



Efficacy of external warming in attenuation of hypothermia in surgical patients

Efikasnost spoljašnjeg zagrevanja u ublažavanju hipotermije kod hirurških bolesnika

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Abstract

Background/Aim. Hypothermia in surgical patients can be the consequence of long duration of surgical intervention, general anaesthesia and low temperature in operating room. Postoperative hypothermia contributes to a number of postoperative complications such as arrhythmia, myocardial ischemia, hypertension, bleeding, wound infection, coagulopathy, and prolonged effect of muscle relaxants. External heating procedures are used to prevent this condition. The aim of this study was to evaluate the efficiency of external warming system in alleviation of cold stress and hypothermia in patients who underwent major surgical procedures. **Methods.** The study was conducted in the Military Medical Academy in Belgrade. A total of 30 patients of both genders underwent abdominal surgical procedures, randomly divided into two equal groups: the one was externally warmed using warm air mattress (W), while in the control group (C) surgical procedure was performed in regular conditions, without additional warming. Oesophageal temperature (Te) was used as indicator of changes in core temperature, during surgery and awakening postoperative period, and temperature of control sites on the right hand (Th) and the right foot (Tf) reflected the changes in skin temperatures during surgery. Te and skin temperatures

were monitored during the intraoperative period, with continuous measurement of Te during the following 90 minutes of the postoperative period. Heart rates and blood pressures were monitored continuously during the intraoperative and awakening period. **Results.** In the W group, the average Te, Tf and Th did not change significantly during the intraoperative as well as the postoperative period. In the controls, the average Te significantly decreased during the intraoperative period (from $35.61 \pm 0.35^{\circ}\text{C}$ at 0 minute to $33.86 \pm 0.51^{\circ}\text{C}$ at 120th minute). Compared to the W group, Te in the C group was significantly lower in all the observed periods. Average values of Tf and Th significantly decreased in the C group (from 30.83 ± 1.85 at 20th minute to $29.0 \pm 1.39^{\circ}\text{C}$ at 120th minute, and from 32.75 ± 0.96 to $31.05 \pm 1.09^{\circ}\text{C}$, respectively). **Conclusion.** The obtained results confirm that the external warming using warm air mattress was able to attenuate hypothermia, i.e. substantial decrease in core temperature, compared with the similar exposure to cold stress in the control group.

Key words:

anesthesia, general; digestive system surgical procedures; hypothermia; intraoperative period; postoperative complications; monitoring, physiologic; heating.

Apstrakt

Uvod/Cilj. Hipotermija kod hirurških bolesnika može biti posledica dugotrajne hirurške intervencije, opšte anestezije i niske temperature vazduha u operacionoj sali. Postoperativna hipotermija može dovesti do brojnih postoperativnih komplikacija kao što su aritmija, ishemija miokarda, hipertenzija, krvarenje, infekcija rane, koagulopatija i produženo dejstvo mišićnih relaksanata. Za prevenciju ovog stanja koristi se spoljašnje zagrevanje. Cilj ove studije bio je procena efikasnosti sistema za spoljašnje zagrevanje radi ublažavanja hipotermije kod bolesnika podvrgnutih dugotrajnim hirurškim procedurama. **Metode.** Ovo istraživa-

nje sprovedeno je u Vojnomedicinskoj akademiji u Beogradu na 30 bolesnika oba pola koji su nasumice bili podeljeni u dve jednake grupe: u jednoj je primenjeno spoljašnje zagrevanje madracem sa toplim vazduhom, dok je druga bila bez dodatnog zagrevanja (kontrolna grupa). U toku hirurške intervencije, kao i tokom postoperativnog perioda buđenja, promene unutrašnje temperature praćene su preko ezofagusne sonde (Te), a promene temperature kože intraoperativno preko kontrolnih tačaka na desnoj šaci (Th) i desnom stopalu (Tf). Srčana frekvencija i vrednosti krvnog pritiska praćeni su kontinuirano tokom hirurške intervencije, kao i u toku perioda buđenja. **Rezultati.** U zagrevanoj grupi, prosečne vrednosti Te, Tf i Th nisu se značajno menjale

tokom intraoperativnog i postoperativnog perioda. U kontrolnoj grupi, prosečna vrednost T_e značajno se smanjila tokom intraoperativnog perioda (sa $35,61 \pm 0,35^\circ\text{C}$ u nultom minutu na $33,86 \pm 0,51^\circ\text{C}$ u 120. minutu). U odnosu na zagrevanu grupu, T_e je u kontrolnoj grupi bila značajno niža u svim posmatranim periodima. Prosečne vrednosti T_{f1} i T_{f2} značajno su se smanjile u kontrolnoj grupi (sa $30,83 \pm 1,85$ u 20. minutu na $29,0 \pm 1,39^\circ\text{C}$ u 120. minutu, odnosno sa $32,75 \pm 0,96$ na $31,05 \pm 1,09^\circ\text{C}$). **Zaključak.** Rezultati ove studije potvrđuju da spoljašnje zagre-

vanje madracem s toplim vazduhom može da ublaži hipotermiju, odnosno da spreči značajno sniženje unutrašnje temperature do kojeg dolazi tokom izlaganja stresu usled hladnoće tokom hirurške intervencije.

Ključne reči:

anestezija, opšta; hirurgija digestivnog sistema, procedure; hipotermija; intraoperativni period; postoperativne komplikacije; fiziološke funkcije, praćenje; grejanje.

Introduction

Unintended perioperative hypothermia is common in surgical patients and is related to significant morbidity and mortality. Monitoring of body temperature and avoiding the unintended perioperative hypothermia using active and passive warming techniques are key factors of prevention of complications including surgical infection, delayed wound healing, adverse myocardial events, and increased bleeding¹. Surgical patients are prone to hypothermia as a combination of thermoregulation impairment induced by anaesthetics, long duration of surgical procedures, widely open abdominal or thoracic cavity, and relatively low air temperature in operating room². Induction of general anaesthesia also leads to redistribution of heat from the warm core thermal compartment to peripheral tissues³. Additionally, the characteristics of volatile anaesthetics to inhibit thermogenesis and muscle relaxants to inhibit perioperative shivering, also contribute to hypothermia^{4,5}.

Perioperative hypothermia enables the onset of numerous postoperative complications such as arrhythmia, myocardial ischemia, blood pressure increase, bleeding, coagulopathy, wound infection, and prolonged activity of muscle relaxants⁶. Another common consequence of perioperative hypothermia is postoperative shivering, which is experienced by patients as extremely unpleasant. Shivering itself may lead to wound distension, hence may increase postoperative pain. Monitoring of vital functions is also more difficult when shivering is present. Both oxygen consumption and carbon dioxide production are increased, together with increase in metabolic rate, which can worsen the pre-existing illnesses⁶.

Up to 90% of body heat is lost from the skin⁷; hence, the prevention of heat loss via skin is necessity in surgical interventions. Elimination of heat loss from skin enables the increase of core temperature up to 1°C every hour. This may be achieved by passive insulation of body surface with cover sheets. It may reduce the heat loss by 30%, whether the sheets are warmed or not⁸, and the same results are achieved with infrared lamps. The

most effective prevention of heat loss so far has been achieved by usage of blankets with circulating warm water, while forced-air warming mattresses may even conduct a substantial amount of heat into the body⁷.

Perioperative temperature monitoring, as well as active warming of patients are still non-standard procedures in Europe⁹. In the previous study, Zeba et al.¹⁰ investigated efficiency of perioperative internal warming. The intravenous application of amino acids resulted in alleviation of hypothermia, due to their thermogenic properties. Considering the characteristics of heat exchange during general anaesthesia, in this study we wanted to investigate the other aspect of maintaining the constant temperature – reduction of heat loss from skin, using perioperative warming with forced-air mattress.

Methods

The participants enrolled in this investigation were 30 patients who underwent the extensive abdominal surgical procedure, duration of which was 2 hours and longer. In all the patients the same method of general balanced anaesthesia (GBA) was used. For premedication, 10 mg of diazepam [(intramuscular injection) was administered one hour before anaesthesia induction. Midazolam [0.05–0.15 mg/kg of body weight (BW)], fentanyl (2–6 mg/kg BW), propofol (1–2.5 mg/kg BW) and rocuronium (0.6–1 mg/kg BW) were used for induction of GBA. Anaesthesia and analgesia were maintained with 2–4 vol% of volatile aesthetic sevoflurane (respiratory volume of 6–8 mL/kg BW) with intermittent bolus of 25–50 mg of fentanyl. Neuromuscular blockade was maintained with intermittent bolus of 0.15 mg/kg BW of rocuronium. The participants were randomized into two groups: 15 patients were externally warmed during operation with warming mattress (W group), while other 15 were non-warmed controls (C group). The patients in both groups were similar by age, gender distribution, body weight, diagnosis and surgical procedure, including duration of anaesthesia (Table 1).

Table 1

Characteristics of the patients and environments in both groups		
Characteristics of the patients	W	C
Age (years), $\bar{x} \pm \text{SD}$	63.25 ± 5.8	65.19 ± 4.89
Males (%)	53.33	60
Females (%)	46.66	40
Body weight (kg), $\bar{x} \pm \text{SD}$	72.9 ± 6.12	74.28 ± 5.16
Duration of anaesthesia (min), $\bar{x} \pm \text{SD}$	133.46 ± 12.02	141.28 ± 16.13
Temperature in operation theatre ($^\circ\text{C}$), $\bar{x} \pm \text{SD}$	21.14 ± 1.64	21.25 ± 1.52
Relative humidity in operation theatre (%), $\bar{x} \pm \text{SD}$	55.6 ± 5.55	57.13 ± 6.28
Wind speed in operation theatre (m/s), $\bar{x} \pm \text{SD}$	0.22 ± 0.04	0.21 ± 0.04

W – warming mattress (W group); C – control group.

The investigation was approved by the Ethical Committee of the Military Medical Academy and corresponded to the standards of thermal strain evaluation by physiological measurements¹¹. Signed informed consents were obtained from each participant, in accordance with the standards of medical safety during examination in cold environment¹². The investigation was conducted in the Military Medical Academy, Belgrade, during 2013.

The external warming system tested in this study was KANMED WarmCloud OT-600-001 (Kanmed AB, Bromma, Sweden). This electric medical device consists of warm air mattress placed under the patient where it produces warm air cushion. Temperature and pressure in the warm air mattress are generated by a main unit, which is placed under the operating table, and controlled by a hand controller. The main unit's air hoses are connected to the mattress. Once the mattress is pressurized, warm air circulates under the patient in a closed system.

The patients were introduced into operation theatre nude, covered with a cotton sheet. Climatic conditions were continuously measured by the automatic monitoring system AMI300 (Kimo Instruments, France). Values of temperature, relative humidity, and air velocity were recorded every 10 minutes. The patients were placed onto the operating table, either with warming mattress (W group), or without it (C group). At 0th minute, anaesthesia was induced, and oesophageal and skin temperature probes were placed. In the following 20 minutes, preparations before surgery were done: isolation of operative site, covering the rest of body surface with sheets, disinfection of the skin. Approximately at the 20th minute, the surgeon started with the surgical procedure, which lasted at least 2 hours. When surgery was done, the patients were awakened, the mattress was removed and they were transported to awakening room. Oesophageal temperatures were monitored for further 90 minutes.

Skin temperatures were automatically monitored and recorded in real-time by physiological data monitoring system MP150 (Biopac Systems, Inc. USA), with interface module UIM100C and skin temperature amplifier modules SKT100C and skin thermistor transducers TSD202E. Core temperature was measured as oesophageal,¹¹ using temperature probes 400 Series (Datex-Ohmeda Instrumentarium Corp. Finland). A probe was introduced in the anesthetised patient, into the lower part of the oesophagus and placed up against the left wall of the oesophagus. This position enables registration of temperature changes in arterial blood in descendent aorta, which leans with its back

surface onto that side of the oesophagus. Oesophageal temperature (T_e) was measured continually, with data recording every 10 minutes.

In extreme ambient conditions skin temperature tends to vary over the body surface. In surgical patients, the measurement of local skin temperatures, i.e. the choice of measurement sites is dictated by the given position of the body during surgery. Considering the prerequisite demands of the major abdominal surgical procedures, we selected two measuring points: right foot (T_f) and right hand (T_h). Local skin temperatures were continually measured.

During intraoperative and awakening period, heart rates and blood pressure were continuously monitored using Datex-Ohmeda General Electric Anaesthesia Monitor S/5 (Beaverton, USA), and recorded every 10 minutes. Blood pressure was monitored via the intra-arterial catheter placed into radial artery after the induction of anaesthesia.

Data are presented as mean values and standard deviations ($\pm$ SD). Normal distribution was tested by Shapiro-Wilk's test. The differences between the warmed and non-warmed group, as well as the differences between two terms of measurement in the same group were tested by Student's t-test for independent samples, Man-Whitney and Kruskal-Wallis test. The statistical significance was accepted at $p < 0.05$.

Results

Comparable reviews of core i.e. a oesophageal temperature values in the groups with a warming system and without it are shown in Figure 1. At the beginning of the observation period, core temperatures did not differ between the groups: 35.83 ± 0.35 in the W vs $35.61 \pm 0.35^\circ\text{C}$ in the C group ($p = 0.1922$). In the W group, average core temperature did not change significantly from 0th minute towards the 120th minute: 35.83 ± 0.35 vs $35.33 \pm 0.50^\circ\text{C}$, respectively ($p = 0.2719$). In the group C temperature steadily decreased from the beginning towards the end of the observation period, with a statistically high significance: 35.61 ± 0.35 vs $33.86 \pm 0.51^\circ\text{C}$, respectively ($p < 0.000$). Also, except at the very beginning (0th minute), patients in the group C had significantly lower core temperatures. The average decrease in core temperature from 0 to 120th minute in the non-warmed patients was $1.75 \pm 0.47^\circ\text{C}$.

In the postoperative period we recorded the increase in oesophageal temperatures in both groups (Figure 2). However,

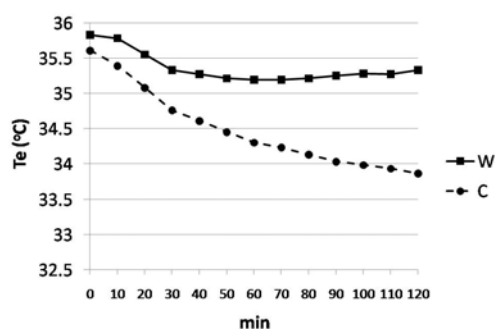


Fig. 1 – Average oesophageal temperatures (T_e) during surgery in both groups.

W – warming mattress (W group); C – control group.

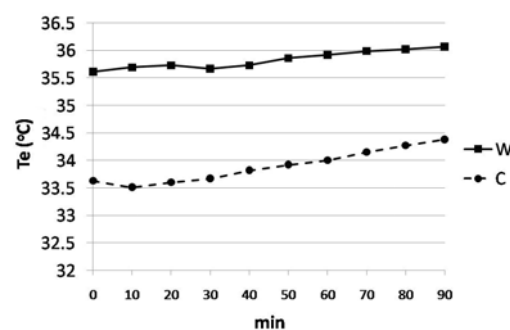


Fig. 2 – Average oesophageal temperatures (T_e) during the awakening period in both groups.

W – warming mattress (W group); C – control group.

temperatures in the warmed patients were significantly higher throughout the entire 90 minutes of awakening, with the temperatures at the end (90th minute) as follows: $36.07^{\circ}\text{C} \pm 0.69$ in the W, and $34.38 \pm 0.79^{\circ}\text{C}$ in the group C ($p < 0.000$).

Peripheral skin temperatures were measured on the right foot and right hand (Figures 3 and 4). In the first 20 minutes of the observed period (before surgical incision), temperatures were rising, due to the effects of premedication, as well as isolation of operative site for surgical procedure itself. In the warmed patients, the foot temperatures remained at the similar level from the 20th towards the 120th minute: 33.41 ± 0.89 vs $32.97 \pm 1.09^{\circ}\text{C}$, respectively ($p = 0.4621$), while in the control group the decrease was statistically highly significant: 30.83 ± 1.85 vs $29.0 \pm 1.39^{\circ}\text{C}$, respectively ($p < 0.000$). The average decrease in foot temperature in the control group was $1.83 \pm 1.13^{\circ}\text{C}$, and the mean

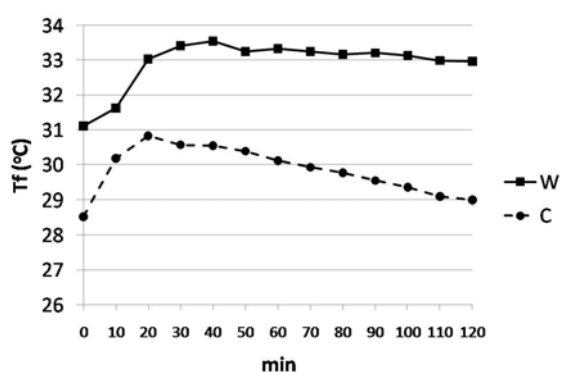


Fig. 3 – Average foot temperatures (Tf) during surgery in both groups.

W – warming mattress (W group); C – control group.

temperatures during the entire period were significantly lower compared to the warmed group ($p < 0.000$).

The mean temperatures of skin surface at the other measurement site (right hand) followed the same pattern: in the warmed patients the temperature was maintained throughout the observed period (from 33.78 ± 0.66 at the 20th minute to $33.55 \pm 0.74^{\circ}\text{C}$ at the 120th minute, $p = 0.2447$), while in the control group hand temperatures decreased significantly (from 32.75 ± 0.96 at 20th minute towards $31.05 \pm 1.09^{\circ}\text{C}$ at the 120th minute, $p = 0.0076$). The temperatures were significantly higher in warmed group compared to the controls in all the observed periods ($p < 0.05$). The average decrease in the mean hand temperature in the control group was $1.69 \pm 1.65^{\circ}\text{C}$.

Average values of heart rates at the beginning of surgery did not differ between the groups: 76.60 ± 11.04 in the W group vs 72.73 ± 16.04 bpm in the C group. Average values of both systolic and diastolic blood pressure did not differ as well, and were 126.93 ± 21.24 vs 131.53 ± 15.26 mmHg and 76.60 ± 11.65 vs 72.80 ± 9.39 mmHg, respectively. Throughout the intraoperative period, average values of heart rates were higher in the warmed group, with a statistical significance recorded from 80–100th minute (78.47 ± 13.95 vs 65.40 ± 13.33 bpm; $p = 0.046$ in 80th minute; 76.53 ± 12.02 vs 64.47 ± 12.90 ; $p = 0.043$ in 90th minute; 77.40 ± 10.11 vs 64.87 ± 14.18 ; $p = 0.030$ in

100th minute), but at the 120th minute, there was no statistical difference between the groups.

Both systolic and diastolic pressures were similar in both groups from the beginning toward almost the end of the intraoperative period. Statistically significant differences were recorded only at 100th minute (for systolic pressure 126.93 ± 21.24 in the group W vs 131.53 ± 15.26 mmHg in the group C, $p = 0.000$, and for diastolic pressure 80.40 ± 9.50 vs 68.13 ± 7.59 mmHg; $p = 0.000$).

During awakening, average values of heart rates were significantly higher in the warmed group in almost every period of monitoring, and ranging from 74.73 ± 14.43 at 0th minute to 83.40 ± 10.41 bpm at 90th minute, comparing to the controls (from 66.00 ± 16.32 at 0th minute to 76.87 ± 17.95 bpm at 90th minute). At the same time, in both groups the similar average values of systolic and diastolic pressure were measured.

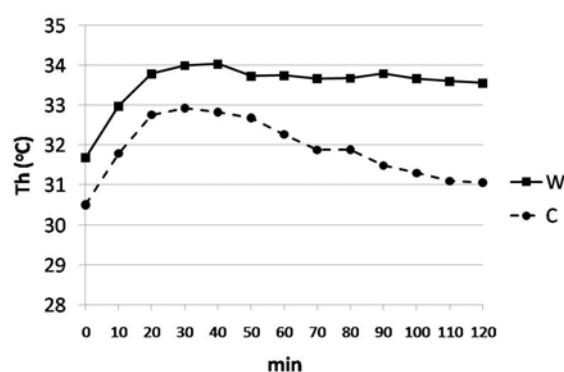


Fig. 4 – Average hand temperatures (Th) during surgery in both groups.

W – warming mattress (W group); C – control group.

Discussion

Data collected by measurements of physiological parameters of cold stress in the warmed and non-warmed patients during surgical interventions point to several key conclusions. First, our results confirm the influence of general anesthetics on thermoregulation impairment, which is in surgical patients enhanced with relatively low environmental temperature. In our investigation temperatures in operation room ranged from 19.8 to 22.7°C , in combination with relative humidity between 47% and 78% and still air, which resulted in lower equivalent temperatures by approximately 2°C . In surgical patients hypothermia is pronounced by inhibition of efficient mechanisms of thermogenesis such as shivering, which can be explained by properties of muscle relaxants and volatile anaesthetics. Another contributing factor to hypothermia in our patients was widely open abdominal cavity¹³. Evaporation and convection from wet tissues may eliminate up to 2 kJ per mL evaporated water¹⁴.

Operating room does not represent extreme environment, except for surgical patients. With air temperature below 23°C , it does not provide enough warmth for provide the maintenance of normal core temperature in patients. When temperature in operating room drops below 21°C , every patient experiences hypothermia⁵. However, colder environment is more approp-

riate for surgeons and other staff, considering the heat stress induced by sterile uniforms, rubber gloves, rubber aprons, and high level of stress resulting in increased sweating.

Body temperature is usually unequally distributed, with core values limited to head and trunk (internal organs in skull, chest and abdomen), while peripheral parts of the body are typically colder by 2–4°C. Normally, there is temperature gradient from core to peripheral areas, which is maintained by constriction of blood vessels in skin. This distribution is substantially impaired during general anaesthesia. First phase of decrease in core temperature is the result of redistribution of heat from central compartment towards colder peripheral tissue (particularly in distal parts such as hands and feet)¹⁵. This is the result of dilatation of blood vessels in skin which is one of the effects of general anaesthesia. Redistribution also impose the enlargement of central compartment of the human body during general anaesthesia, from the volume limited to the head and trunk (internal organs in the skull, chest and abdomen) to expanded volume including arms and legs, as well. This redistribution of warm blood towards the peripheral areas leads to warming of hands and feet, but also contributes to decrease of core temperature by 0.5–1.5°C¹⁶.

When heat loss from the skin is eliminated, metabolic heat would increase the mean body temperature by approximately 1°C every hour. Although we found a number of papers reported heat exchange between human body and environment, monitoring of heat flux by infrared (IR) thermography in surgical patients, as an example of objective measurement was not used so far. In our study, we also continued with the approach of collecting data by physiological measurements. Giesbrecht et al.⁷ showed that active skin warming using forced-air warming systems may completely eliminate heat loss from skin surface. In 6 volunteers the authors investigated thermal exchange under conditions of operating room (ambient temperature $24.5 \pm 0.8^\circ\text{C}$; subjects minimally clothed, reclined on hospital bed), and recorded a significant increase in core temperatures when warming systems were applied.

Our results showed that in the warmed group core temperature after induction of anaesthesia decreased, particularly in the first 30 minutes, but not significantly. After that period, we observed a *plateau*, i.e. the temperature levels remained in the normal range (above 35°C). In the non-warmed group, however, decrease is more pronounced in the first 30 minutes, with the constant drop throughout the entire observed period. Mean values from the 30th minute towards the 120th minute were below 35°C, with end-point temperature $33.86 \pm 0.51^\circ\text{C}$, which means that non-warmed patients were hypothermic.

This is in accordance with the results of randomized, prospective clinical trial conducted by Hynson and Sessler¹⁷. The authors investigated the effect of forced-air warmer on tympanic temperature in 10 patients who underwent prolonged surgery and found that in warmed patients there was significantly less decrease in core temperature compared to controls: the temperature in warmed patients dropped from preinduction moment towards the third hour of anaesthesia by 0.5°C, while in the control group, at the same time, the decrease was $2.0 \pm 0.7^\circ\text{C}$.

In our investigation, at the end of surgery core temperatures in the control group were between 32.7°C and 35.4°C, meaning that all the patients had temperature below 36°C. In the warmed group, however, the values varied from 33.5°C and 36.3°C, and in 5 patients of 15 the temperature was above 36°C. During awakening period in the group W we measured normal core temperature in additional 5 patients, while at the same time only one control became normothermic.

Vanni et al.¹⁸ in 2007 evaluated the effect of preoperative (in 10 patients) and intraoperative (in other 10 patients) skin-surface warming using forced-air warming system during lower abdominal surgery under spinal anaesthesia and concluded that the applied warming procedures did not avoid, but did minimize hypothermia. Ambient temperature was similar as in our investigation (20°C to 23°C). In this investigation, despite the significantly higher temperatures in warmed patients compared to controls, at the end of surgery only 50% of warmed patients were normothermic (tympanic temperature above 36°C). This can be explained by the differences between spinal and general anaesthesia regarding thermoregulation. Spinal anaesthesia obliterated any effective peripheral and central thermoregulatory control and hence might worsen cold stress.

Hemodynamic and respiratory stability in anaesthesia is crucial in response to all the perioperative influences, including hypothermia¹⁹. Even mild hypothermia may lead to cardiovascular impairments such as postoperative increase in heart rate and blood pressure, increase in vascular resistance, ventricular dysrhythmia and irritability, and myocardial depression²⁰. In our investigation, average values of heart rates recorded in the control group were lower than in the warmed group both during the intraoperative and postoperative period. The results obtained in a study of Bahar et al.²¹ on the possibilities of attenuating the perioperative hypothermia indicate that hypothermic patients have higher heart rates, but other authors, like Chi et al.²² report lower heart rates, which is in accordance with our results.

The same authors report that mild intraoperative hypothermia does not influence arterial blood pressure²². Our results may confirm their findings, because we did not observe any significant differences between the warmed patients and the controls regarding systolic and diastolic blood pressure. The average values in the warmed group were slightly higher compared to the controls, but remained in the normal range. However, there are some limitations in results interpretations in our study, which are derived from the fact that our patients were sedated in the monitored postoperative period in order to facilitate the presence of oesophageal temperature probes.

The duration of warming is also important. In a larger prospective randomized trial conducted in 2003, Wong et al.²³ investigated the effect of perioperative systemic warming on nasopharyngeal temperature in 47 warmed and 56 control patients during major elective abdominal surgery. They found that preoperative warming in duration of 2 hours, and continual warming throughout the surgical procedure and 2 hours after can completely prevent the intraoperative hypothermia. The difference between this study and our re-

sults may be explained by the duration of warming: in our study we did not use preoperative warming, for that reason, our patients had lower core temperatures on anaesthesia induction (35.83°C compared to 36.5°C).

However, there is another major difference in the results obtained in our investigation and in the given study. Our patients were not warmed during the awakening period, contrary to patients in Wong's study, but core temperatures at the end of the observation period were similar (36.7 vs 36.3°C). These results point that pre- and intraoperative warming are more important in minimizing general anaesthesia-induced hypothermia than postoperative warming.

Conclusion

The results of temperature monitoring confirm that body core temperature (measured as oesophageal temperature) as well as local skin temperatures are significantly higher in the patients who underwent major abdominal surgery when warmed with a forced-air mattress, compared to the control conditions. The external warming proved to be efficient in alleviation of peri- and postoperative hypothermia. Considering the above, our results may be useful for further research activities directed to elimination or minimizing this important problem in surgical units.

REFERENCES

- Hart SR, Bordes B, Hart J, Corsino D, Harmon D. Unintended perioperative hypothermia. *Ochsner J* 2011; 11(3): 259–70.
- Morin AM, Kernat KM, Klotz M, Niestolnik R, Ruy VE, Wulf H, et al. Risk factors for bacterial catheter colonization in regional anaesthesia. *BMC Anesthesiol* 2005; 5(1): 1–10.
- Sessler DI, Ponte J. Shivering during epidural anesthesia. *Anesthesiology* 1990; 72(5): 816–21.
- Sessler DI. Temperature monitoring and perioperative thermoregulation. *Anesthesiology* 2008; 109(2): 318–38.
- Díaz M, Becker DE. Thermoregulation: Physiological and Clinical Considerations during Sedation and General Anesthesia. *Anesth Prog* 2010; 57(1): 25–32.
- Buggy DJ, Crossley AW. Thermoregulation, mild perioperative hypothermia and postanaesthetic shivering. *Br J Anaesth* 2000; 84(5): 615–28.
- Giesbrecht GG, Ducharme MB, McGuire JP. Comparison of forced-air patient warming systems for perioperative use. *Anesthesiology* 1994; 80(3): 671–9.
- Sessler DI, McGuire J, Sessler AM. Perioperative thermal insulation. *Anesthesiology* 1991; 74(5): 875–9.
- Torossian A. TEMMP (Thermoregulation in Europe Monitoring and Managing Patient Temperature) Study Group. Survey on intraoperative temperature management in Europe. *Eur J Anaesthesiol* 2007; 24(8): 668–75.
- Zeba S, Surbatović M, Jević M, Filipović N, Popović N, Radaković S, et al. Influence of perioperative administration of amino acids on thermoregulation response in patients underwent colorectal surgical procedures. *Vojnosanit Pregl* 2007; 64(6): 421–4. (Serbian)
- ISO 9886: 2004 – Ergonomics – evaluation of thermal strain by psychological measurements. 2004. Available from: [www.iso.org/iso/catalogue_detail?csnumber](http://www.iso.org/iso/catalogue_detail?csnumber=68811). [cited 2008 June 25].
- ISO 12894: 2001 – Ergonomics of the thermal environment – Medical supervision of individuals exposed to extreme hot or cold environment. Geneva: International Organization of Standardization; 2008.
- Roe CF. Effect of bowel exposure on body temperature during surgical operations. *Am J Surg* 1971; 122(1): 13–5.
- Technical Bulletin (TB MED), 507/AFPAM (I). Washington, Dc: Headquarters Department of the Army and Air Force; 2003. p. 48–152.
- Sessler DI. Temperature regulation and monitoring. In: Miller RD, Eriksson LI, Fleisher LA, Wiener-Kronish JP, editors. *Miller's anesthesia*. 7th ed. Philadelphia: Churchill Livingstone, Elsevier; 2010. p. 1533–56.
- Matsukawa T, Sessler DI, Sessler AM, Schroeder M, Ozaki M, Kurz A, et al. Heat Flow and Distribution during Induction of General Anesthesia. *Anesthesiology* 1995; 82(3): 662–73.
- Hynson JM, Sessler DI. Intraoperative warming therapies: a comparison of three devices. *J Clin Anesth* 1992; 4(3): 194–9.
- Vanni SM, Castiglia YM, Ganem EM, Júnior GR, Amorim RB, Ferrari F, et al. Preoperative warming combined with intraoperative skin-surface warming does not avoid hypothermia caused by spinal anesthesia in patients with midazolam premedication. *Sao Paulo Med J* 2007; 125(3): 144–9.
- Surbatović M, Vesic Z, Djordjević D, Radaković S, Zeba S, Jovanović D, et al. Hemodynamic stability in total intravenous propofol anesthesia with midazolam coinduction versus general balanced anaesthesia in laparoscopic cholecystectomy. *Vojnosanit Pregl* 2012; 69(11): 967–72. (Serbian)
- Díaz M. Hypothermia and temperature regulation considerations during anesthesia. Available from: <http://www.sld.cu/galerias/pdf/sitios/anestesiologia/hypothermia> [last assessed 2011 June 9]
- Babar MY, Tawil ME, Ezat H, Tolba M. An Approach to minimize perioperative hypothermia and its complications. *AJAIC* 2005; 8(1): 55–61.
- Chi OZ, Choi YK, Lee DI, Kim YS, Lee I. Intraoperative mild hypothermia does not increase the plasma concentration of stress hormones during neurosurgery. *Can J Anaesth* 2001; 48(8): 815–8.
- Wong PF, Kumar S, Bobra A, Whetter D, Leaper DJ. Randomized clinical trial of perioperative systemic warming in major elective abdominal surgery. *Br J Surgery* 2007; 94(4): 421–6.

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