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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, TSA [1], Eun Joo Tai [2]; Joana L. Dwan [3]

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.

JUSTIFICATIVA E OBJETIVOS: *Hipotermia intra-operatória é complicação frequente, favorecida por operação abdominal. A eficácia da associação dos métodos de aquecimento por condução e convecção na prevenção de hipotermia e seus efeitos no período de recuperação pós-operatória foram os objetivos deste estudo.*

MÉTODO: *Quarenta e três pacientes de ambos os sexos de 18 a 88 anos de idade, submetidos à laparotomia xifopúbica 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 (M_i), horas consecutiva (M_1, M_2), final da operação (M_{fo}) e anestesia (M_{fa}), entrada ($M_{e\text{-}REC}$) e saída ($M_{s\text{-}REC}$) da recuperação pós-anestésica (SRPA), além das incidências de tremores e queixas de frio no pós-operatório.*

RESULTADOS: *Os grupos foram semelhantes em todas as variáveis analisadas, exceto nas temperaturas em M_2, M_3, M_4, M_{fo} e M_{fa}. O grupo COND reduziu a temperatura a partir da segunda hora da indução anestésica, mas o grupo COND + CONV só na quarta hora. Em COND, observou-se hipotermia na entrada e saída da SRPA.*

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 xyphopubic 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 (M_i), consecutive hours (M_1, M_2), end of surgery (M_{es}) and anesthesia (M_{ea}), and admission ($M_{a\text{-}REC}$) and discharge ($M_{d\text{-}REC}$) 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 M_2, M_3, M_4, M_{es}, and M_{ea}. 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: COMPLICATIONS, hypothermia; MONITORING, temperature; POSTOPERATIVE RECOVERY, tremors; SURGERY, abdominal; TREATMENT, warming.

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cutânea resultante leva ao isolamento térmico do compartimento central[12], retardando a transferência de calor a partir da superfície [11,27]. Assim, é mais do que razoável supor que a hipotermia desenvolvida durante o período intra-operatório possa prolongar essa condição durante o período de recuperação, acarretando todo cortejo de complicações dela originados.

Na atual pesquisa, apesar de observada hipotermia no pós-operatório apenas no grupo COND, não foram observadas diferenças na incidência das queixas de frio (p = 0,730). Do total, 3 dos 24 pacientes do grupo COND e 3 dos 19 pacientes do grupo COND + CONV queixaram-se de frio em algum momento da sua permanência em recuperação pós-operatória, valores semelhantes aos observados em outros estudos, nos quais também foram empregados métodos de aquecimento ativo no intra-operatório [7,28-30].

O tremor é complicação importante decorrente da hipotermia [4,5]. No presente estudo as incidências de tremores foram semelhantes nos grupos (p = 0,181), a despeito dos pacientes do grupo COND terem apresentado temperaturas mais baixas (35,3°C ± 0,7°C) que os pacientes do grupo COND + CONV (36,2°C ± 1,1°C) na admissão da recuperação pós-anestésica.

Outros autores concluíram que há relação inversa entre a incidência de tremores pós-operatórios e a temperatura central [29]. Contudo, a média de idade dos pacientes daquele estudo foi cerca de 20 anos maior que a dos pacientes do atual, e, como o mesmo grupo já demonstrara [6], idosos tremem menos.

Tanto os resultados de outros estudos [9,15,31,32] como o observado na atual pesquisa sugerem que a quantidade de calor transferido ao paciente é o principal determinante na prevenção da instalação da hipotermia perioperatória e de seu corolário de complicações [25,33-38].

A eficácia em evitar a hipotermia no período intra-operatório da associação dos métodos condutivo e convectivo foi superior àquela conseguida pelo método de condução empregado de forma isolada, retardando o seu aparecimento e diminuindo a intensidade dessa condição adversa.

Além disso, apenas a associação dos dois métodos foi capaz de impedir o surgimento de hipotermia no período de recuperação pós-anestésica.

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

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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 [2].

Hypothermia can be intentional or inadvertent, but it is always secondary to inhibition of thermoregulatory mechanisms induced by anesthesia, along with exposure of 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, for this reason, 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 rewarm 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: $E = \sqrt{n} / sd$ [17], 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.
Patients with prior temperature derangements, such as fever or pre-anesthetic hypothermia, were excluded.
Patients with coagulopathies, heart disease, peripheral vascular disease, decreased level of consciousness for any reason, and those with nasopharyngeal lesions hindering placement of the temperature sensor were also excluded. Patients in the study did not undergo associated spinal block (combined anesthesia) due to possible interference with the central temperature [3,6].
The study population was randomly divided, by flipping a coin, in two groups.
The COND group (circulating-water mattress) was formed by 24 patients and the COND+CONV group (mattress and forced-air blanket) had 19 patients.
Heat generators, both for the mattress and blanket, were regulated for the target temperature of 37° C ± 0.5° C, being turned off at the end of the procedure. The temperature of the operating room (OR) was controlled at 22º C ± 0.1° C, while the temperature of the post-anesthetic recovery room (PARR) and intensive care unit (ICU) was controlled at 25°C ± 0.2°C. Humidity was controlled from 70% to 80% in all study environments (OR, PARR, and ICU).
During the surgery, patients were supine (horizontal dorsal decubitus) with their arms abducted 90° in relation to the longitudinal axis.
In the COND group, the circulating-water mattress was covered with a cotton sheet, patients were covered up to the cervical region with a simple surgical field until exposure of the abdomen for the xyphopubic incision.
In the COND+CONV group, besides the procedure described before, patients were covered with a forced-air blanket, including their arms, anterolateral segment of the thorax and neck, from the internipple line to the thyroid cartilage.
During the procedure, only the area of the surgery was exposed.
To monitor the central temperature, the extremity of the probe, which was introduced through the nose after tracheal intubation, was positioned in the transition between the hypopharynx and the esophagus [18]. The temperature was recorded on a multiparametric monitor (DIXTAL® model DX2010). The anesthesiologists responsible for the patients were instructed to maintain their anesthetic routines, without changing it due to the inclusion of the patient in the study to avoid bias.
The temperature was analyzed on the following moments:
After induction (M_i), each consecutive hour (M_1, M_2, $M_3 \ldots M_n$), at the end of the surgery (M_{es}) and end of anesthesia (M_{ea}), and upon admission to ($M_{a\text{-}REC}$) and discharge ($M_{d\text{-}REC}$) from the post-anesthetic recovery room (PARR) or intensive care unit.
Weight, gender, age, and duration of surgery and anesthesia (in minutes) were also analyzed to assess the homogeneity of the study population, as well as tremors and complaint of feeling cold, and length of stay in the PARR.
Monitoring included, besides the thermometer, continuous electrocardioscope on D_{II}, 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 post-operative recovery room (PORR) or ICU were not observed (Table II).

An intergroup difference in temperature on all moments from the third hour (M_3) on (Table III and Figure 1) was observed.

Table I – Anthropometric Data

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

*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

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

*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 (M_i), During the next 4 consecutive Hours (M_1, M_2, M_3, and M_4), at the End of Surgery (M_{es}), and at the End of Anesthesia (M_{ea})

	COND	COND + CONV	p
M_i (°C)	36.2 ± 0.6 (n = 24)	35.9 ± 0.4 (n = 19)	0.085
M_1 (°C)	36.0 ± 0.6 (n = 24)	35.9 ± 0.5 (n = 19)	0.772
M_2 (°C)	35.7 ± 0.6 (n = 23)	36.0 ± 0.7 (n = 19)	0.129
M_3 (°C)	35.7 ± 0.7 (n = 19)	36.5 ± 0.7 (n = 14)	0.003
M_4 (°C)	35.8 ± 0.8 (n = 13)	36.8 ± 0.7 (n = 11)	0.004
M_{fo} (°C)	35.8 ± 0.7 (n = 24)	36.8 ± 1.0 (n = 19)	< 0.001
M_{fa} (°C)	35.7 ± 0.8 (n = 24)	37.0 ± 1.1 (n = 19)	< 0.001

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

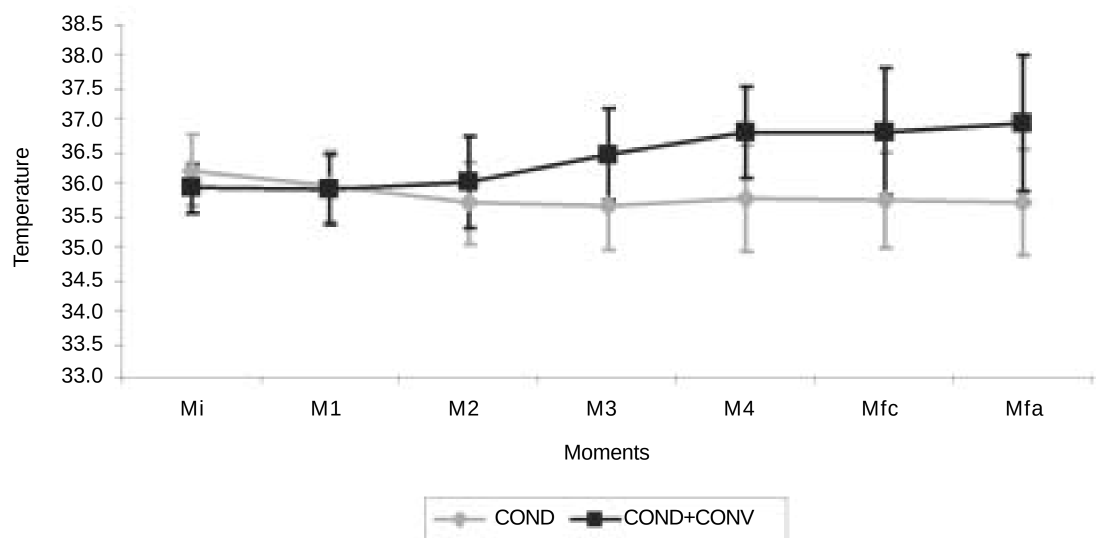

Figure 1 – Recovery Nasopharyngeal temperature (central) throughout the study. COND = conductive; COND+CONV = conductive + convective. Nasopharyngeal temperature (central) during surgery on the moments corresponding to induction (M_i), the next four consecutive hours (M_1, M_2, M_3, and M_4), at the end of surgery (M_{es}), and end of anesthesia (M_{ea}).

Table IV – Nasopharyngeal Temperature (central) Upon Admission to ($M_{a\text{-}REC}$) and Discharge from ($M_{d\text{-}REC}$) Post-Anesthetic Recovery

	COND	COND + CONV	P
$M_{a\text{-}REC}$ (°C)*	35.3 ± 0.7	36.2 ± 1.1	0.015
$M_{d\text{-}REC}$ (°C)*	35.8 ± 0.7	36.4 ± 0.9	0.015
Significance	0.048	0.081	

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

The COND group showed differences between the initial temperature, considered the control temperature (M_i), and the temperature measured on all consecutive moments from the second hour on: M_2 ($p < 0.001$), M_3 ($p < 0.001$), M_4 ($p = 0.005$), M_{es} ($p < 0.01$), and M_{ea} ($p < 0.001$). On the other hand, in the COND+CONV group, differences were observed between the initial temperature (M_i) and the temperature four hours after the beginning of the procedure: M_4 ($p = 0.002$), M_{es} ($p < 0.001$), and M_{ea} ($p < 0.001$). 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 normalcy of the patients before undergoing the warming method evaluated. The temperature measured immediately after anesthetic induction (M_i) 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 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 developed hypothermia during post-anesthetic recovery. The resulting cutaneous vasoconstriction causes thermal isolation of the central compartment [2], delaying heat transference from the surface [11,27]; 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 [7,28-30].

Tremor is the most important complication of hypothermia [4,5]. 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 [29]; 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 [9,15,31,32] 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 [25,33-38].

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.

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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 período 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 (M_i), horas consecutiva (M_1, M_2), final de la operación (M_{fo}) y anestesia (M_{fa}), entrada (M_{e-REC}) y salida (M_{s-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 M_2, M_3, M_4, M_{fo} y M_{fa}. 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.*