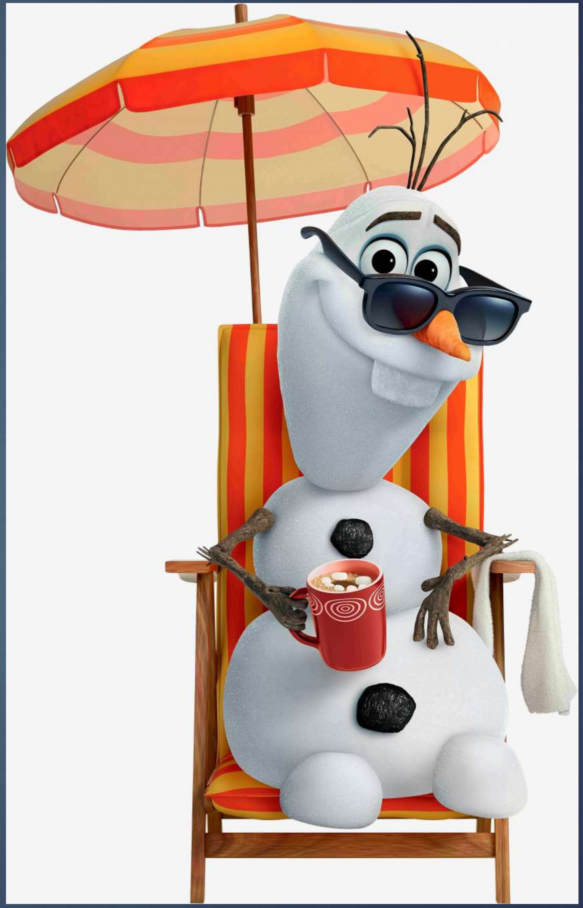

The cold never bothered me anymore.
SPEAKERS: PATCHAREE SRISWASDI, MD, MPH
NATTAYA RAYKATEERAROJ, MD
MODULATORS: CHAOWANAN KHAMTUIKRUA,MD

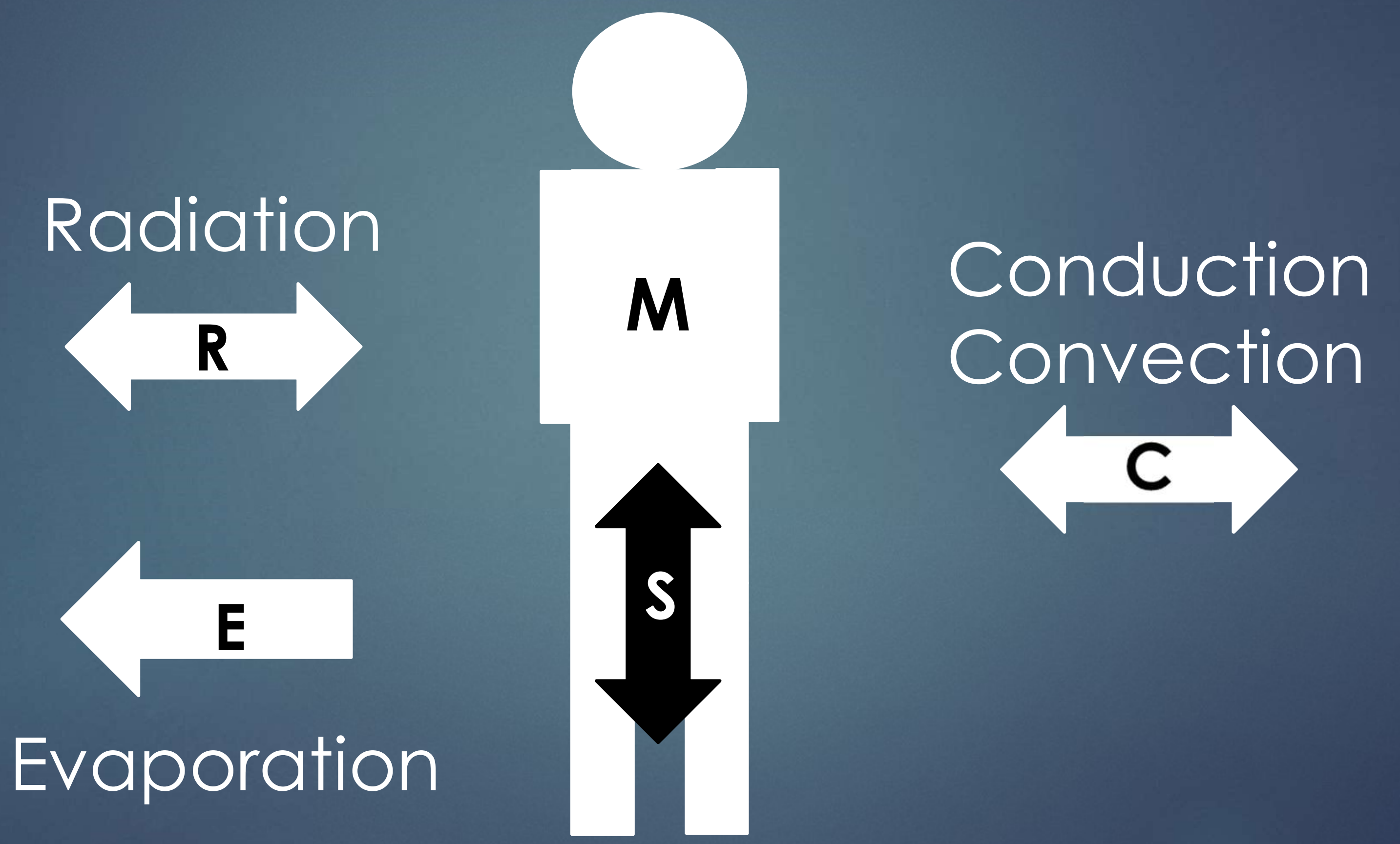
Outline

- **Heat balance & Heat loss mechanisms**
- **Thermoregulation physiology**
  - Awake VS Anesthetized patient
- **Inadvertent perioperative hypothermia (IPH)**
  - Consequences of IPH & Risk of hyperthermia
  - NICE guideline IPH recommendation
- **Intraoperative warming intervention**
  - Fluid warming & Body warming

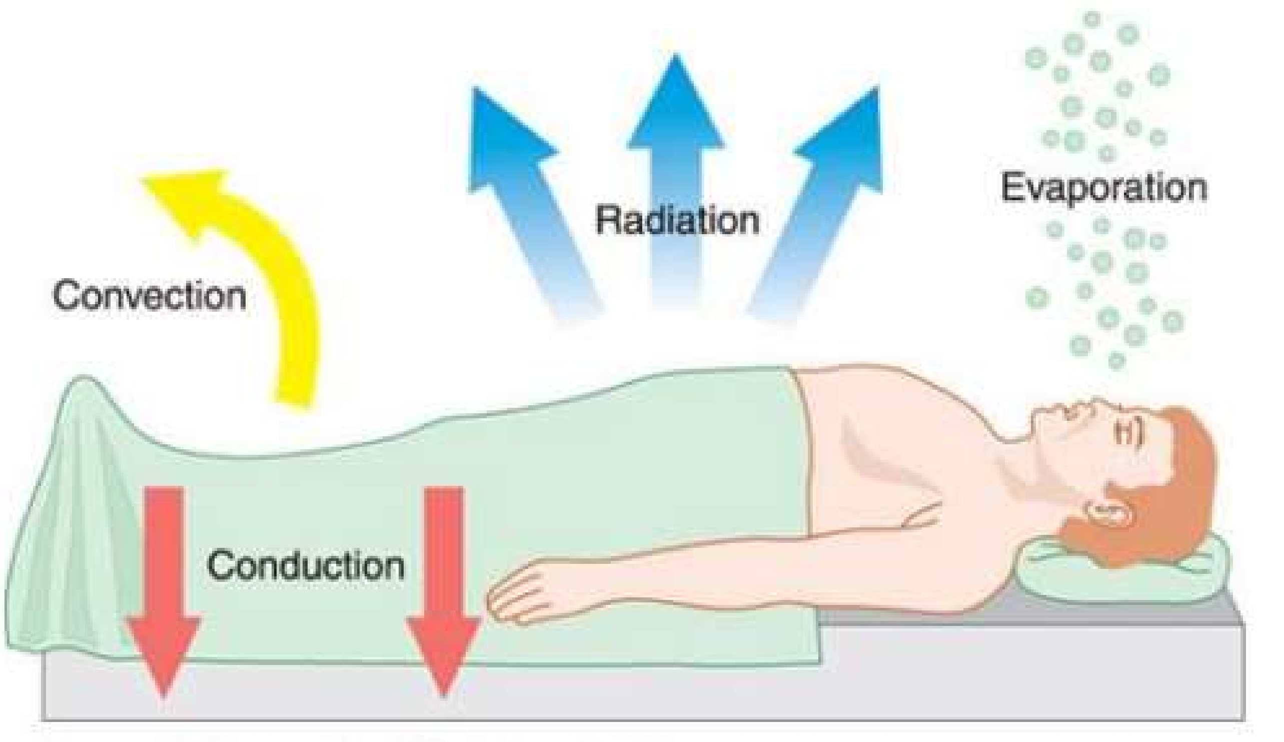
Heat balance
Heat loss mechanisms



Heat balance in human



Heat loss mechanisms



Source: D.E. Longnecker, S.C. Mackey, M.F. Newman, W.S. Sandberg, W.M. Zapol: Anesthesiology, Third Edition

Thermoregulation Physiology

Thermoregulation physiology

- Tightly controlled core temperature for the effective body function.
  - Enzyme and transport mechanisms
- Thermoregulation
  - INPUT: Peripheral: skin & deep tissue

    Central: Spinal cord, brain stem & hypothalamus
- In health, maintains temperature at 36.7-37.1C by hypothalamus
  - Outside this temperature inter-threshold range
  - Generate homeostatic & behavioral mechanisms to return to normothermia

Riley, C., and J. Andrzejowski. "Inadvertent perioperative hypothermia." *Bja Education* 18.8 (2018): 227-233.

Thermoregulation physiology Response to thermal changes

Hypothermia

- Behavioral changes >> clothing and shelter to keep warm
- Homeostatic warming methods
  - Alpha-1-adrenergic receptor >> Vasoconstriction
  - Non-shivering (NS) thermogenesis: No muscular activity
    - Brown fat metabolism via beta-3-adrenergic receptors
      - ↑mitochondria >> ↑lipid oxidation>> ↑ATP and heat.
      - Important in infants & neonate, less significant in adult.

Riley, C., and J. Andrzejowski. "Inadvertent perioperative hypothermia." *Bja Education* 18.8 (2018): 227-233.

Thermoregulation physiology Response to hypothermia

Hypothermia

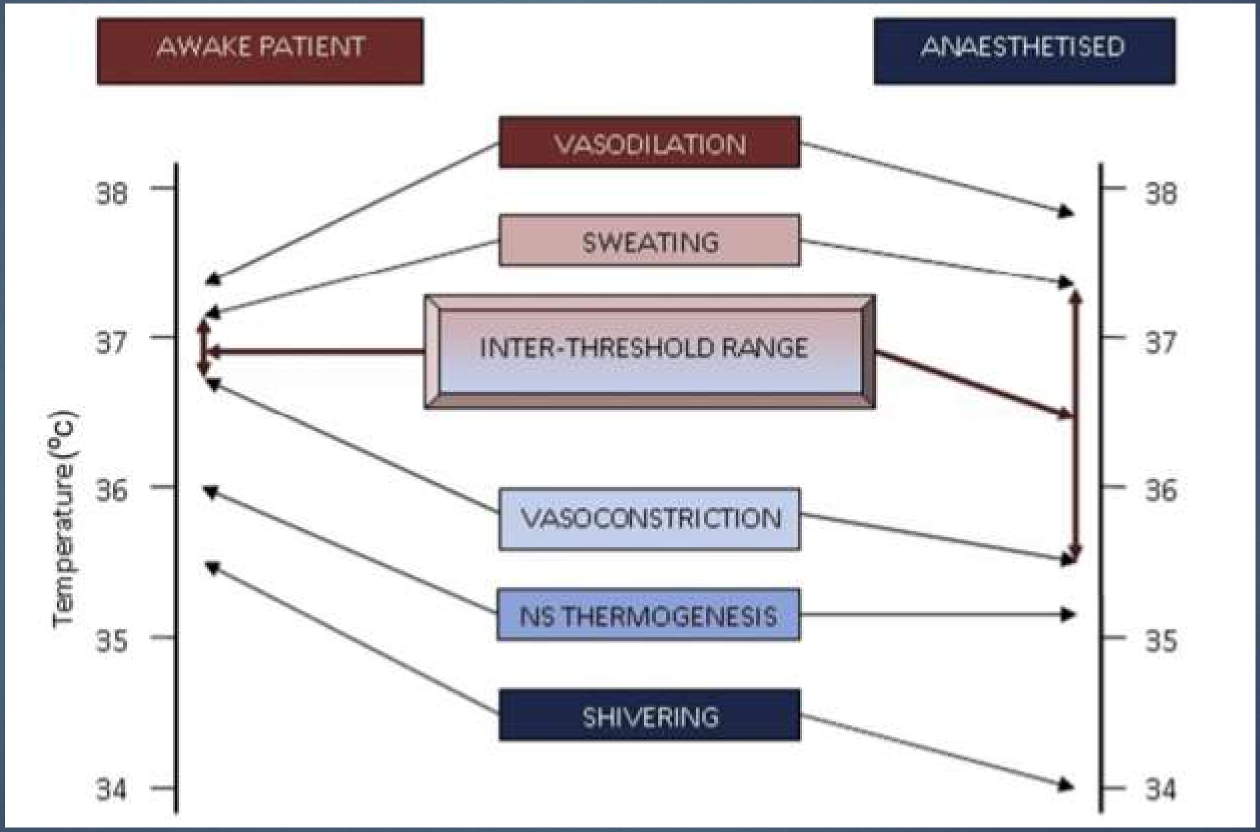
- Homeostatic warming methods
  - Shivering thermogenesis (Muscular activity)
    - To produce metabolic heat with increased mechanical work.
    - Can increases metabolism to 6-fold of basal metabolic rate

Hyperthermia

- Behavioral changes >> shedding clothing & seeking shade.
- Homeostatic warming methods >> sweating and vasodilatation

Riley, C., and J. Andrzejowski. "Inadvertent perioperative hypothermia." *Bja Education* 18.8 (2018): 227-233.

Thermoregulation physiology
Awake VS Anesthetized patient



Riley, C., and J. Andrzejowski. "Inadvertent perioperative hypothermia." *Bja Education* 18.8 (2018): 227-233.

Effect of anesthesia on heat balance General anesthesia

- Abolished behavioral responses
- Widened the inter-threshold range, from ~0.4 to 4.0C.
- Compromised homeostasis
- In elderly, reduced vasoconstriction and shivering thresholds.
- Ineffective response to heat loss during anesthesia

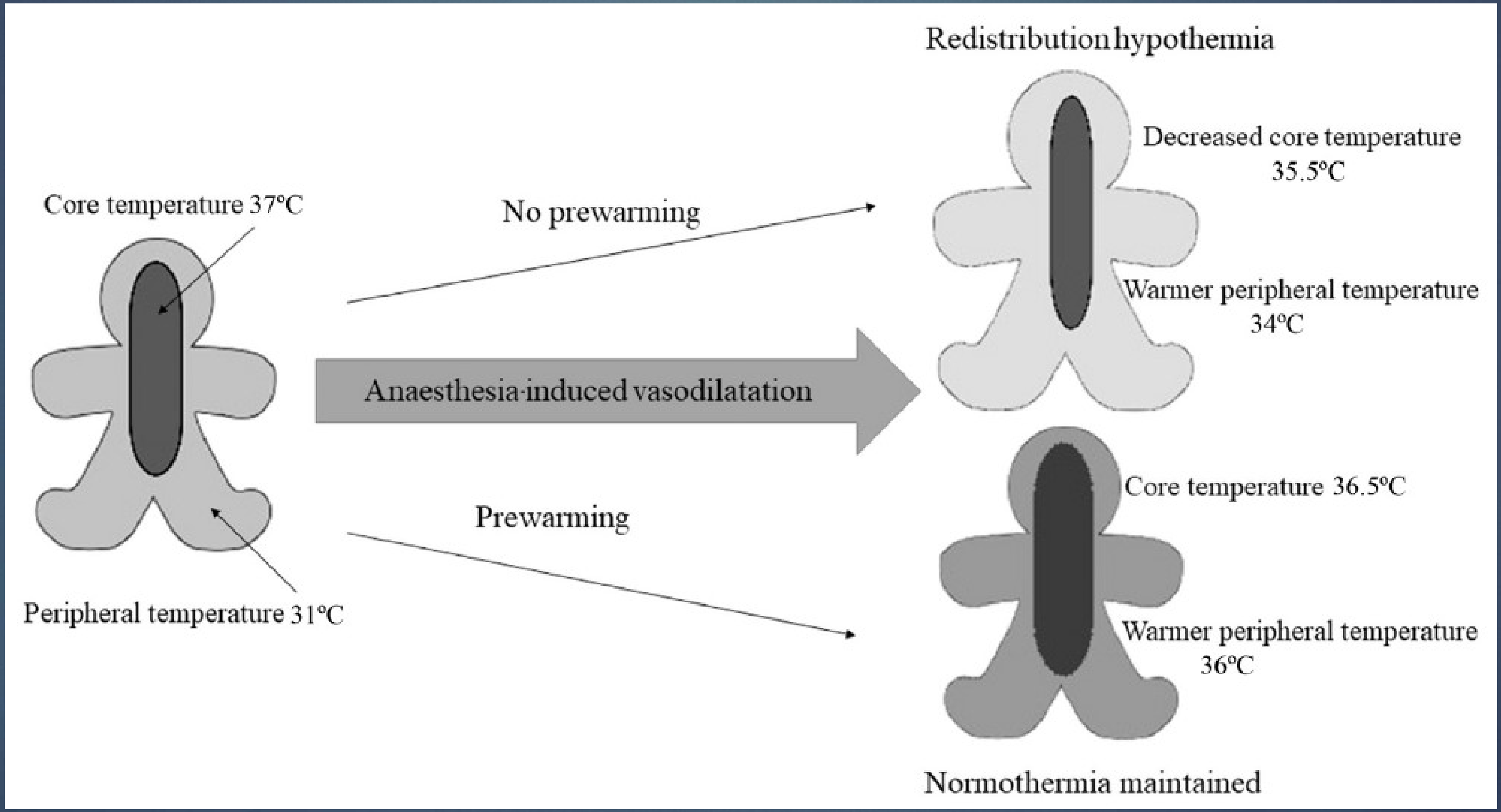
Riley, C., and J. Andrzejowski. "Inadvertent perioperative hypothermia." *Bja Education* 18.8 (2018): 227-233.

Effect of anesthesia on heat balance Regional anesthesia

- Initially hypothermia
- Below level of the block
  - Vasodilatation
    - Redistribution of cooler peripheral blood to the core
  - Decreased afferent input from the peripheral thermal centers.
    - Decreases shivering & vasoconstriction thresholds
- Above level of the block
  - Vasoconstriction to compensate the heat loss

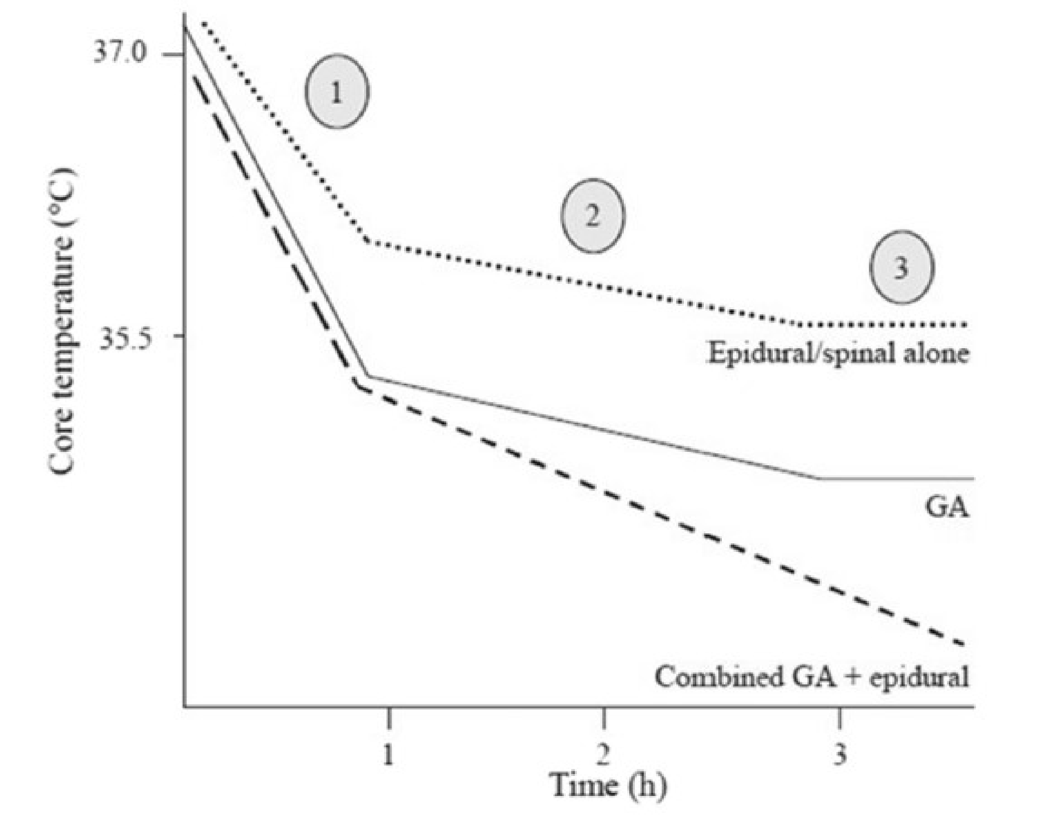
Riley, C., and J. Andrzejowski. "Inadvertent perioperative hypothermia." *Bja Education* 18.8 (2018): 227-233.

Effect of anesthesia on heat balance



Riley, C., and J. Andrzejowski. "Inadvertent perioperative hypothermia." *Bja Education* 18.8 (2018): 227-233.

Effect of anesthesia on heat balance
Cause of heat loss in anesthesia



Riley, C., and J. Andrzejowski. "Inadvertent perioperative hypothermia." *Bja Education* 18.8 (2018): 227-233.

Inadvertent Perioperative Hypothermia

Inadvertent perioperative hypothermia (IPH)

- Core body temperature < 36C.
- Common preventable consequence of anesthesia.
  - Occurs in 50-90% of surgical patients
- Increases morbidity and potentially increases mortality.
- Strategies should be used to maintain normothermia.
  - Before, during, and after surgery

Riley, C., and J. Andrzejowski. "Inadvertent perioperative hypothermia." *Bja Education* 18.8 (2018): 227-233.

Consequences of perioperative hypothermia

- Surgical site infection: ↓blood flow & ↓ oxygen flux to the tissues
- Shivering:
  - Unreliable monitoring
  - ↑ postoperative pain
  - ↑ carbon dioxide production
  - ↑ catecholamine >> ↑ CO >> ↑ ABP >> ↑ myocardial workload
  - ↑ Cardiac event

Riley, C., and J. Andrzejowski. "Inadvertent perioperative hypothermia." *Bja Education* 18.8 (2018): 227-233.

Consequences of perioperative hypothermia

- ↑ transfusion requirements
  - ↓ Platelet function & coagulation
- Drug metabolism:
  - ↑ Tissue solubility of volatile anesthetics
  - ↓ Hepatic metabolism
    - Prolong action of propofol & opioids
    - Prolong action of neuromuscular blocking agent
  - ↓ rate of Hoffman degradation

Riley, C., and J. Andrzejowski. "Inadvertent perioperative hypothermia." *Bja Education* 18.8 (2018): 227-233.

Risks and avoidance of overheating

Intraoperative hyperthermia

- Infants & children are most at risk of overheating.
- Risk of over heating
  - ↑ peripheral blood flow & capillary permeability, and edema
- **Usually rare**: Consider MH, sepsis, IVH, drug/blood transfusion adverse reactions
- **Consequences** of Intraoperative hyperthermia
  - Sweating to loss heat.
  - ↑ MAC of inhalation, ↓ duration of neuromuscular blocking agent

Riley, C., and J. Andrzejowski. "Inadvertent perioperative hypothermia." *Bja Education* 18.8 (2018): 227-233.

NICE National Institute for Health and Care Excellence

Inadvertent perioperative hypothermia

Information

Patients (and their families and care givers) should be informed that:

- Staying warm before surgery will lower the postoperative complication.
- The hospital environment may be colder than their own home.
- They should bring additional clothing.
- They should inform staff if they feel cook at any time during their hospital stay.

NICE National Institute for Health and Care Excellence

Inadvertent perioperative hypothermia

Preoperative phase

- High risk of IPH, if any 2 of the following apply:
  - ASA grade II to V (the higher the grade, the greater the risk)
  - Preoperative temperature below 36.0°C
    (and preoperative warming is not possible because of clinical urgency)
  - Undergoing combined general and regional anesthesia
  - Undergoing major or intermediate surgery
  - At risk of cardiovascular complications.

NICE National Institute for Health and Care Excellence

Inadvertent perioperative hypothermia

Intraoperative phase

- **In the theatre suite**
  - The ambient temperature ≥21°C, while the patient is exposed
- **Fluid warming**
  - Using a fluid warming device in IV fluids > 500 ml & blood products to 37°C.
- **Irrigation fluids**
  - Warmed in a thermostatically controlled cabinet to 38°C to 40°C.

NICE National Institute for Health and Care Excellence

Inadvertent perioperative hypothermia

Intraoperative phase

- **Induction of anesthesia**
  - Start induction of anesthesia when temperature > 36.0°CWarm patients
- **Intraoperative**: Using a forced-air warming device…
  - Anesthesia > 30 minutes
  - Anesthesia < 30 minutes with higher risk of IPH
  - Consider a resistive heating mattress/blanket

NICE National Institute for Health and Care Excellence

Inadvertent perioperative hypothermia

Postoperative phase: Recovery area

- Measured & documented temperature on arrival, then every 15 minutes.
- If temperature < 36.0°C, using forced-air warmer.
- Transfer to ward only the patient's temperature > 36.0°C.

NICE National Institute for Health and Care Excellence

Inadvertent perioperative hypothermia

Postoperative phase: On the ward

- Measured & documented temperature on arrival at ward, as a part of routine 4-hourly observations.
- Provided at least 1 cotton sheet, 2 blankets, or a duvet.
- If the patient's temperature falls below 36.0°
  - Using forced-air warmer until they are comfortably warm .
  - Measured & documented temperature every 30min during warming.

Intraoperative warming intervention

Cochrane Library

Cochrane Database of Systematic Reviews

Warming of intravenous and irrigation fluids for preventing inadvertent perioperative hypothermia (Review)

Campbell G, Alderson P, Smith AF, Warttig S

Intraoperative warming intervention

- **↓ redistribution of heat**
  - Pre-warming before anesthesia
- **Passive warming systems**:
  - ↑ environmental temperature
  - Passive insulation: covering exposed body surfaces
  - Closed or semi closed anesthesia circuits with low flows.

Campbell, Gillian, et al. "Warming of intravenous and irrigation fluids for preventing inadvertent perioperative hypothermia. " *Cochrane Database of Systematic Reviews* 4 (2015).

Intraoperative warming intervention

- **Active warming systems**
  - Infrared lights
  - Mattresses or blankets with warm water circulation
  - **Forced air warming**
  - **Warming of intravenous and irrigation fluids**
  - Warming & humidifying of anesthetic air
  - Warming of CO_2 in laparoscopic surgery

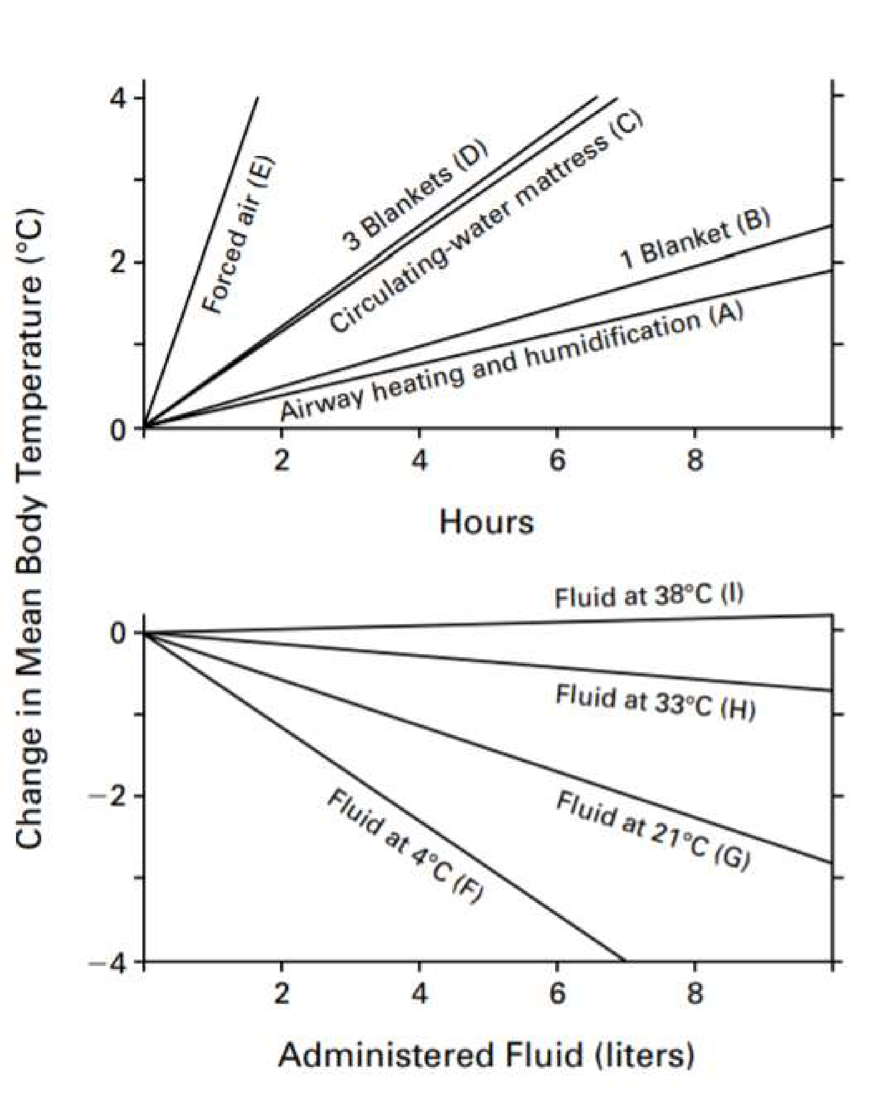
Campbell, Gillian, et al. "Warming of intravenous and irrigation fluids for preventing inadvertent perioperative hypothermia." *Cochrane Database of Systematic Reviews* 4 (2015).

Fluid warming methods

Warmed fluids ***VS*** Room temperature fluids

- **Warmed IV fluids group**
  - 0.5°C Higher core temperature at 30, 60, 90, 120 minutes after anesthetic induction
  - Lower risk of shivering
  - No statistically significant differences in blood loss
- **Warmed irrigation fluids group**
  - No statistically significant difference in body temperature

Campbell, Gillian, et al. "Warming of intravenous and irrigation fluids for preventing inadvertent perioperative hypothermia. " *Cochrane Database of Systematic Reviews* 4 (2015).



Effects of Warming Methods

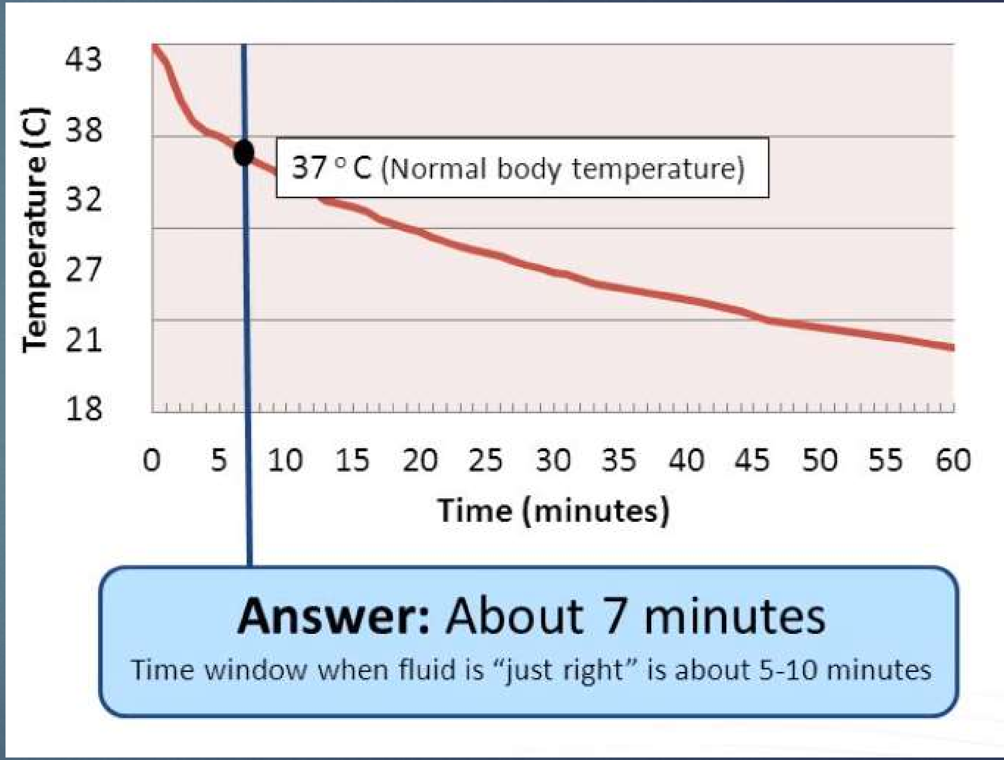
IV fluids

- The colder IV fluid, the colder patients.
- ↓ 0.25°C, very liter of **ambient temperature fluid, 21 °C.**
- ↓ 0.5°C, very liter of cold fluid, such as **blood at 4 °C.**
  - Hyper viscosity & difficult to infuse
  - Worsening peripheral vasoconstriction

Sessler, Daniel I. "Mild perioperative hypothermia." *New England Journal of Medicine* 336.24 (1997): 1730-1737.

Methods of warming fluid

How fast does 1 liter of 43 °C fluid get colder?



1. Cabinet warmer

- Pre-warm fluid get cool rapidly.

2. Bedside warming

- Consistent delivery of warm fluids.
  - Dry heat VS water bath systems

**** Water may support growth of bacteria**
**** CDC guidelines recommend against medical devices containing water in the OR, suggesting remove a potential source of contaminated water.**

3M™ Ranger™ Blood/Fluid Warming System

Easy-to-Use Flexible Warming Unit

- Safety & effectively warms fluids from KVO to 30000mL/hr.
- Disposable warming set

Dry Heat Technology & Control System

- Monitors & maintain 41 °C, 4 times each second
- Quickly reacts to change in flow rate

Safety Features

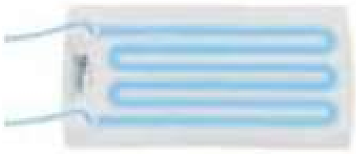
- Alarm system in the event of cooling/overheating
- Secondary alarm system provides fail-safety backup

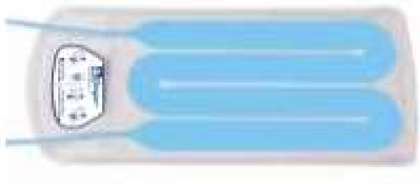
Dry heat means No water.
No risk of water-related infection.

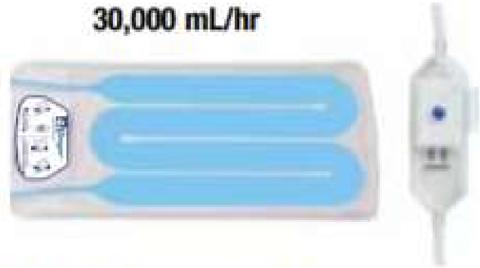
The Range in the Ranger™ System

KVO

6,000 mL/hr	9,000 mL/hr	30,000 mL/hr







Pediatric Disposable Set

Low Flows

- Aliquot fluid administration
- Cost effective
- Reduces priming volume

Standard Flow Disposable Set

Moderate Flows

- Responsive to changes in flow rates
- Able to warm at higher flow rates
- Cost effective

High Flow Disposable Set

High Flows

- Auto-venting bubble trap
- Fluid volume capacity
- Cost effective

Body warming devices

Body warming devices

convective warming or direct-contact thermal conduction.

- Forced-air warmer
- Water filled mattress
- Electric warming blankets
- Radiant warmer
- Electric heating pad
- Plastic garment

Body warming devices

- Forced-air convective warming systems are recommended by National Institute for Health and Care Excellence (NICE) in targeted peri-operative patients

- current guidance advocates the use of active forced-air warming as opposed to passive insulation methods for operations with an **anticipated operating time of ≥ 30 min**

Forced-air warmers

- Forced-air warmers operate by distributing heated air generated by a **power unit** through a specially designed **downstream blanket** resulting in heat transfer to the covered body surface
- The **dual benefit** of transferring heat to the body and reducing heat losses by stopping convective and radiant heat loss from the skin under the air warmer

Type of forced-air warming systems

- An early study showed that the total heat transfer from the **Bair Hugger system(power unit and blanket) was significantly greater** than the Warmtouch(Mallinckrodt Medical Inc, St. Louis, MO, USA), Thermacare(Gaymar Industries, Orchard Park, NY, USA) and WarmAir (Cincinnati Sub-Zero Products, Cincinnati, OH, USA) systems when used to warm non-anaesthetised healthy volunteers with full body blankets

Giesbrecht GG, Ducharme MB, McGuire JP. Comparison of forced-air patient warming systems for perioperative use. Anesthesiology 1994; 80: 671–9.

forced-air warming systems

- It has also been argued that the **efficacy** of forced-air warming systems is primarily determined by the associated blanket properties as opposed to the power unit

Br€auer A, Bovenschulte H, Perl T, Zink W, English MJ, QuintelM. What determines the efficacy of forced air-warming sys-tems? A manikin evaluation with upper body blankets.Anesthesia and Analgesia 2009; 108: 192–8.

forced-air warming systems

- In contrast to the nozzle temperature and airflow generated by the power unit, the blanket’s ability to optimise the patient-blanket temperature gradient, and its capacity to distribute heat evenly correlates well with the heat transfer ability of the forced-air system according to manikin studies.
- Blanket air temperature is typically 3.6-10 F lower than the temperature of the air from the hose.

Warming blanket

- The **surface area covered** by the warming blanket also has a significant influence on forced-air warming performance as greater coverage both reduces exposure and offers a larger interface for heat transfer.

- This is particularly important for forced-air warming because <u>air has a very low specific heat capacity</u>.

Warming blanket

Warming blanket

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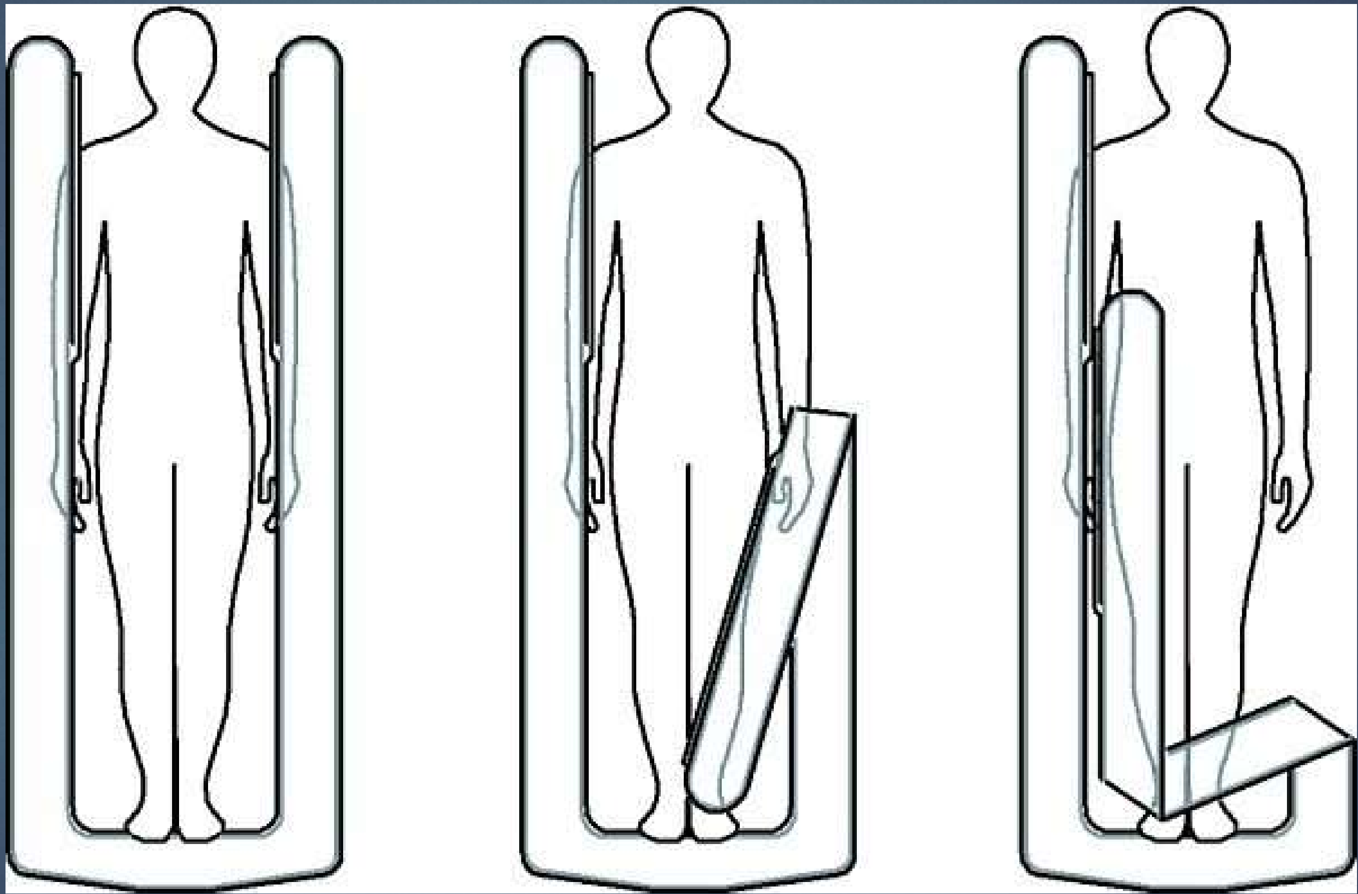
Warming blanket



Warming blanket

- Clinical studies involving neonates during major non-cardiac surgery have also shown that **re-usable blankets made of water resistant canvas** were equally efficacious in preventing intra-operative hypothermia compared with a standard Bair Hugger blanket model

Kongsayreepong S, Gunnaleka P, Suraseranivongse S, et al. A reusable, custom-made warming blanket prevents core hypothermia during major neonatal surgery. Canadian Journal of Anesthesia 2002; 49: 605–9.

Forced-air warming device safety

Acta Anaesthesiol Scand 1999; **43**: 173–176

ACTA ANAESTHESIOLOGICA SCANDINAVICA
ISSN 0001-5172

The potential for increased risk of infection due to the reuse of convective air-warming/cooling coverlets

D. C. Sigg, A. J. Houlton and P. A. Iaizzo
Department of Anesthesiology, University of Minnesota, Minneapolis, Minnesota, USA

- The correct use of **microbial filters** and the recommended perforated blankets has been shown to prevent their transmission.

Forced-air warming device safety

Anaesthesia 2012, 67, 244–249 doi:10.1111/j.1365-2044.2011.06983.x

Original Article

Effect of forced-air warming on the performance of operating theatre laminar flow ventilation*

K. B. Dasari,[1] M. Albrecht[2] and M. Harper[3]

- forced-air warming systems can create significant temperature gradients within the operating room that have the potential to **disrupt laminar airflow patterns and contaminate the surgical site with floor-level air** mobilised by convection currents

Forced-air warming device safety

- **Analysis of theatre air samples** in positive pressure theatres has shown a significant decrease in bacterial counts when forced-air warming was used correctly

Huang JKC, Shah EF, Vinodkumar N, Hegarty MA, Greatorex RA. The Bair Hugger patient warming system in prolonged vascular surgery: an infection risk? Critical Care 2003; 7: R13–6.

Convective Warming Therapy Does Not Increase the Risk of Wound Contamination in the Operating Room

Robert S. Zink, MD, and Paul A. Iaizzo, PhD

Department of Anesthesiology, University of Minnesota, Minneapolis, Minnesota

Anesth Analg 1993;76;50-3

Forced-air warming device safety

- forced-air warmer use has been associated **with thermal injuries** in both adults and children, some of which have required surgical intervention and prolonged wound care
- The underlying causes in the majority of cases involve **incorrect assembly of the warmer hose to the blanket** or accidental disconnections allowing hot air to be blown directly on to the patient's skin for a prolonged period of time ('hosing')

Forced-air warming device safety

PATIENT SAFETY

Misuse of forced-air warming devices can be hazardous

By V. Doreen Wagner, RN, MSN, CNOR

- A novel underbody forced-air warming blanket has also been implicated with the development of full thickness pressure ulcers following its **prolonged use in a patient with vascular disease**

Resistive heating device

- Resistive heating is a warming modality that utilises a low-voltage electric current that passes through semiconductive polymer or carbon fibre systems to generate heat.
- Heat transfer occurs primarily by **conduction**, and skin contact is achieved through either a mattress or blanket

Resistive heating device safety

- Resistive heating relies on **direct skin contact to warm patients** and can cause significant burns if the mattress or blanket temperatures become inappropriately elevated.

- Full thickness burns requiring split skin grafting and scar therapy have occurred

British Journal of Anaesthesia **93** (**4**): 586–9 (2004)
doi:10.1093/bja/aeh236 Advance Access publication August 6, 2004

Thermal injuries in three children caused by an electrical warming mattress

D. J. Dewar[1], J. F. Fraser[2]*, K. L. Choo[3] and R. M. Kimble[4]

Circulating water devices

- Circulating water devices operate by passing heated water within mattresses, blankets or garments in contact with patients. Due to the **greater specific heat capacity and thermal conductivity of water**, it is a more effective medium to transfer heat when compared with air

Circulating water devices

- The **interface between patient and circulating water mattress has an important impact** on device performance and to achieve optimum heat transfer, the mattress ideally needs unimpeded high thermal contact with well-perfused skin.
- **the posterior surface is poorly perfused** from the weight of the body compressing cutaneous capillaries

Circulating water devices

- Most comparative studies in children have shown **inferior performance of water mattress warming** against forced-air warming

Buisson P, Bach V, Elabbassi EB, et al. Assessment of the efficiency of warming devices during neonatal surgery. European Journal of Applied Physiology 2004; 92: 694–7.

Take-Home Messages

- Perioperative hypothermia Occurs in 50-90% of surgical patients
- Increases morbidity and potentially increases mortality
- Anesthesia abolished body responses to hypothermia
- Perioperative warming intervention: Pre-, intra-,postoperative phase
- Number of body warming devices have been developed utilising either convective warming or direct-contact thermal conduction.

Thank you