COMPARISON OF PASSIVE WARMING WITH HEAT-BAND VERSUS RESISTIVE HEATING BLANKET FOR PREVENTION OF INADVERTENT PERIOPERATIVE HYPOTHERMIA IN LAPAROTOMY FOR GYNAECOLOGIC SURGERIES

BY

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COMPARISON OF PASSIVE WARMING WITH HEAT-BAND VERSUS RESISTIVE HEATING BLANKET FOR PREVENTION OF INADVERTENT PERIOPERATIVE HYPOTHERMIA IN LAPAROTOMY FOR GYNAECOLOGIC SURGERIES

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Introduction: Inadvertent perioperative hypothermia (IPH) (defined as core body temperature <35.5°C) is still a common problem despite advancement in a variety of warming systems. In our centre, a common approach to patient warming is by resistive heating blanket, a costly device. To find a cost-effective alternative to patient warming, a group of local researchers innovated a new passive warming device called Heat-Band. We compared the efficacy of the Heat-Band with resistive heating blanket in preventing IPH and its complications during laparotomy for gynaecologic surgeries.

Objectives: To compare perioperative core body temperature and complications of hypothermia when using Heat-Band and resistive heating blanket in laparotomy for gynaecologic surgeries.

Patient and Methods: Thirty-two patients undergoing laparotomy for gynaecologic surgeries under combined general-epidural anaesthesia, with expected duration of surgery between two to four hours, were randomized to receive either Heat-Band or resistive heating. In both groups, the warming devices were applied immediately after placement of epidural catheter and induction of general anaesthesia. Core body temperatures measured at several perioperative timepoints in the two groups were compared. Time to extubation, incidence of post-anaesthesia shivering and intraoperative blood loss were also measured and compared between groups.

Results: There was no significant difference between the two groups in terms of demographic, anaesthesia and surgical details. The core body temperatures were comparable between the two groups at preoperative period, immediately after induction of anaesthesia, skin incision, one hour after incision, complete skin closing, at extubation, upon arrival to recovery, and one hour postoperatively. There were also no significant differences between the two groups in terms of time to extubation, incidence and intensity of post-anaesthesia shivering and intraoperative blood loss. Neither device failures (as indicated by patients who developed IPH in recovery) nor incidence of adverse effects from warmer usage have been reported in both groups.

Conclusion: Heat-Band results in comparable maintenance of core body temperature with the resistive heating in the perioperative period of laparotomy for gynecologic surgeries. It also results in comparable recovery from anaesthesia, incidence of shivering and intraoperative blood loss with the resistive heating. We concluded that Heat-Band is a cost-effective alternative to active warming during anaesthesia and surgery of intermediate duration.

Dr. Wan Mohd. Nazaruddin Wan Hassan: Supervisor

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DEDICATION

This dissertation work is dedicated to my husband, Adam Zechariah Taylor, who has been a constant source of support and encouragement during the challenges of postgraduate school and life. This work is also dedicated to my parents, Faridah and Wan Shukeri, who have always loved me unconditionally and whose good examples have taught me to work hard for the things that I aspire to achieve.

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ABSTRAK

KAJIAN PERBANDINGAN PEMANASAN PASIF HEAT-BAND DAN PEMANASAN SELIMUT ELEKTRIK DALAM MENGELAKKAN PERIOPERATIF HIPOTERMIA SEMASA PEMBEDAHAN LAPAROTOMI GINEKOLOGIS

Pengenalan:

Perioperatif hipotermia (ditakrifkan sebagai suhu teras badan <35.5°C) merupakan satu masalah yang masih lagi berlaku meskipun terdapat pelbagai kemajuan dalam sistem pemanasan badan. Di pusat kami, pendekatan yang biasa digunakan untuk pemanasan badan pesakit semasa menjalani pembedahan ialah melalui selimut elektrik, suatu alat yang mahal. Dalam usaha untuk mencari kaedah pemanasan yang kos efektif, sekumpulan penyelidik tempatan telah merekacipta alat pemanas pasif baru yang dipanggil Heat-Band. Kami telah membandingkan keberkesanan alatan Heat-Band ini dengan kaedah pemanasan selimut elektrik dalam mengelakkan perioperatif hipotermia dan komplikasinya semasa pembedahan laparotomi ginekologis.

Metodologi:

Seramai 32 pesakit yang menjalani pembedahan laparotomi ginekologis di bawah kombinasi pembiusan am dan epidural yang dijangka memakan masa selama dua hingga empat jam telah dirawakkan kepada sama ada pemanasan Heat-Band atau pemanasan selimut elektrik. Dalam kedua-dua kumpulan, alat pemanas itu diaplikasikan sejurus selepas kateter epidural selesai ditempatkan dan pembiusan am

diberikan. Suhu teras badan pada beberapa titik waktu sekitar pembedahan telah diukur dan dibandingkan di antara kedua-dua kumpulan tersebut. Masa sehingga ekstubasi, insidensi menggeletar selepas bius, dan jumlah pendarahan semasa pembedahan dalam kedua-dua kumpulan turut dinilai dan dibandingkan.

Keputusan:

Tiada perbezaan yang signifikan di antara kedua-kedua kumpulan berkenaan maklumat demografis, pembiusan dan pembedahan. Suhu teras badan adalah sebanding di antara kedua-dua kumpulan ketika tempoh pra-pembedahan, sejurus selepas induksi bius, semasa irisan kulit, sejam selepas irisan kulit, lengkapnya kulit ditutup, ketika ekstubasi, sesampainya di bilik pemulihan dan sejam selepas itu. Tiada perbezaan yang signifikan didapati di antara kedua-dua kumpulan dari segi masa sehingga ekstubasi, insidensi menggeletar selepas bius, dan jumlah pendarahan semasa pembedahan. Tiada kejadian kegagalan peralatan (ditakrifkan sebagai pesakit yang mengalami hipotermia semasa di bilik pemulihan) dan juga kesan sampingan dari penggunaan alat pemanasan dilaporkan di dalam kedua-kedua kumpulan.

Kesimpulan:

Heat-Band menghasilkan pengekalan suhu teras badan sebanding dengan yang dicapai menggunakan selimut pemanas elektrik ketika pembedahan laparotomi ginekologis. Pemulihan dari kesan bius, insidensi menggeletar dan jumlah pendarahan semasa pembedahan juga adalah sebanding. Kami membuat kesimpulan bahawa Heat-Band adalah alternatif kepada pemanasan aktif yang kos-efektif apabila diaplikasikan ketika pembedahan yang berjangkamasa sederhana.

ABSTRACT

COMPARISON OF PASSIVE WARMING WITH HEAT-BAND VERSUS RESISTIVE HEATING BLANKET FOR PREVENTION OF INADVERTENT PERIOPERATIVE HYPOTHERMIA IN LAPAROTOMY FOR GYNAECOLOGIC SURGERIES

Introduction:

Inadvertent perioperative hypothermia (IPH) (defined as core body temperature <35.5°C) is still a common problem despite advancement in a variety of warming systems. In our centre, a common approach to patient warming is by resistive heating blanket, a costly device. To find a cost-effective alternative to patient warming, a group of local researchers innovated a new passive warming device called Heat-Band. We compared the efficacy of the Heat-Band with resistive heating blanket in preventing IPH and its complications during laparotomy for gynaecologic surgeries.

Methods:

Thirty-two patients undergoing laparotomy for gynaecologic surgeries under combined general-epidural anaesthesia, with expected duration of surgery between two to four hours, were randomized to receive either Heat-Band or resistive heating. In both groups, the warming devices were applied immediately after placement of epidural catheter and induction of general anaesthesia. Core body temperatures measured at several perioperative timepoints in the two groups were compared. Time to extubation, incidence of post-anaesthesia shivering and intraoperative blood loss were also measured and compared between groups.

Results:

There was no significant difference between the two groups in terms of demographic, anaesthesia and surgical details. The core body temperatures were comparable between the two groups at preoperative period, immediately after induction of anaesthesia, skin incision, one hour after incision, complete skin closing, at extubation, upon arrival to recovery, and one hour postoperatively. There were also no significant differences between the two groups in terms of time to extubation, incidence and intensity of post-anaesthesia shivering and intraoperative blood loss. Neither device failures (as indicated by patients who developed IPH in recovery) nor incidence of adverse effects from warmer usage have been reported in both groups.

Conclusion:

Heat-Band results in comparable maintenance of core body temperature with the resistive heating in the perioperative period of laparotomy for gynecologic surgeries. It also results in comparable recovery from anaesthesia, incidence of shivering and intraoperative blood loss with the resistive heating. We concluded that Heat-Band is a cost-effective alternative to active warming during anaesthesia and surgery of intermediate duration.

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ABBREVIATIONS

ASA	American Society of Anaesthesiologists
BW	Body weight
BMI	Body mass index
CAD	Coronary artery disease
CPB	Cardio-pulmonary bypass
FAW	Forced-air warmer
GA	General anaesthesia
HUSM	Hospital Universiti Sains Malaysia
ICU	Intensive care unit
IM	Intramuscular
IPH	Inadvertent perioperative hypothermia
IV	Intravascular
OR	Operating room
PACU	Post-anaesthesia care unit
PAS	Post-anaesthesia shivering

RA	Regional anaesthesia
RCT	Randomized-controlled trial
SWI	Surgical wound infection

CHAPTER 1

INTRODUCTION

Inadvertent perioperative hypothermia (IPH) (defined as core body temperature <35.5°C) is one of the common complications during anaesthesia and surgery. It causes several adverse events including shivering, delayed recovery from anaesthesia, morbid myocardial outcomes, surgical wound infection and coagulopathy resulting in increased transfusion requirement (Frank et al., 1993, Frank et al., 1995, Frank et al., 1997, Sessler, 1997). Consequently, it is a standard practice to monitor temperature and adopt strategies to prevent heat loss in the perioperative period.

In our centre, one of the widely used warming devices is the resistive heating blanket (Geratherm® Blanket Patient Warming Systems) (Figure 1.1). A low voltage current heats the blanket at a temperature that can be set between 30°C and 42°C (Figure 1.2 left). The heats are then transferred to the patients primarily by conduction. This device therefore requires direct skin contact to work effectively and incorrect placement of the blanket can lead to poor heat transfer. The blanket is available in segments, allowing a large fraction of the body surface area to be warmed during surgery. This can, however, lead to an array of wires, posing some practical difficulties (Figure 1.2 right). Its requirement for electricty to operate means that the device is subject to electrical failures and running cost. In addition, this warming device costs several thousand dollars and thus may not be affordable in less-affluent centres.

Figure 1.1: Resistive heating blanket (Geratherm® Blanket Patient Warming Systems)

Source: http://www.geratherm.de/en/temperature-management-2. April 15, 2014.

Figure 1.2: Control unit for the temperature of the connected blankets (left) and corresponding wires that are inevitably present when multiple blankets are used (right).

In an attempt to find a cost-effective alternative to this warming device, researchers from our operating room (OR) has introduced a new passive warmer called Heat-Band (Figure 1.3). This warmer is significantly economical yet effective from our experience of using it on patients over the past several years. Since it was first introduced in 2010, Heat-Band has won several innovation awards at both local and national levels. However, there is yet any clinical trial evaluating its efficacy to date.

Figure 1.3: Heat-Band.

Heat-Band is a resistive insulator which is designed to entrap air within its fiber matrix. This air is still and forms an insulating barrier which prevents convective heat loss and associated hypothermia. The insulating material of Heat-Band is produced in three layers, which are, from inside to outside: soft cotton, polyester and synthetic polyurethane leather. The device is available as a wrap-around garment for different body parts including limbs and torso. Each garment has encircling elements that can be securely fastened to eliminate accidental opening or dislodging of the garment when worn by the patients. Since it does not require electricity to operate, Heat-Band cannot burn patients, is not subject to electrical failures, is lightweight and wireless (see Table 1.1 for a comparative summary of Heat-Band and resistive heating blanket).

As it is a reusable item, Heat-Band should be decontaminated in between patients to reduce the risk of cross-contamination. Heat-Band can be classified as a non-critical item, which referred to item that comes into contact with healthy skin but not mucous membranes. Being a non-critical item, cleaning is a sufficient method of its decontamination and this is achieved with washing the device with cool water and detergent by automated method. Prior to cleaning process, the device is unfastened to ensure unrestricted contact of all parts of the instrument with solution.

In this study, we compared the effectiveness of Heat-Band with the resistive heating blanket (Geratherm® Blanket Patient Warming Systems), in a randomized, controlled manner in patients undergoing laparotomy for gynecologic surgeries under combined general-epidural anaesthesia.

Table 1.1: Comparative summary of Heat-Band versus resistive heating blanket.

	Heat-Band	**Resistive heating**
Type	Passive warming device.	Active warming device.

	Heat-Band	Resistive heating
Product description	A resistive insulator with triple layer construction: soft cotton (innermost), polyester(middle), synthetic polyurethane leather (outermost).	Polymer electric blanket supplied by low-voltage current with temperature that can be set between 30-42°C.
Principle of heating	Prevents convective and conductive heat loss.	Provides conductive warming.
Clinical efficacy	Unknown as there is no clinical trial evaluating its efficacy to date. From our experience, it is felt to be acceptably effective in preventing IPH.	Conflicting evidence from several clinical trials.
Differences between the two devices	· Relatively inexpensive (RM 200/piece, complete set RM 1000) · No electricity required · Available as a wrap-around garment.	· Expensive (RM 18 000) · Requires electricity to operate · Available as over-body blanket.
Similarities between the two devices	· Reusable, need cleaning in between patients, hence possible risk of cross-contamination · Available in segments allowing independent body parts warming.	· Reusable, need cleaning in between patients, hence possible risk of cross-contamination · Also available in segments allowing large fraction of body surface area warming. However, this can lead to an array of wires, posing some practical difficulties.

CHAPTER 2

2.1 Research Question

Is there any difference in the perioperative core body temperature of patients and the complications of hypothermia when using Heat-Band and resistive heating blanket?

2.2 General Objective

To compare perioperative core body temperature and complications of hypothermia when using Heat-Band and resistive heating blanket in laparotomy for gynaecologic surgeries.

2.3 Specific Objectives

i) To compare perioperative core body temperature when using Heat-Band and resistive heating blanket in gynaecological laparotomy at 0 = preoperatively; 1 = OR baseline; 2 = incision; 3 = 1 hour after incision; 4 = closing; 5 = at extubation; 6 = arrival at recovery; and 7 = 1 hour postoperatively.

ii) To compare time to extubation when using Heat-Band and resistive heating blanket in gynaecological laparotomy;

iii) To compare incidence of post-anaesthesia shivering (PAS) and its intensity when using Heat-Band and resistive heating blanket in gynaecological laparotomy;

iv) To compare amount of intraoperative blood loss when using Heat-Band and resistive heating blanket in gynaecological laparotomy.

2.4 Study Hypotheses

i) There is a difference in the perioperative core body temperature when using Heat-Band and resistive heating blanket in laparotomy for gynaecologic surgeries.

ii) There is a difference in the time to extubation when using Heat-Band and resistive heating blanket in laparotomy for gynaecologic surgeries.

iii) There is a difference in the incidence of PAS and its intensity when using Heat-Band and resistive heating blanket in laparotomy for gynaecologic surgeries.

iv) There is a difference in the amount of intraoperative blood loss when using Heat-Band and resistive heating blanket in laparotomy for gynaecologic surgeries.

CHAPTER 3

LITERATURE REVIEW

3.1 Introduction and Context

The normal core body temperature range of adult patients is between 36 to 37.5°C . Hypothermia can be defined as a core body temperature of below 36.0°C, although some studies have considered lower limits because of a high incidence of patients below 36°C . The incidence of IPH at the time of admission to intensive care unit (ICU) was 57.1%, 41.3%, and 28.3% according to the definition of core temperature <36.0°C, <35.5°C, and <35.0°C respectively (Kongsayreepong et al., 2003).

This chapter presented the findings from our review of relevant literature related to (1) Physiology of IPH; (2) Risk factors for IPH; (3) Consequences of IPH; (4) Detection and monitoring and (5) Prevention of IPH.

3.2 Physiology of IPH

Core body temperature is determined by the the relationship between heat production (product of metabolism) and heat dissipation (to the environment). Both are adjusted in order to maintain core body temperature within narrow limits (36 to 37.5°C); temperature is lowest in the morning and highest in the evening. Maintenance of normothermia ensures a constant rate of metabolism, enhanced nervous system conduction, and optimal skeletal muscle contraction.

3.2.1 Heat Loss

Heat loss from the body occurs by four mechanisms: radiation, convection, conduction and evaporation.

Radiation, the transfer of energy between objects via electromagnetic waves, accounts for 40-50 per cent of the body's total heat loss in the OR (Howell, 1979). Radiant heat loss is proportional to the temperature difference between the patient and the environment. Peripheral vasodilation induced by anaesthetic agents raises the skin temperature, encouraging a high flow of heat from the body surface to cool OR surfaces.

Convection refers to the direct transfer of energy by collisions between body surface molecules and moving air molecules. Ambient temperature, air velocity, and surface area are the main determinants of convective heat loss. It is markedly reduced by trapping a layer of still air between the skin and the atmosphere, which is the principle underlying Heat-Band. In naked patients lying in air-conditioned OR, 25-35 per cent of the total heat loss occurs via convection (Bourke et al., 1984).

Evaporative heat loss occurs because the vaporization of water (or volatile skin preparation solutions) demands heat. Evaporation occurs rapidly from prepped areas of the skin, exposed peritoneum, and from the respiratory tract, which must humidify dry anaesthetic gases. Conduction, the transfer of heat by direct contact between objects plays a minor role in intraoperative cooling. In surgical patients, the use of cool intravenous and irrigating solutions and underlying wet sheets, are examples of conductive losses.

3.2.2 Physiology of Thermoregulation

Thermoregulation is the process of maintaining normal core body temperature and involves positive and negative feedback by the brain to minimize variations from preset normal values, or thresholds.

The thermoregulatory system contains three key elements: afferent input, central processing, and the efferent response. Afferent input is triggered by thermal-sensitive receptors found not only in skin but throughout most of the body. Cold receptors are excited by temperature below a set threshold and generate impulses that travel mainly via A-delta fibers. Temperatures above threshold excite heat receptors that generate impulses along unmyelinated C fibers. Information is then integrated at several levels within the spinal cord and brain, finally arriving at the primary thermoregulatory center within the hypothalamus.

The hypothalamus integrates most afferent input and coordinates the various efferent outputs required to maintain a normothermic level. A core temperature below the threshold for cold response will produce vasoconstriction and shivering; nonshivering thermogenesis occurs in infants. A core temperature above the threshold for heat response will produce vasodilation and sweating. The most effective response for thermoregulation above all is behavioural response for thermoregulation. This includes dressing appropriately, modifying environmental temperature, and assuming bodily positions that diminish or enhance heat loss.

3.2.3 Reasons for IPH

Reasons for IPH include not only patients' exposure to a typical cold temperature in OR environment and their inability to initiate behavioural response, but the proclivity of anaesthetic agents to promote heat loss.

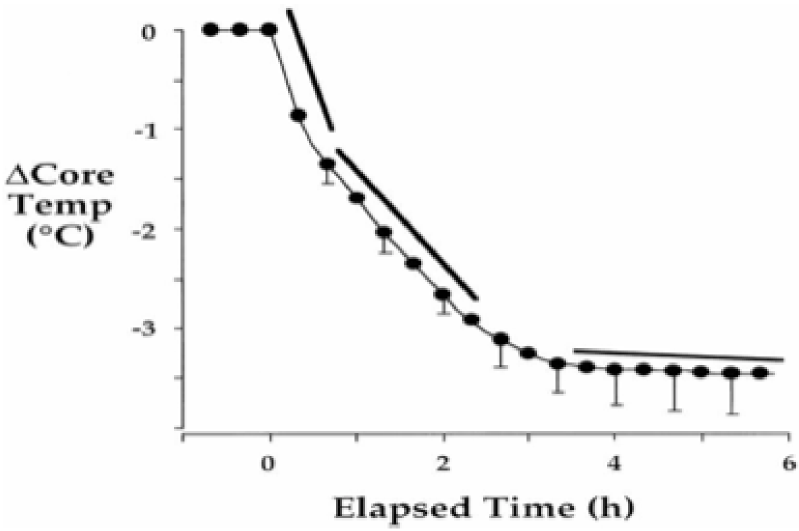
Anaesthetic agents promote heat loss through vasodilation. These drugs induce vasodilation by reducing the vasoconstriction threshold to well below core temperature. The effect of this is to allow fairly rapid heat loss from the peripheries. This process is compounded further by the fact that anaesthetics directly impair the elements of thermoregulatory system, occuring both in general and regional anaesthesia. The depressant effect of the general anaesthetics on the hypothalamus results in a diminished threshold for cold response such as vasoconstriction and shivering. Therefore, patients are unable to adjust to cold environments and heat loss results from vasodilation. Following spinal and epidural anaesthesia, blockade of afferent fibers from large regions obviously prevents cold input to the hypothalamus.

Other reasons for IPH include:

- reduced heat production due to reduced metabolic activity;
- fluid deprivation before anaesthesia resulting in patients being dry and poorly perfused, impairing heat distribution;
- use of unwarmed intravenous (IV) or irrigation solutions;
- use of certain skin preparation methods that result in evaporation;
- evaporation from surgical sites.

3.2.4 Sequence of Temperature Changes During Anaesthesia

Hypothermia during general anaesthesia (GA) develops with a characteristic three-phase pattern (Figure 3.1).



balance and distribution during the core-temperature plateau in anesthetized

humans. Anesthesiology, 83, 491-9.

In phase 1, there is a prompt decrease in core body temperature from 1 to 1.5℃ during the first hour of anaesthesia. This occurs due to core-to-peripheral heat redistribution. Redistribution results because anaesthetic drugs inhibit the tonic vasoconstriction that normally maintains a large core-to-peripheral temperature gradient. This process of heat redistribution during regional anaesthesia (RA)(spinal or epidural) is different, in that it is generally restricted to the lower body. Consequently, redistribution decreases core body temperature about half as much when compared with other anaesthesia.

After the first hour of anaesthesia, the core body temperature usually decreases at a slower and linear rate in the next two to three hours. It reflects continuing heat loss to the environment, which exceeds the metabolic production of heat. This usually begins at the start of surgery as the patient is exposed to the cold cleaning fluids, and exposure to the cold OR environment.

Once core body temperature falls below the thermoregulatory threshold, peripheral vasoconstriction increases and acts to limit the heat loss from the core. When core heat production equals heat loss to the periphery, core body temperature reaches a plateau. This plateau may not occur in RA or during combined regional and GA. In RA the decrease in core body temperature is not discontinued by the physiologically driven response of thermoregulatory vasoconstriction. This is because constriction in the legs is blocked peripherally.

3.3 Risk Factors for IPH

Numerous factors contribute to the risk of IPH. Risk is perceived to depend on patient characteristics; surgery factors; anaesthesia factors; perioperative pharmacological agents and environmental factors. The risk factors review below is splitted into two: one concerned with hypothermia risks associated with pharmacological agents used perioperatively, and the other covering all other risk factors.

3.3.1 Pharmacological Risk Factors

Premedication Drug: Midazolam

Matsukawa et al. (2001) conducted a randomized controlled trial (RCT) in volunteers, which showed a dose effect of premedication with midazolam on core body temperature: there was no significant difference in core temperature at 30 minutes for 25ug/kg intramuscular (IM) compared with no midazolam, but a significant difference for 75ug/kg IM when compared with either the 25ug/kg IM dose or the control group.

GA Drug: Propofol and Sevoflurane

Kwak et al. (2011) compared the effects of sevoflurane and propofol on core body temperature of 50 patients undergoing laparoscopic major abdominal surgery of more than 90 minutes. Core body temperature was measured with an esophageal stethoscope with a temperature sensor after the start of the pneumoperitoneum (baseline) and at 15-min intervals until completion of surgery. The result of this study showed that a decrease in core body temperature during sevoflurane anesthesia was not different than propofol anesthesia, and the incidence of IPH of the two groups did not differ.

Ikeda et al. (1999) compared anesthetic induction with either 2.5 mg/kg propofol IV or inhalation of 5% sevoflurane in 20 patients undergoing minor oral surgery. Anesthesia in both groups was subsequently maintained with sevoflurane and 60% nitrous oxide in oxygen. The outcome was core temperature intraoperatively. Core temperature in patients who received propofol were consistently lower than those in patients who received inhaled sevoflurane. This is in contrast with Kwak et al. (2011) study that showed the decrease in core body temperature during sevoflurane anaesthesia was not different than propofol anaesthesia.

Based on these two studies, it may be summarized that both propofol and sevoflurane contribute towards IPH. However, the evidence of whether propofol or sevoflurane causes more hypothermia is inconclusive.

Reversal of Muscle Relaxants

No study was found on neostigmine, the reversal agent used in this study, on its effect on core body temperature. However, Horn et al. (1998) compared IV physostigmine versus placebo (saline) in 60 patients having surgery of the ear or nose. The drugs were given at the end of anaesthesia; patients were extubated 5 minutes later and core temperature measured 15 minutes after that. The result showed no significant difference between interventions.

Anti-muscarinic Agent: Atropine

Matsukawa et al. (2001) compared atropine 0.01mg/kg IM versus saline placebo in 20 patients given preoperatively. The outcome was the change in core body temperature, compared with baseline, 30 minutes later, just before induction of anaesthesia. Meta-analysis of the comparison gave a significantly higher mean temperature for the atropine group, 30 minutes after the intervention was given.

Analgesia: Opiod

No literatures can be found on the effect of fentanyl, the opiod used in this study, on core body temperature.

Two studies compared pethidine versus control (saline), given at the end of surgery in 90 patients (Horn et al., 1998, Piper et al., 2000). Patients were extubated and the core body temperature measured 15 and 60 minutes after that. Meta-analysis of Horn et al. (1998) and Piper et al. (2000) showed no significant differences in core temperature, measured at 15 and 60 minutes after extubation, between pethidine and placebo.

Two studies compared the effects of tramadol and placebo, given at the beginning of wound closure (Mathews et al., 2002, De Witte et al., 1998). Meta-analysis of the Mathews et al. (2002) study, in 100 patients, showed no significant difference in the incidence of IPH (less than 36.0°C) postoperatively. De Witte et al. (1998) recorded the core body temperature at extubation in 40 patients. There was no significant difference between interventions.

Vasopressor

Ephedrine

Jo et al. (2011) compared ephedrine infusion with placebo in 24 patients undergoing spine surgery under GA. The outcome was core temperature every 15 minutes after intubation until the end of surgery. At the end of the study period, the core body temperature was significantly decreased in the control group, whereas those in the ephedrine group were stably maintained.

Phenylephrine

Ro et al. (2009) compared continuously-infused phenylephrine 0.5 mcg/kg/min with placebo in 20 patients undergoing elective orthopaedic surgery under spinal anaesthesia. Ikeda et al. (1999) compared infusion of 0.5 mcg/kg/min phenylephrine with placebo in patients undergoing minor oral surgery under GA. The outcome of both studies was core body temperature at the end of surgery compared with the control group. These studies showed that core body temperature in the untreated patients decreased significantly more than in those given phenylephrine.

These studies suggested that drugs that produce vasoconstriction may reduce the magnitude of hypothermia, possibly by inhibiting core-to-peripheral redistribution of body heat.

Inotropic Agent : Dobutamine

Shitara et al. (1996) compared dobutamine infusion with placebo in 16 patients undergoing GA. The outcome was core body temperature 40 minutes after induction of anaesthesia. The core body temperature decreased further in the dobutamine group than in the control group. This study suggested that inotropic agents may induce hypothermia, presumably by facilitating heat transfer through the increase in cardiac output.

3.3.2 Patient Risk Factors

Age

Four cohort studies (Kongsayreepong et al., 2003, El-Gamal et al., 2000, Lau et al., 2001, Vorrakitpokatorn et al., 2006) investigated the effect of age on the incidence of IPH postoperatively. Each study considered age as a categorical variable. The incidence of IPH did not appear to be affected by adult age, but, in the large Lau et al. (2001) study (18,758 patients), older adults (over 65 years), had significantly more patients with a core body temperature below 35°C postoperatively.

Gender

One cohort study (Flores-Maldonado et al., 1997) in 130 patients showed no significant effect of gender on the incidence of IPH.

American Society of Anaesthesiologists (ASA) grade

Lau et al. (2001) conducted a large cohort studies 18,759 patients investigating the effect of ASA grade on the incidence of IPH in PACU or ICU. The patients were subdivided into categories I, II, III, IV, V. There was a statistically significant difference of the incidence of IPH at higher ASA grades compared with ASA I.

Body weight (BW)

One cohort study (Kongsayreepong et al., 2003) in 184 patients showed a small statistically significant effect of BW on the incidence of IPH (temperature less than 36.0°C) in ICU; with less hypothermia for a higher BW. This study suggested that increased BW may have a small protective effect on the incidence of IPH in ICU. However, the Kurz et al.(1995) study in 40 patients reported no significant effect of BW on change in core temperature over the first hour of surgery. Frank et al. (2000) (n=44) also reported no significant effect of BW on the core temperature in PACU. No studies investigated body mass index (BMI) or body surface area.

Diabetes

Kongsayreepong et al. (2003) investigated the effect of a history of diabetic neuropathy compared with no history on the incidence of IPH in ICU and found no significant difference. Kitamura et al. (2000) reported the core body temperature intraoperatively, for groups of patients with diabetes and no neuropathy versus those without diabetes. There were no significant differences between groups at any time. However, among the patients with diabetes, at three hours intraoperatively, those with neuropathy had significantly lower core body temperature than those without neuropathy.

Preoperative temperature

Two cohort studies (Kongsayreepong et al., 2003, Abelha et al., 2005) included patient preoperative temperature in the multivariate analyses of incidence of IPH in ICU. The mean core temperature initially in Abelha et al. (2005) was 36.37°C (SD 0.49); in Kongsayreepong et al. (2003) it was 37.0°C (SD 0.7). Meta-analysis of 369 patients found a statistically significant effect of preoperative temperature as a risk factor for IPH.

3.3.3 Anaesthesia Risk Factors

Type of anaesthesia: Regional versus GA

Flores-Maldonado et al. (1997) showed that there was no significant difference for general versus spinal or epidural anaesthesia in the incidence of IPH intraoperatively (n=130).

However, Hendolin et al. (1982), a small RCT that compared general versus epidural anaesthesia in 38 patients, recorded the incidence of IPH according to two definitions, less than 36.0°C and less than 35.0°C. There was no significant difference when the definition less than 36.0°C was applied, but for a temperature below 35.0°C, there was a statistically significant difference, with the epidural group being warmer.

Overall, it is unclear whether the risk of IPH differ between regional or GA. This is emphasised by the evidence from the small Hendolin et al. (1982) study that indicates that conclusions depend on the definition of IPH.

Type of anaesthesia: Combined versus Not Combined

Two studies analysed the effect of combined (both general and regional) anaesthesia versus not combined. Kongsayreepong et al. (2003) compared combined anaesthesia with general and regional separately in 184 patients and Lau et al. (2001) compared combined with GA in 18,759 patients. Meta-analysis of the two studies in 18,943 patients showed the incidence of IPH in ICU or PACU was significantly higher for combined general and regional anaesthesia compared with general or regional anaesthesia separately.

3.3.4 Surgery Risk Factors

Magnitude of Surgery

Three cohort studies (Abelha et al., 2005, Flores-Maldonado et al., 1997, Kongsayreepong et al., 2003) investigated the effect of magnitude of surgery on the incidence of IPH. Operations were divided by the authors into:

- major; body cavities and/or major vessels exposed (for example: major abdominal, thoracic, major vascular, hip arthroplasty);
- intermediate; body cavities exposed less than major (for example: appendectomy);
- minor; superficial surgery.

One study (Flores-Maldonado et al., 1997) recorded the incidence of IPH (temperature less than 36.0°C) intraoperatively in 130 patients. There was a statistically significant effect of magnitude of surgery, with major surgery giving rise to a higher incidence of IPH. Two other studies recorded the incidence of IPH in ICU. Meta-analysis of the two studies in 369 patients, showed a statistically significant effect, with major surgery giving rise to a higher incidence of IPH.

Urgency of Surgery

One cohort study (Kongsayreepong et al., 2003) investigated the effect of urgency of surgery on the incidence of IPH (temperature less than 36.0°C) in ICU. There was no significant difference between elective and emergency surgery.

Type of Surgical Procedure

Two RCTs (Nguyen et al., 2001b, Danelli et al., 2002) compared laparoscopic and open procedures, for gastric bypass and colorectal surgery respectively. Both studies reported significantly longer durations of surgery for the laparoscopic procedure. Danelli et al. (2002) stated that there was no significant difference between the two interventions at any time intraoperatively or postoperatively. There was no significant difference in core temperature intraoperatively for Nguyen et al. (2001).

Patient Position Intraoperatively

One small RCT (Nakajima et al., 2002) investigated the effect of patient position during surgery. The patients were randomly assigned to one of four positions: supine (n = 8); 15° to 20° head-down tilt (Trendelenburg position, n = 8); leg-up (lithotomy position, n = 8); leg-up combined with head-down tilt (n = 8). The designated positions were initiated 10 minutes after the induction of GA and were maintained for three hours. There was no significant difference in core body temperature between the Trendelenburg and supine positions at any time. There were significantly higher core body temperatures at two and three hours for leg-up and leg-up with head-down tilt, in comparison with the supine position.

Duration of Surgery

Two studies recorded the effect of duration of surgery as a risk factor for the incidence of IPH in PACU or ICU. Kongsayreepong et al. (2003) (temperature less than 36.0°C) and Vorrakitpokatorn et al. (2006) (temperature less than 35.0°C) both investigated the duration of surgery, as subdivided into above and below two-hours. There was a statistically significant effect for Kongsayreepong et al. (2003) favouring shorter times, but no significant difference for Vorrakitpokatorn et al. (2006). The studies differed as follows:

- in their definitions of hypothermia (less than 36.0°C and less than 35.0°C respectively);
- in their recovery areas, which were respectively ICU and PACU;
- in the range of durations of surgery: Kongsayreepong et al. (2003) had a range of 0.25 to 10.25h; Vorrakitpokatorn et al. (2006) had a mean duration of two hours (SD 49 minutes).

Overall, it appears that the Kongsayreepong et al. (2003) study was more reliable because of the greater range of operation durations and the definition of hypothermia. Based on this study, it may be concluded that, there is a significant effect of duration of surgery, above and below two hours, on the incidence of IPH in ICU.

3.3.5 Environmental Risk Factors

OR Temperature

One study (Flores-Maldonado et al., 1997) in 130 patients reported the effect of OR temperature on the incidence of IPH intraoperatively (temperature less than 36.0°C). This showed a large statistically significant effect of OR temperature for a mean of 22.9°C (SD 1.2) in patients undergoing either regional or GA. Another study (Kongsayreepong et al., 2003) in 184 patients undergoing combined, general or regional anaesthesia, for a theatre temperature of mean 19.5 to 20.6°C (SD 1.8), showed a statistically significantly in favour of warmer ORs.

Humidity

One study (Hind, 1994) in 30 patients, investigated the effect of OR humidity in the range 50 to 65%, and found that this was not significantly correlated with the core body temperature.

Anaesthesia Ready Time

Surprising temperature drops can occur prior to the patient's arrival in the OR, due to their lack of clothing, the vasodilating effects of the premedication, and the long wait in the chilly corridor (Newman, 1971).

3.3.6 Other Risk Factors

Intravenous (IV) Fluid Infusion

Kongsayreepong et al. (2003) has given volume of fluids given 0.1 to 11.2 litres and the volume was dichotomised into above and below four litres. This study showed that fluid volume above and below four litres did not have a significant effect on the incidence of hypothermia. Abelha et al. (2005) reported a range of crystalloid fluid volumes from 0.2 to 10.5 litres, with a mean of 2.9 litres. This was found to have a statistically significant effect, with lower volumes giving less hypothermia in ICU.

Irrigation Fluids

One study (Vorrakitpokatorn et al., 2006) in 128 patients reported a large significant effect of room temperature irrigation fluid, above and below 20 litres, on the incidence of IPH in PACU (temperature less than 35.0°C). Lower volumes of irrigation fluids resulted in less hypothermia.

Blood Transfusion

Two cohort studies investigated the effect of blood transfusion versus no transfusion on the incidence of IPH; Flores-Maldonado et al. (1997) gave 10% of 130 patients blood at 4°C and Vorrakitpokatorn et al. (2006) gave 16% of the 128 patients blood. Flores-Maldonado et al. (1997) found a statistically significant difference in the incidence of core body temperature below 36.0°C, with the transfused group was more hypothermic. Vorrakitpokatorn et al. (2006) found no significant difference in the incidence of temperatures below 35.0°C.

3.4 Consequences of IPH

3.4.1 IPH and Shivering

Two studies with 16 patients in each (Just et al., 1993, Camus et al., 1995) assessed shivering in the recovery room. The categories used for evaluation of shivering were unclear in Camus et al. (1995), but the incidence of shivering for