be avoided because of the possible complications that can adversely affect the surgical outcomes. Hypothermia increases the metabolic demand of the myocardium by

### Table 2. Perioperative Clinical Data

<table>
<thead>
<tr>
<th>Variables</th>
<th>Group RT (n = 36)</th>
<th>Group W (n = 36)</th>
<th>$P$ Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypothermia [n (%)]</td>
<td>33 (91.6)</td>
<td>34 (94.4)</td>
<td>.276</td>
</tr>
<tr>
<td>CBT (°C)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Last</td>
<td>35.4 ± 0.6</td>
<td>35.5 ± 0.6</td>
<td>.554</td>
</tr>
<tr>
<td>Lowest</td>
<td>35.4 ± 0.5</td>
<td>35.4 ± 0.5</td>
<td>.776</td>
</tr>
<tr>
<td>VAS pain score (from 0 to 10)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Immediately postoperatively</td>
<td>8.3 ± 2.1</td>
<td>9.0 ± 1.7</td>
<td>.169</td>
</tr>
<tr>
<td>Postoperative day 1</td>
<td>2.9 ± 1.8</td>
<td>3.0 ± 1.1</td>
<td>.742</td>
</tr>
<tr>
<td>PT difference</td>
<td>0.0 ± 0.2</td>
<td>0.1 ± 0.1</td>
<td>.372</td>
</tr>
<tr>
<td>Decrease in hemoglobin level (g/dL)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight gain (kg)</td>
<td>-0.5 ± 2.2</td>
<td>0.3 ± 0.8</td>
<td>.446</td>
</tr>
<tr>
<td>Shivering [n (%)]</td>
<td>3 (8)</td>
<td>1 (3)</td>
<td>.347</td>
</tr>
<tr>
<td>Dizziness [n (%)]</td>
<td>3 (8)</td>
<td>1 (3)</td>
<td>.349</td>
</tr>
</tbody>
</table>

CBT, core body temperature.

### Table 3. Number of Normothermic Patients During Recovery Period in PACU

<table>
<thead>
<tr>
<th>PACU Stay</th>
<th>Group RT (n = 36)</th>
<th>Group W (n = 36)</th>
<th>$P$ Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 min</td>
<td>14 (42)</td>
<td>18 (50)</td>
<td>.477</td>
</tr>
<tr>
<td>30 min</td>
<td>14 (42)</td>
<td>24 (66)</td>
<td>.033*</td>
</tr>
<tr>
<td>60 min</td>
<td>36 (100)</td>
<td>36 (100)</td>
<td>&gt;.99</td>
</tr>
</tbody>
</table>

Data are presented as number of patients (percent).

*Significance is set at $P < .05$. 
cold-induced sympathoadrenal activation without vasocostriction and increases the circulating catecholamine levels, which can lead to tachycardia, hypertension, systemic vasocostriction, and imbalance between myocardial oxygen supply and demand; these complications, in turn, can cause serious problems in high-risk patients.

Hypothermia can also lead to coagulopathy and increase perioperative blood loss by causing platelet or clotting factor enzyme dysfunction and impaired fibrinolytic activity. This can affect the immune function and promote perioperative wound infection, as well as delay recovery and cause thermal discomfort in the PACU.

Considering these issues, the use of warmed irrigation fluid could be important especially during intra-abdominal and intrathoracic endoscopic or arthroscopic surgeries because these surgeries involve the use of a large amount of irrigation fluid for a long duration. On the other hand, few clinical studies have supported the use of warmed irrigation fluid to decrease perioperative hypothermia during arthroscopic shoulder surgery.

Kim et al. performed a clinical study on 50 patients undergoing arthroscopic shoulder surgery. Their patients were randomly allocated to receive irrigation fluid either at room temperature or warmed to temperatures between 37°C and 39°C. The authors found that hypothermia occurred more often when using room-temperature fluid than warmed fluid for irrigation during surgery. They also noted that the patient’s age and the amount of irrigation fluid used correlated with the core body temperature when using room-temperature irrigation fluid.

In the study by Board and Srinivasan, 24 patients undergoing arthroscopic subacromial decompression received room-temperature (22°C) or warmed (36°C) irrigation fluid. The mean maximum drop in the room-temperature fluid group and the warmed fluid group was 1.67°C and 0.33°C, respectively (P < .001). Furthermore, the drop in the core body temperature in the room-temperature fluid group was maintained, whereas normothermia was resumed within 30 minutes in the warmed fluid group during the operation.

However, we have to consider an important limitation of the 2 previously mentioned studies. The target temperature of warmed irrigation fluid was 37°C to 40°C in both studies. These high target temperatures may be associated with complications. High target temperatures were found to be associated with complications such as hyperthermia and skin burns in 1 patient in our pilot study. Therefore the use of irrigation fluid warmed to over 36°C is not recommended for arthroscopic surgery. The discrepancies between the results of our study and the previous studies may be attributed to the higher temperature of warmed irrigation fluid in the latter. In addition, the operations were not homogeneous (including both rotator cuff surgery and Bankart operation) in the study of Kim et al., which might have led to differences in age distribution and operative time. On the other hand, all patients in our study underwent the same surgical procedure (i.e., rotator cuff repair) by the same surgeon. These factors might have contributed to the differences in the results.

The results of several studies performed thus far are supportive of those of our study. Kelly et al. documented that in knee arthroscopy, patients receiving warmed irrigation fluid did not maintain a higher core body temperature than those receiving room-temperature fluid but that they had a greater decline in temperature than the control group; they speculated that this may be because of the heat loss associated with warm irrigation fluid—mediated vasodilatation within the tissues of the knee joint.

Jaffe et al. conducted a clinical study to determine the effect of irrigation fluid temperature (room temperature vs warmed) on the changes in core body temperature in patients undergoing transurethral resection of the prostate, and they suggested that the irrigation fluid temperature was not a factor responsible for altering the core body temperature in these patients. They showed that factors such as the length of time spent in the operating room and the ambient temperature of the operating room, along with the amount of irrigation fluid absorbed, may have a greater impact on the core body temperature than the irrigation fluid temperature itself.

Interventions to maintain patient body temperature in the operating room include covering the patient’s head and body, increasing the ambient room temperature, using warming intravenous fluids, and applying external warming devices. We believe that with good nursing care, a minimal operative time, and the proper use of warming blankets, the incidence of postoperative hypothermia from arthroscopic rotator cuff surgery can be minimized. PACU staff should be encouraged to aggressively support body heat retention through the use of warmed sheets or blankets, forced-air warming devices, warmed intravenous fluids, and heat lamps.

**Limitations**

This study has several limitations. First, no standard temperature has been set for the irrigation fluid. We arbitrarily decided that the irrigation fluid should not be of a temperature greater than 36°C to avoid skin burns or hyperthermia. Second, 2 different methods were used for measuring core body temperature. During the operation, the core body temperature was measured with an esophageal stethoscope, but a digital tympanic thermometer was used in the PACU. There might be some differences between these 2 modalities. Finally, it would be difficult to apply these results to patients aged older than 70 years or those undergoing a prolonged operation for more than 2 hours because these clinical
conditions were beyond the scope of our data. Excluding patients whose procedures will take longer and who will be at higher risk of intraoperative hypothermia may introduce bias into the study by only examining a group of patients who are relatively resistant to hypothermia from the outset. Further studies are needed to address the effects of fluid temperature on patients undergoing more complex, lengthy operations or patients who require external warming devices either before or during surgery.

**Conclusions**

Warmed irrigation fluid was not superior to room-temperature irrigation fluid in reducing the occurrence of perioperative hypothermia during arthroscopic shoulder surgery.

**References**