Controle de Temperatura em Intervenção Cirúrgica Abdominal Convencional: Comparação entre os Métodos de Aquecimento por Condução e Condução Associada à Convecção*

*Temperature Control in Conventional Abdominal Surgery: Comparison between Conductive and the Association of Conductive and Convective Warming

Marcelo Lacava Pagnocca, TSA1, Eun Joo Tai2; Joana L. Dwan3

RESUMO
Pagnocca ML, Tai EJ, Dwan JL — Controle de Temperatura em Intervenção Cirúrgica Abdominal Convencional: Comparação entre os Métodos de Aquecimento por Condução e Condução Associada à Convecção.

MÉTODO: Quarenta e três pacientes de ambos os sexos de 18 a 88 anos de idade, submetidos à laparotomia xifopubiana sob anestesia geral e monitorização da temperatura esofágica, foram distribuídos de modo aleatório em dois grupos de aquecimento: COND (n = 24), com colchão de circulação de água a 37°C no dorso e COND + CONV (n = 19), com a mesma condição associada à manta de ar aquecido a 42°C sobre o tórax e membros superiores. Analisados peso, sexo, idade, duração da operação e anestesia, temperaturas na indução anestésica (Mi), horas consecutivas (M1, M2), e ponto de entrada (MREC) e saída (MREC) da recuperação pós-anestésica (SRPA), além das incidências de tremores e queixas de frio e no pós-operatório.

RESULTADOS: Os grupos foram semelhantes em todas as variáveis analisadas, exceto nas temperaturas em M1, M2, e M4, final da operação (Mes) e anestesia (Mfa), entrada (MREC) e saída (MREC) da recuperação pós-anestésica (SRPA), além das incidências de tremores e queixas de frio no pós-operatório.

CONCLUSÕES: Associar métodos de aquecimento retardou a instalação e diminui a intensidade da hipotermia intra-operatória, mas não reduziu a incidência das queixas de frio e tremores.

Unitermos: CIRURGIA, abdominal; COMPLICAÇÕES, hipotermia; MONITORIZAÇÃO, temperatura; RECUPERAÇÃO PÓS-OPERATÓRIA, tremores; TRATAMENTO, aquecimento.

SUMMARY
Pagnocca ML, Tai EJ, Dwan JL — Temperature Control in Conventional Abdominal Surgery: Comparison Between Conductive and the Association of Conductive and Convective Warming.

BACKGROUND AND OBJECTIVES: Intraoperative hypothermia is a common complication, and its development is favored by abdominal surgeries. The efficacy of the association of conductive and convective warming methods in the prevention of hypothermia, and its effects during postoperative recovery were the objectives of this study.

METHODS: Forty-three patients of both genders, ages 18 to 88 years, undergoing xiphopubic laparotomy under general anesthesia and monitoring of the esophageal temperature were randomly divided in two groups, according to the warming method: COND (n = 24), circulating-water mattress at 37°C on the back, and COND + CONV (n = 19), circulating-water mattress associated with warm air blanket at 42°C over the thorax and upper limbs. Weight, gender, age, duration of surgery and anesthesia, temperature on anesthetic induction (M1), consecutive hours (M2, M4), end of surgery (Mfa) and anesthesia (Mfa), and admission (MREC) and discharge (MREC) from the post-anesthetic recovery room (PARR), besides the postoperative incidence of tremors and complaints of cold, were analyzed.

RESULTS: Both groups were similar regarding all parameters analyzed, except temperatures on M1, M2, M4, and M4. The temperature of patients in the COND group decreased from the second hour of anesthetic induction on, but in the COND + CONV group it only happened in the fourth hour. Patients in the COND group presented hypothermia upon admission and discharge from the PARR.

CONCLUSIONS: The association of different warming methods delayed the beginning and reduced the severity of intraoperative hypothermia, but it did not reduce the complaints of feeling cold and tremors.

Key Words: COMPLICAÇÕES, hipotermia; MONITORIZAÇÃO, temperatura; POSTOPERATIVE RECOVERY, tremors; SURGERY, abdominal; TREATMENT, warming.
Temperature Control in Conventional Abdominal Surgery: Comparison between Conductive and the Association of Conductive and Convective Warming

Marcelo Lacava Pagnocca, TSA, M.D.; Eun Joo Tai, M.D.; Joana L. Dwan, M.D.

INTRODUCTION

Hypothermia is very common during the anesthetic-surgical procedure 1,2. This condition is defined as a reduction in central temperature below 36°C 3. In mammals, the central compartment is formed by intracavitary contents and the central nervous system, richly vascularized tissues where temperature is relatively constant, while the peripheral compartment corresponds to the body surface (skin) and limbs, whose temperature is usually 2°C to 4°C below the central temperature 4.

Hypothermia can be intentional or inadvertent, but it is always secondary to inhibition of thermoregulatory mechanisms induced by anesthesia, along with exposure to the temperature of the operating room 3,4. This condition can cause several complications in the surgical patient 5, especially the elderly 6 and patients with cardiovascular disorders 7. Thus, when undesirable, hypothermia should be avoided.

Patients undergoing different abdominal surgeries are especially susceptible due to exposure usually prolonged of the large visceral surface to the temperature of the operating room when the conventional approach is used 8,9.

Cutaneous vasoconstriction triggered by hypothermia is the main mechanism of reduction of heat loss from the central compartment to the environment 3,4, but it also decreases the transference of heat to the central compartment 10 and, therefore, although warming from the skin is not prevented 11, it is more easily achieved while skin vasoconstriction has not developed 12. Thus, it is probably easier to maintain intraoperative normothermia than to rewarl patients in the postoperative period.

To avoid the inadvertent development of intra and postoperative hypothermia, methods that limit the loss of heat from the skin to the environment can be used 13. Forced-air warming blankets are among the most effective methods 14,15, transferring more than 50 Watt.hour⁻¹ of energy to the patient 16. However, to be effective, they should cover a large extension of the body surface, which is not feasible in open abdominal surgeries and, in those cases, circulating-water mattresses can be used.

Association of both devices should transfer a higher amount of heat than each one separately; however, until now the efficacy of this association in preventing inadvertent hypothermia in surgeries with large tissue exposure associated
with important loss of heat to the environment has not been determined. This hypothesis motivated the present study. The objective of this study was to compare the efficacy of the forced-air blanket to the association of forced-air blanket and circulating-water mattress, in this type of surgery, in two aspects: maintaining intraoperative normothermia and avoiding hypothermia in the immediate postoperative period.

METHODS

After approval by the Ethics on Research Committee of the institution, patients signed the informed consent after the objectives of the study, possible advantages and risks, and the method of measuring central temperature were explained. Data was collected at the operating room of the Instituto Central do Hospital das Clínicas da Faculdade de Medicina da Universidade de São Paulo. All patients underwent elective surgeries.

Forty-three patients, ages 20 to 88 years, physical status ASA I to III, undergoing exploratory laparotomy with a median xyphopubic incision under standardized general anesthesia with propofol, fentanyl, atracurium, and isoflurane participated in this study.

The size of the study population was calculated with the following formula: 

\[ E = \sqrt{\frac{n}{sd}} \]

where \( E \) corresponds to standard error – established arbitrarily in 10% due to the similarities observed in the literature – \( n \) corresponds to the sample, and \( sd \) corresponds to the standard deviation obtained by observing the temperature at the end of the anesthetic-surgical procedure of the first twenty patients.

The temperature was analyzed on the following moments:
- After induction (\( M_i \)), each consecutive hour (\( M_1, M_2, \ldots, M_n \)), at the end of the surgery (\( M_{es} \)) and end of anesthesia (\( M_{ea} \)), and upon admission to (\( M_{rec} \)) and discharge (\( M_{dis} \)) from the post-anesthetic recovery room (PARR) or intensive care unit.

Monitoring included, besides the thermometer, continuous electrocardiogram on DII, pulse oximeter, non-invasive blood pressure, capnography, inspired and expired gas and isoflurane analyzer, and urine output.

The Chi-square test was used for the statistical analysis of discontinuous parameters like gender, presence of postoperative tremors, and complaints of feeling cold. Analysis of Variance for repeated measurements (ANOVA) was used to analyze intraoperative temperature to detect intragroup differences among the different moments applying, post hoc, multiple comparisons against control (Holm-Sidak test) to identify when the differences occurred. As for temperature during recovery (PARR or ICU), non-paired Student t test was used for the intragroup comparison of admission and discharge temperatures as well as intergroup temperature on the same moment. It was considered a level of significance of 5% (\( p < 0.05 \)).

RESULTS

The sample analyzed was homogenous regarding weight, age, and gender distribution (Table I).

The duration in minutes of the surgical \( (p = 0.367) \) and anesthetic \( (p = 0.402) \) procedures was similar in both groups with 229 ± 104 and 321 ± 123 minutes, respectively, in the conductive Group (COND), and 268 ± 148 and 362 ± 159 minutes in the group with association of methods (COND+CONV). Similarly, intergroup differences in the incidence of tremors,
complaints of feeling cold, and length of stay in the postoperative recovery room (PORR) or ICU were not observed (Table II). An intergroup difference in temperature on all moments from the third hour (M3) on (Table III and Figure 1) was observed.

Table I – Anthropometric Data

<table>
<thead>
<tr>
<th></th>
<th>COND</th>
<th>COND + CONV</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight (kg) *</td>
<td>71.3 ± 20.5</td>
<td>64.7 ± 13.7</td>
<td>0.210</td>
</tr>
<tr>
<td>Age (years) *</td>
<td>54 ± 17</td>
<td>49 ± 19</td>
<td>0.396</td>
</tr>
<tr>
<td>Gender (M/F) (%)</td>
<td>37.5 / 62.5</td>
<td>36.8 / 63.2</td>
<td>0.965</td>
</tr>
</tbody>
</table>

*Results expressed as Mean ± SD.
COND = conductive; COND+CONV = conductive + convective.

Table II – Incidence of Tremors and Complaints of Feeling Cold, and Length of Stay in the Post-Anesthetic Recovery Room or Intensive Care Unit

<table>
<thead>
<tr>
<th></th>
<th>COND</th>
<th>COND + CONV</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tremors (cases / n)</td>
<td>1 / 24</td>
<td>3 / 19</td>
<td>0.181</td>
</tr>
<tr>
<td>Complaints of feeling cold (cases/n)</td>
<td>3 / 24</td>
<td>3 / 19</td>
<td>0.730</td>
</tr>
<tr>
<td>Length of stay in the PARR (min) *</td>
<td>171 ± 181</td>
<td>204 ± 160</td>
<td>0.683</td>
</tr>
<tr>
<td>Length of stay in the ICU (min) *</td>
<td>1248 ± 654</td>
<td>4110 ± 4659</td>
<td>0.210</td>
</tr>
</tbody>
</table>

*Results expressed as Mean ± SD.
COND = conductive; COND+CONV = conductive + convective; n = number of patients.

Table III – Nasopharyngeal Temperature (central) In the Operating Room on Induction (Mi), During the next 4 consecutive Hours (M1, M2, M3, and M4), at the End of Surgery (Mfo), and at the End of Anesthesia (Mfa)

<table>
<thead>
<tr>
<th></th>
<th>COND</th>
<th>COND + CONV</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1 (°C)</td>
<td>36.2 ± 0.6 (n = 24)</td>
<td>35.9 ± 0.4 (n = 19)</td>
<td>0.085</td>
</tr>
<tr>
<td>M2 (°C)</td>
<td>36.0 ± 0.6 (n = 24)</td>
<td>35.9 ± 0.5 (n = 19)</td>
<td>0.772</td>
</tr>
<tr>
<td>M3 (°C)</td>
<td>35.7 ± 0.6 (n = 23)</td>
<td>36.0 ± 0.7 (n = 19)</td>
<td>0.129</td>
</tr>
<tr>
<td>M4 (°C)</td>
<td>35.7 ± 0.7 (n = 19)</td>
<td>36.5 ± 0.7 (n = 14)</td>
<td>0.003</td>
</tr>
<tr>
<td>Mfo (°C)</td>
<td>35.8 ± 0.8 (n = 13)</td>
<td>36.8 ± 0.7 (n = 11)</td>
<td>0.004</td>
</tr>
<tr>
<td>Mfa (°C)</td>
<td>35.8 ± 0.7 (n = 24)</td>
<td>36.8 ± 1.0 (n = 19)</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

Results expressed as Mean ± SD.
COND = conductive; COND+CONV = conductive + convective; n = number of patients who achieved the moment in question; °C = degrees Celsius.

Figure 1 – Recovery Nasopharyngeal temperature (central) throughout the study. COND = conductive; COND+CONV = conductive + convective. Nasopharyngeal temperature (central) during surgery on the moments corresponding to induction (M1), the next four consecutive hours (M2, M3, M4, and Mfo), at the end of surgery (Mfo), and end of anesthesia (Mfa).
The COND group showed differences between the initial temperature, considered the control temperature (M), and the temperature measured on all consecutive moments from the second hour on: M4 (p < 0.001), M5 (p < 0.001), M6 (p = 0.005), M7 (p < 0.01), and M8 (p < 0.001). On the other hand, in the COND+CONV group, differences were observed between the initial temperature (M) and the temperature four hours after the beginning of the procedure: M7 (p = 0.002), M8 (p < 0.001), and M9 (p < 0.001). Intergroup differences in the temperature upon admission to and discharge from the recovery room were not observed; however, the COND group, but not the COND+CONV group, showed a difference between the temperature upon admission to the recovery room and the discharge from this unit (Table IV).

The COND group showed differences between the initial temperature, considered the control temperature (M), and the temperature measured on all consecutive moments from the second hour on: M4 (p < 0.001), M5 (p < 0.001), M6 (p = 0.005), M7 (p < 0.01), and M8 (p < 0.001). On the other hand, in the COND+CONV group, differences were observed between the initial temperature (M) and the temperature four hours after the beginning of the procedure: M7 (p = 0.002), M8 (p < 0.001), and M9 (p < 0.001). Intergroup differences in the temperature upon admission to and discharge from the recovery room were not observed; however, the COND group, but not the COND+CONV group, showed a difference between the temperature upon admission to the recovery room and the discharge from this unit (Table IV).

### DISCUSSION

In intracavitary surgeries, in which the surgical field restricts the warm area, this limitation does not favor normothermia. Therefore, the association of two active warming methods reaching both the anterior, smaller, and the posterior aspect of the body, an area that is not actively warmed, was considered.

Several studies, incorporating different warming methods, comparing active and passive systems 20-22, or active of one type and active of other type 9,14,15,23,24, can be found in the literature, but not comparing the efficacy of the association of two active warming devices, which motivated the present study.

The first analysis of the results assessed whether both groups were comparable, since gender 4, age 6,25, and body mass 4,26 have a significant influence on thermal homeostasis. Weight (p = 0.210), age (p = 0.396), and gender (p = 0.965) were similar in both groups and therefore they formed a homogenous sample eliminating selection bias on group formation.

Similarly, the influence of the length of anesthesia and surgery on the genesis of intraoperative hypothermia was similar in both groups, both for anesthesia (p = 0.367) and surgery (p = 0.402). This is important since the procedures, although all of them involved the abdomen, varied considerably.

Besides, the number of patients in each group was not similar. This numeric asymmetry was secondary to the large number of elective surgeries done in the institution, usually more than a hundred a day. Such demand associated with the need to control the temperature of many of those patients restricted the number of heat generators available, especially for the association group.

Environmental temperature and humidity were strictly controlled, since the operating room has a central air system, which is verified three times a day. This level of care was important, since those parameters interfere directly with the temperature of anesthetized patients 19, especially patients with intracavitary contents exposure 23.

To compare the efficacy of the methods studied, a reference point considered the control was adopted. This control temperature expresses the condition of normolcy of the patients before undergoing the warming method evaluated. The temperature measured immediately after anesthetic induction (M) was used since, in the brief interval between unconsciousness and placement of the heat sensor, the central heat could not have been redistributed, leading to a significant temperature variation 3.

Analysis of variance for repeated measurements demonstrated a reduction in temperature in both groups. Multiple comparisons of those parameters on the different moments against control (Holm-Sidak test) identified when those variations occurred.

In the group of patients warmed only by the conductive warming method (COND), hypothermia was evident on the second hour after anesthetic induction (p = 0.01). In this same group, it was also observed a reduction of almost one degree (35.7°C ± 0.7°C) below that observed (36.5°C ± 0.7°C) in the group of combined methods from the third hour on. Mean temperatures showed a tendency for reduction on consecutive moments, which were progressively lower until discharge of the patient from post-anesthetic recovery, PARR or ICU.

On the other hand, in the group of associated warming methods (COND+CONV), hypothermia was observed only four hours after anesthetic induction (p = 0.002). In this group, mean temperatures showed a tendency for elevation in all subsequent moments, which is the opposite of the COND group. When only the conductive method was used, the temperature showed a tendency for early reduction after anesthetic induction, remaining below the control temperature until the end of the anesthetic procedure.

This condition persisted until the end of post-anesthetic recovery since temperature upon discharge (35.8 ± 0.7°C) was practically the same at admission (35.3 ± 0.7°C) to PARR (p = 0.048), showing the hypothermia, although mild, was still evident at that moment.

When the conductive and convective methods were associated (COND+CONV), a tendency for an increase in temperature until the end of the anesthetic procedure was observed, remaining within normal limits during the surgery. In this

<table>
<thead>
<tr>
<th>Table IV</th>
<th>Nasopharyngeal Temperature (central) Upon Admission to (MREC) and Discharge from (MREC) Post-Anesthetic Recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>COND</td>
</tr>
<tr>
<td>MREC (°C)*</td>
<td>35.3 ± 0.7</td>
</tr>
<tr>
<td>MREC (°C)*</td>
<td>35.8 ± 0.7</td>
</tr>
<tr>
<td>Significance</td>
<td>0.048</td>
</tr>
</tbody>
</table>

*Results expressed as Mean ± SD.
COND = conductive; COND+CONV = conductive + convective.
group, the tendency for an increase in temperature resulted on a post-anesthetic evolution different from that of the other group. When they were transferred to post-anesthetic recovery, either in the PARR or ICU, differences in temperature between admission (36.2 ± 1.1°C) and discharge (36.4 ± 0.9°C) (p = 0.081) from the unit were not observed. And more important, those values are within normal limits.

This seemed the most relevant result of the study, since in both groups active warming was interrupted at the end of the anesthetic procedure, but only the group of combined methods did not develop hypothermia during post-anesthetic recovery. The resulting cutaneous vasoconstriction causes thermal isolation of the central compartment, delaying heat transfer from the surface; therefore, it is reasonable to assume that the hypothermia developed intraoperatively can last throughout the recovery period, leading to all sorts of complications.

In the present study, although hypothermia was observed only in the COND group, postoperative differences in the incidence of complaints of feeling cold (p = 0.730) were not observed. Three out of 24 patients in the COND group and three out of 19 patients of the COND+CONV group complained of feeling cold during the post-anesthetic recovery period, similar to the results of other studies in which intraoperative active warming methods were used.

Tremor is the most important complication of hypothermia. In the present study, the incidence of tremors was similar in both groups (p = 0.181), although patients in the COND group presented lower temperatures (35.5 ± 0.7°C) than the COND+CONV group (36.2 ± 1.1°C) upon admission to post-anesthetic recovery.

Other authors concluded that there is an inverse correlation between the incidence of postoperative tremors and central temperature; however, the mean age of the patients in that study was approximately 20 years greater than in the present study, and those authors had already demonstrated that the elderly shiver less.

The results of other studies and the results of the present study suggest that the amount of heat transferred to the patient is the main determinant in the prevention of perioperative hypothermia and the complications it causes. The association of conductive and convective methods was more effective on preventing hypothermia than the conductive method alone, delaying its development and decreasing its severity. Besides, only the association of both methods was capable of preventing the post-anesthetic development of hypothermia.

REFERÊNCIAS — REFERENCES

RESUMEN
Pagnocca ML, Tai EJ, Dwan JL — Control de Temperatura en Intervención Quirúrgica Abdominal Convencional: Comparación entre los Métodos de Calentamiento por Conducción y Conducción Asociada a la Convección.

JUSTIFICATIVA Y OBJETIVOS: La Hipotermia intraoperatoria es una complicación frecuente, favorecida por la operación abdominal. La eficacia de la asociación de los métodos de calentamiento por conducción y convección en la prevención de hipotermia y sus efectos en el periodo de recuperación postoperatoria, fueron los objetivos de este estudio.

MÉTODO: Cuarenta y tres pacientes de los dos sexos, entre 18 y 88 años de edad, sometidos a la laparotomía xifopúbica bajo anestesia general y monitorización de la temperatura esofágica, aleatoriamente distribuidos en dos grupos de calentamiento: COND (n = 24) colchón de circulación de agua a 37,0°C en el dorso y COND + CONV (n = 19) la misma condición asociada a la manta de aire calentado a 42°C sobre el tórax y los miembros superiores. Se analizó el peso, sexo, edad, duración de la operación y anestesia, temperaturas en la inducción anestésica (Mᵢ), horas consecutivas (Mᵢ, Mᵢ₊₁, Mᵢ₊₂), final de la operación (Mᶠₒ), y anestesia (Mᶠᵤᵦ), entrada (Mₑ-REC) y salida (Mˢ-REC) de la recuperación postanestésica (SRPA), además de las incidencias de temblores y quejidos de frío en el postoperatorio.

RESULTADOS: Los grupos fueron similares en todas las variables analizadas, excepto en las temperaturas en Mᵢ, Mᵢ₊₁, Mᵢ₊₂ y Mᵢ₊₃. El Grupo COND redujo la temperatura a partir de la segunda hora de la inducción anestésica, pero el grupo COND + CONV sólo en la cuarta hora. En COND se observó una hipotermia en la entrada y en la salida de la SRPA.

CONCLUSIONES: El asociar métodos de calentamiento, retardó la instalación y redujo la intensidad de la hipotermia intraoperatoria, pero no redujo la incidencia de los quejidos de frío y los temblores.