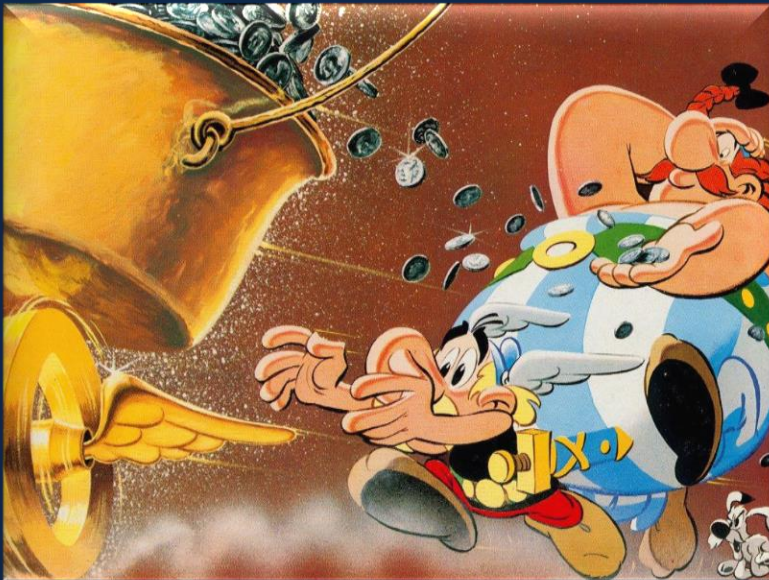


Thermoregulation and Heat Balance

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Department of Anesthesiology

Disclosure



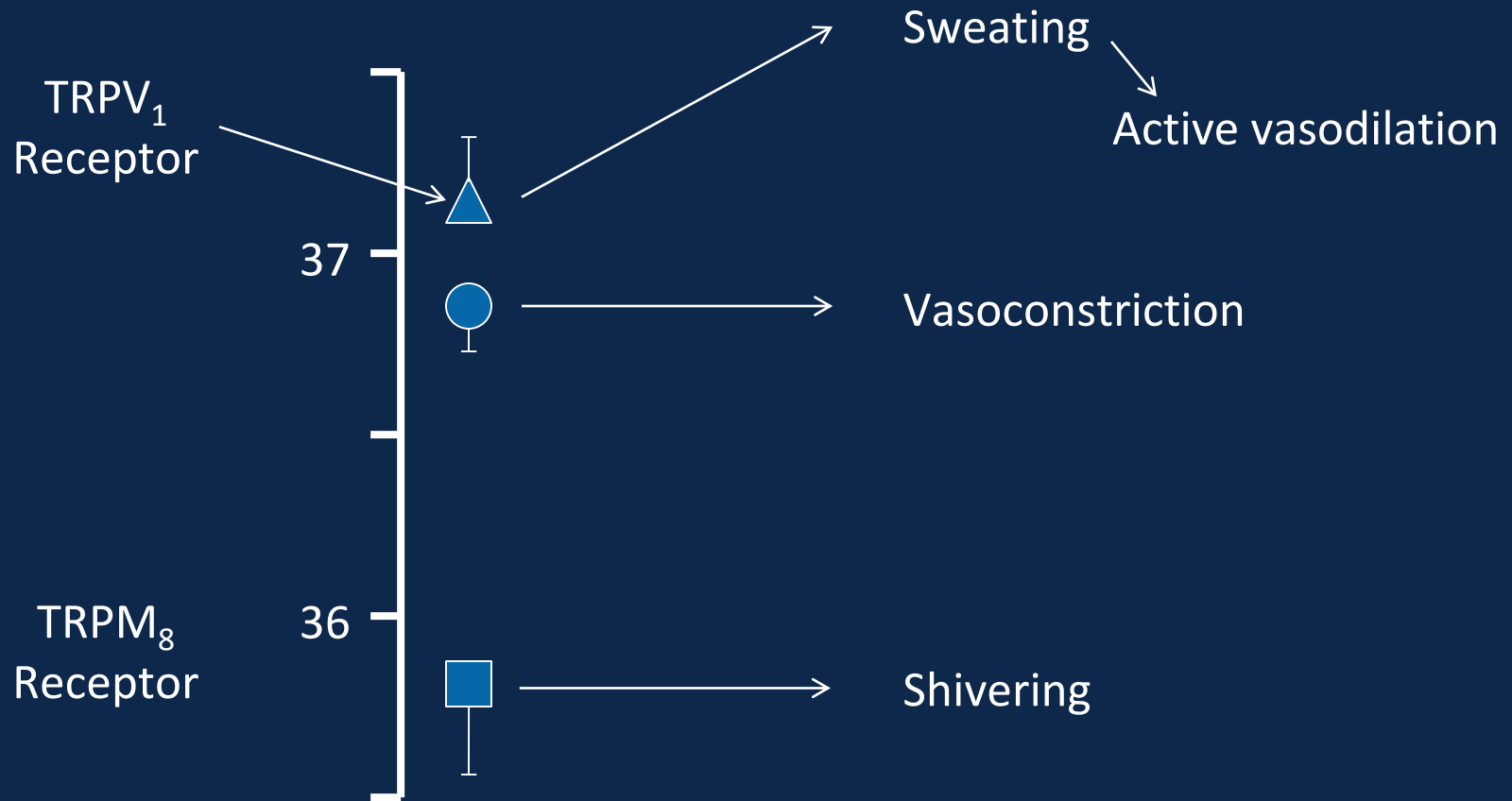
- I am an employee of the University of Michigan.
- My Department receives research funds from various companies
- I have received honorariums to support research endeavors and reimbursement of costs to participate in meetings (e.g., scientific or advisory) from companies such as :
 - The Surgical Company
 - Merck Pharmaceuticals
 - 3M

Thermoregulation & Heat Balance

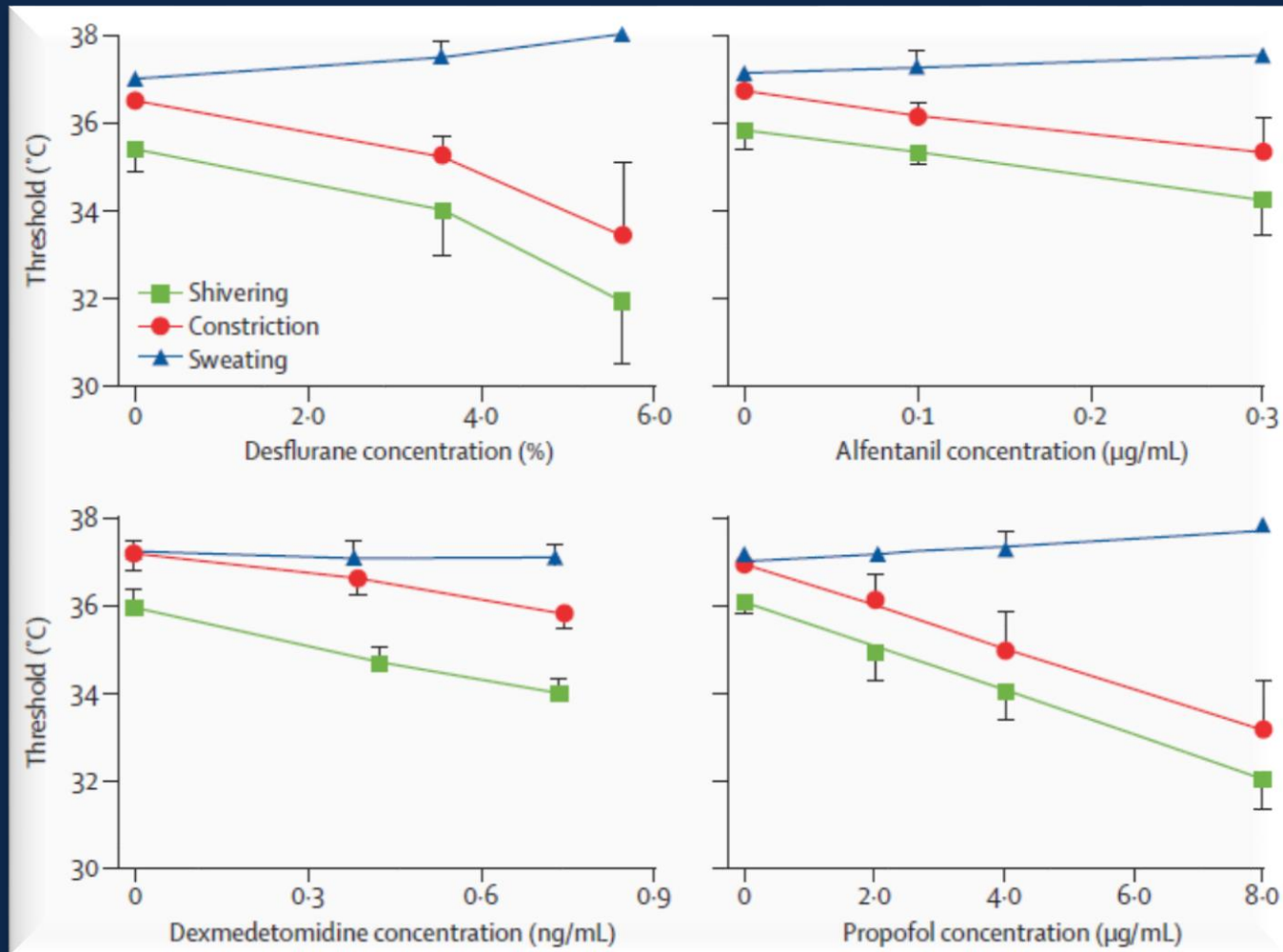
- Thermoregulation during anesthesia
- Temperature monitoring
- Consequences of hypothermia
- Maintaining normothermia



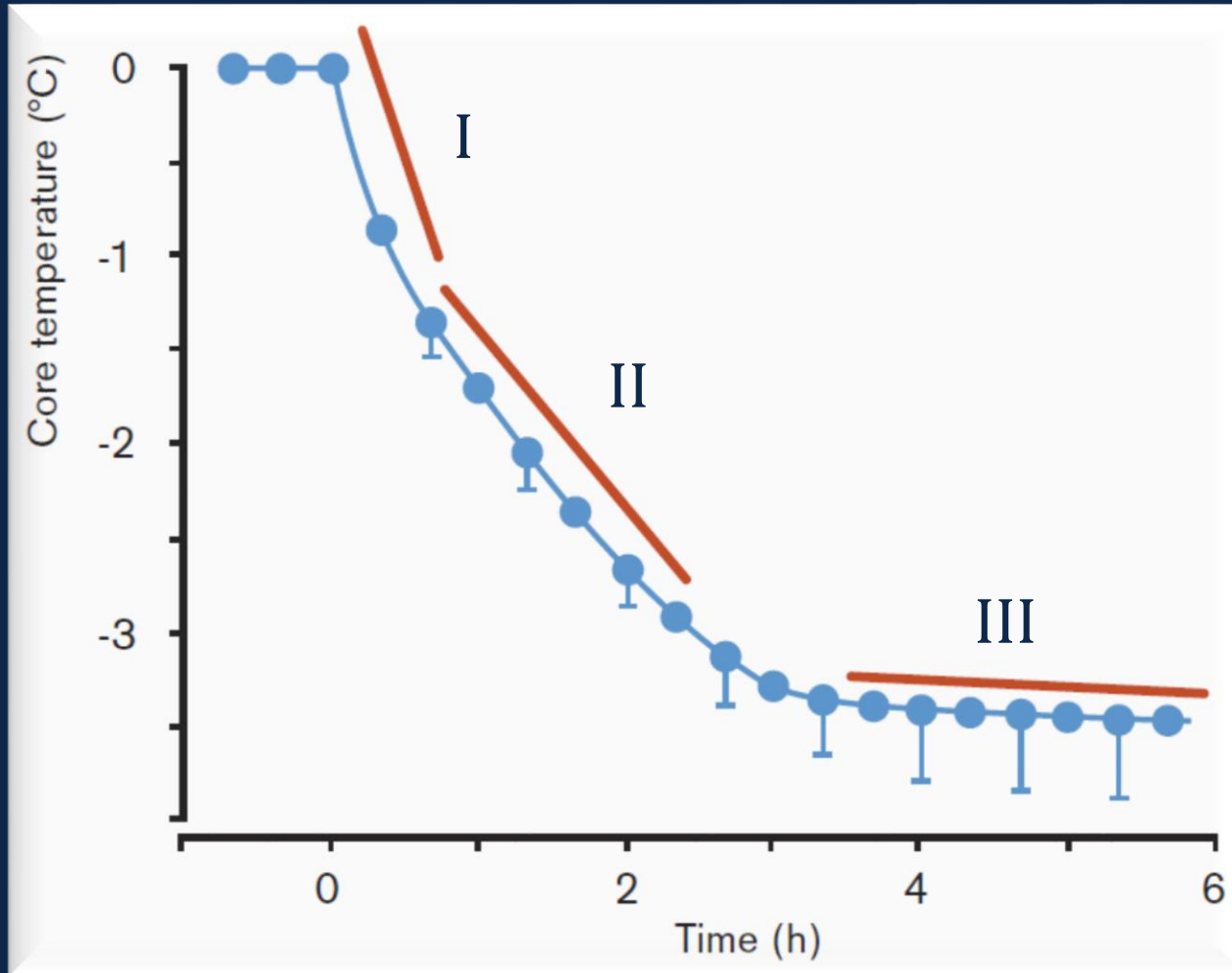
Normal Thermoregulation



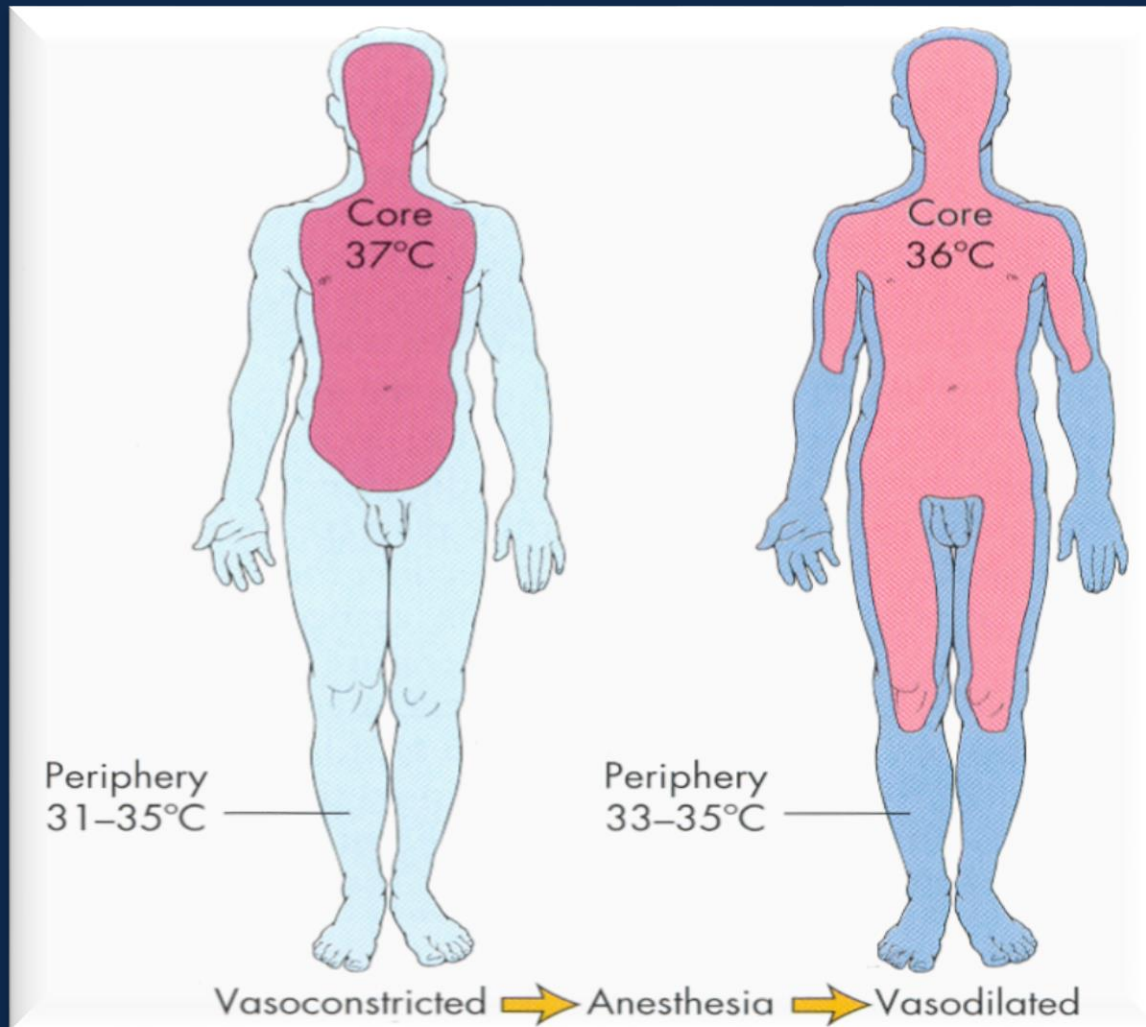
Anesthesia Impairs Thermoregulation



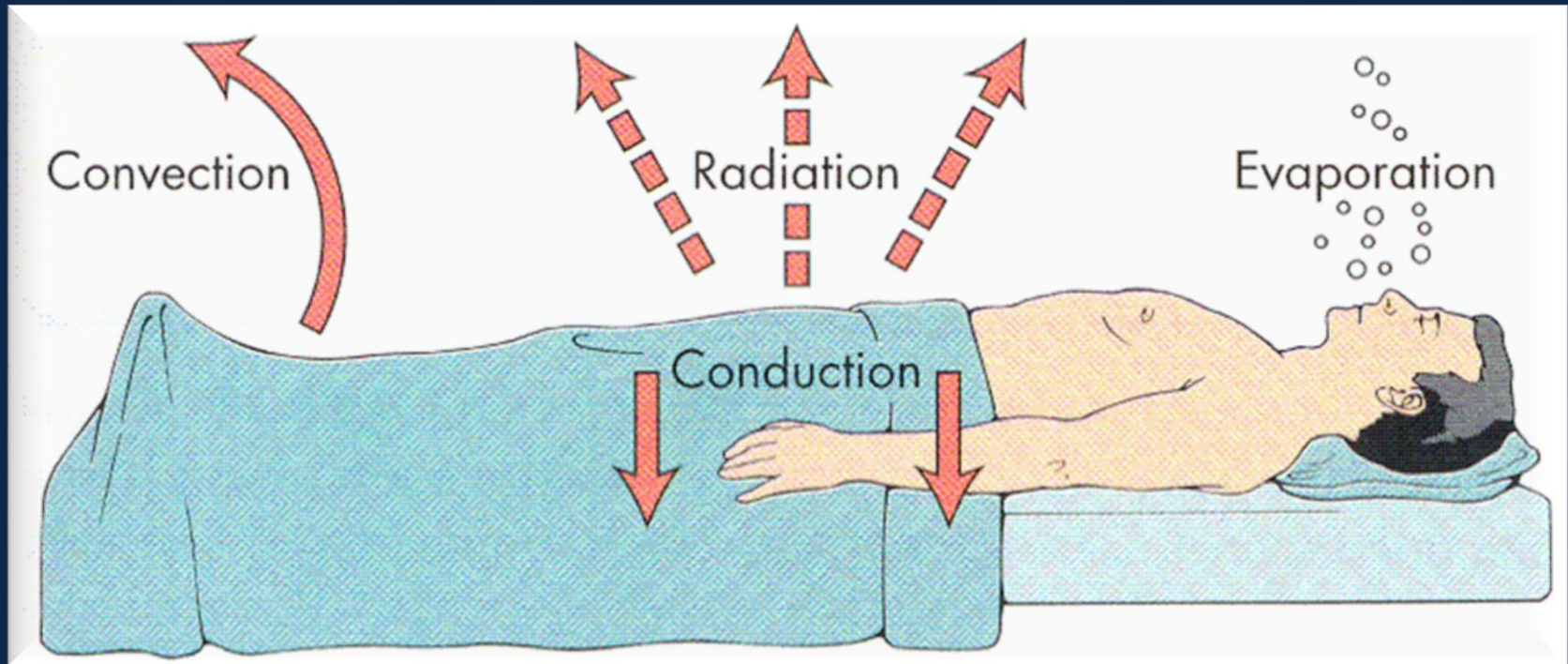
Hypothermia During Anesthesia



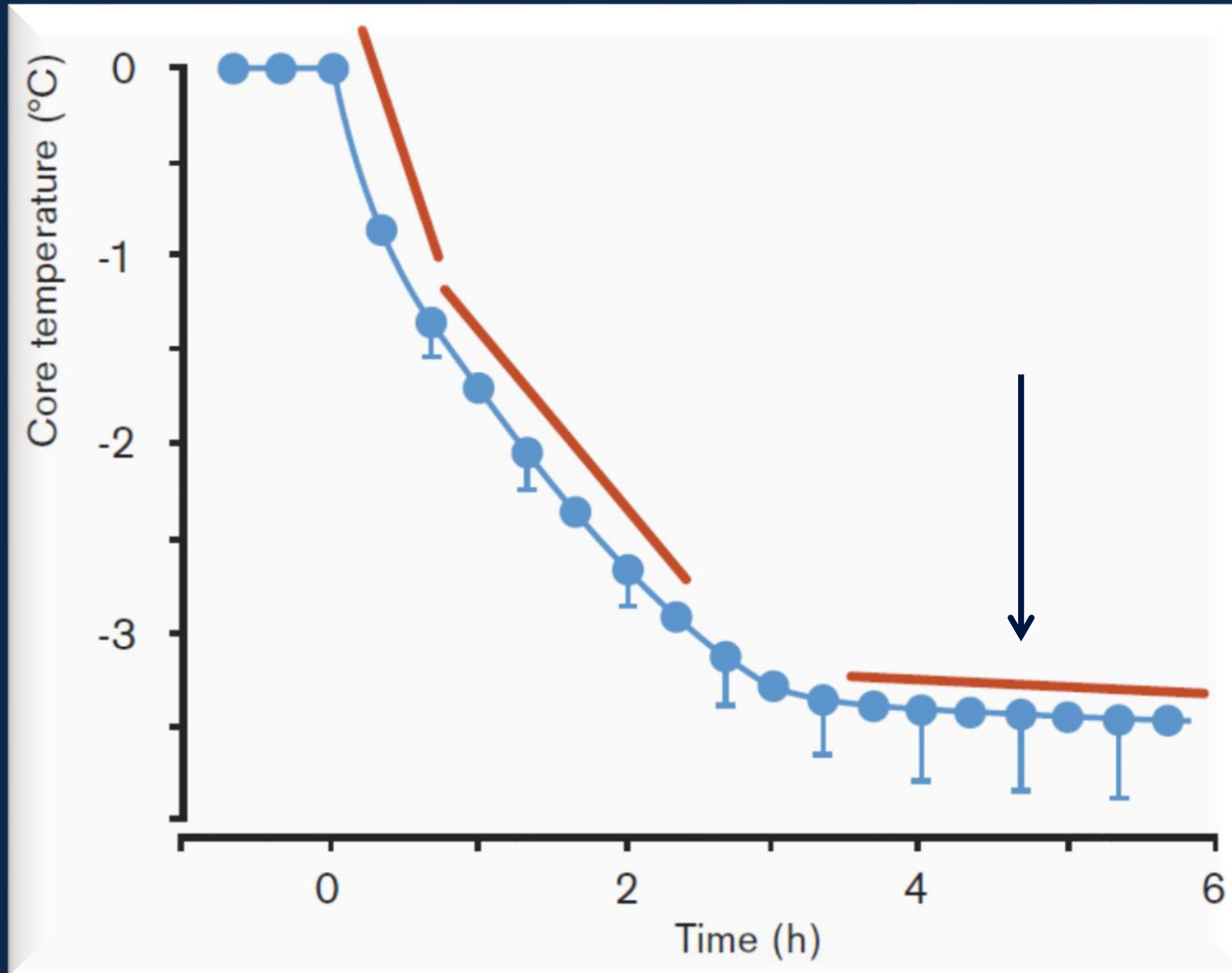
Redistribution Hypothermia



Intraoperative Heat Transfer



Hypothermia During Anesthesia

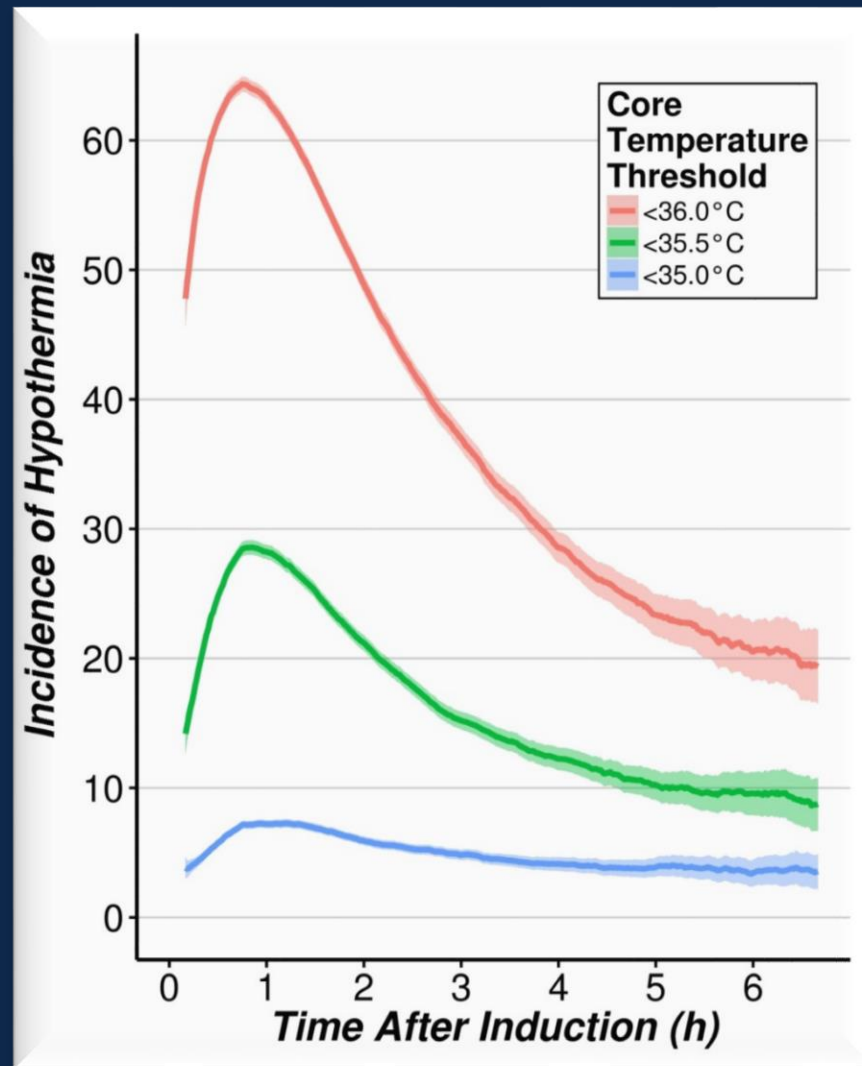


Perioperative Risk Factors for Hypothermia

- Extremes of ages
- Preoperative hypothermia
- Low preoperative blood pressure
- Thin body habitus
- Large body surface area exposure
- Preexisting conditions such as hypothyroidism, hypoglycemia, acute alcohol intoxication, malnourishment, burns, trauma
- Cold OR temperatures (<64° F)
- General or Regional anesthesia, highest with combined GA and RA
- Large blood loss (>30ml/kg)
- Anesthesia for >30 minutes
- Case longer than 2 hours
- Cold wound irrigants



Intraoperative Hypothermia is Common



Summary: General Anesthesia

Central thermoregulatory inhibition

- Little effect on warm defenses
- Dose-dependent increase in interthreshold range

Intraoperative hypothermia

- Redistribution of heat (initial decrease)
- loss exceeding heat production (slow linear decrease)
- Core-temperature plateau with sufficient hypothermia

Substantial and prolonged hypothermia common



Complications of Mild Hypothermia

Many!

Well documented

- Prospective randomized trials
- 1-2° C hypothermia

Effects on many different systems

- Most patients at risk for at least one complication



Surgical Site Infections

Common

- >500,000 surgical site infections per year in the States
- 1-3% incidence overall; ≈10% after colon surgery

Serious

- Increases hospital duration, Doubles ICU admission and mortality

Costly

- \$1.6 billion annually in the United States
- 3.7 million excess hospital days yearly in the States

Progression to infection determined by

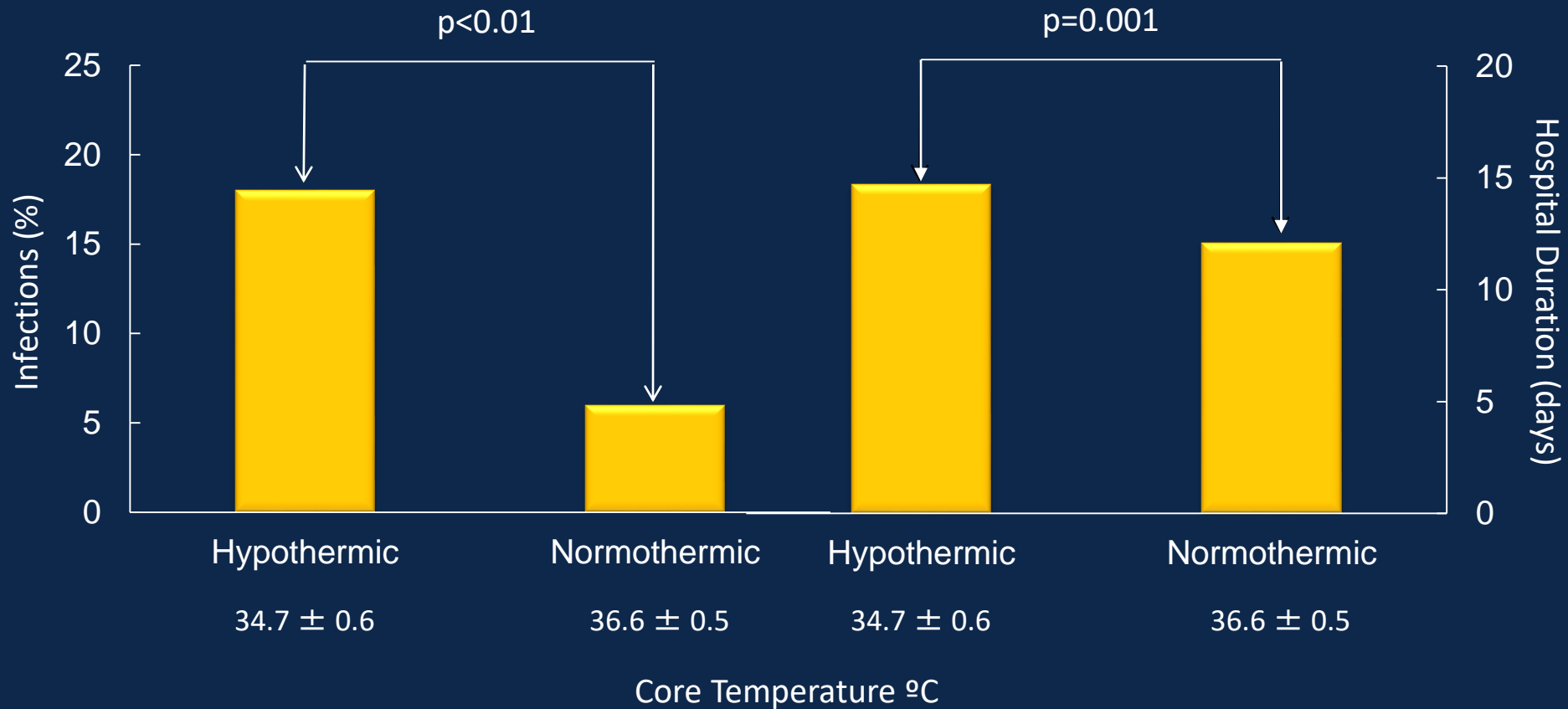
- Prophylactic antibiotics
- Host defense, bacterial killing

Primary determinants of tissue oxygen availability

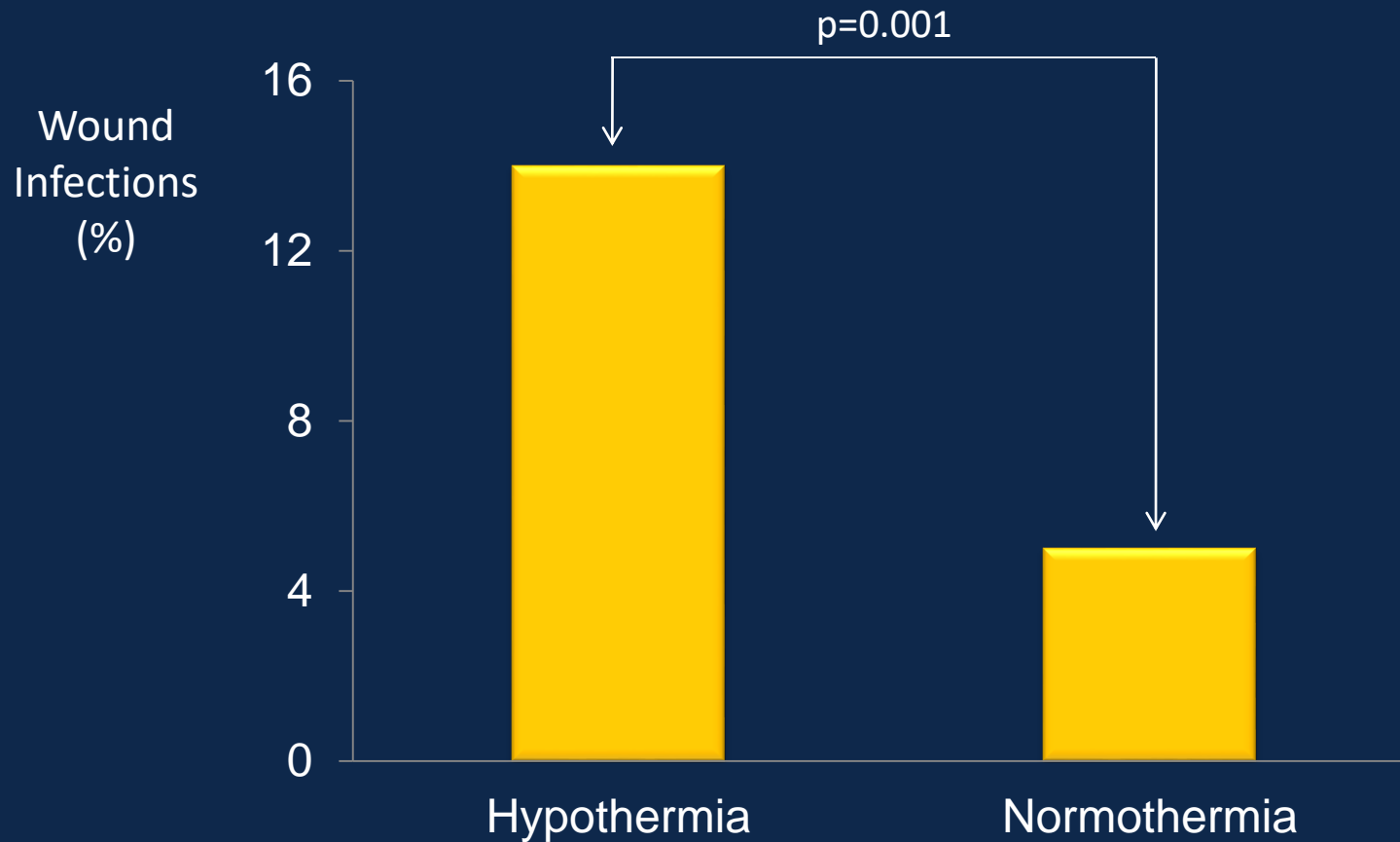
arterial oxygen tension, cardiac output, and local perfusion



Hypothermia & Wound Infection



Hypothermia Confirmation



Blood Transfusion

5 million US patients receive a blood transfusion per year

14.2 million units of packed red blood cells transfused per year

~ 40% of all transfused units administered by anesthesia personnel

Transfusion can save lives

- Appropriate triggers unknown

Associated with complications

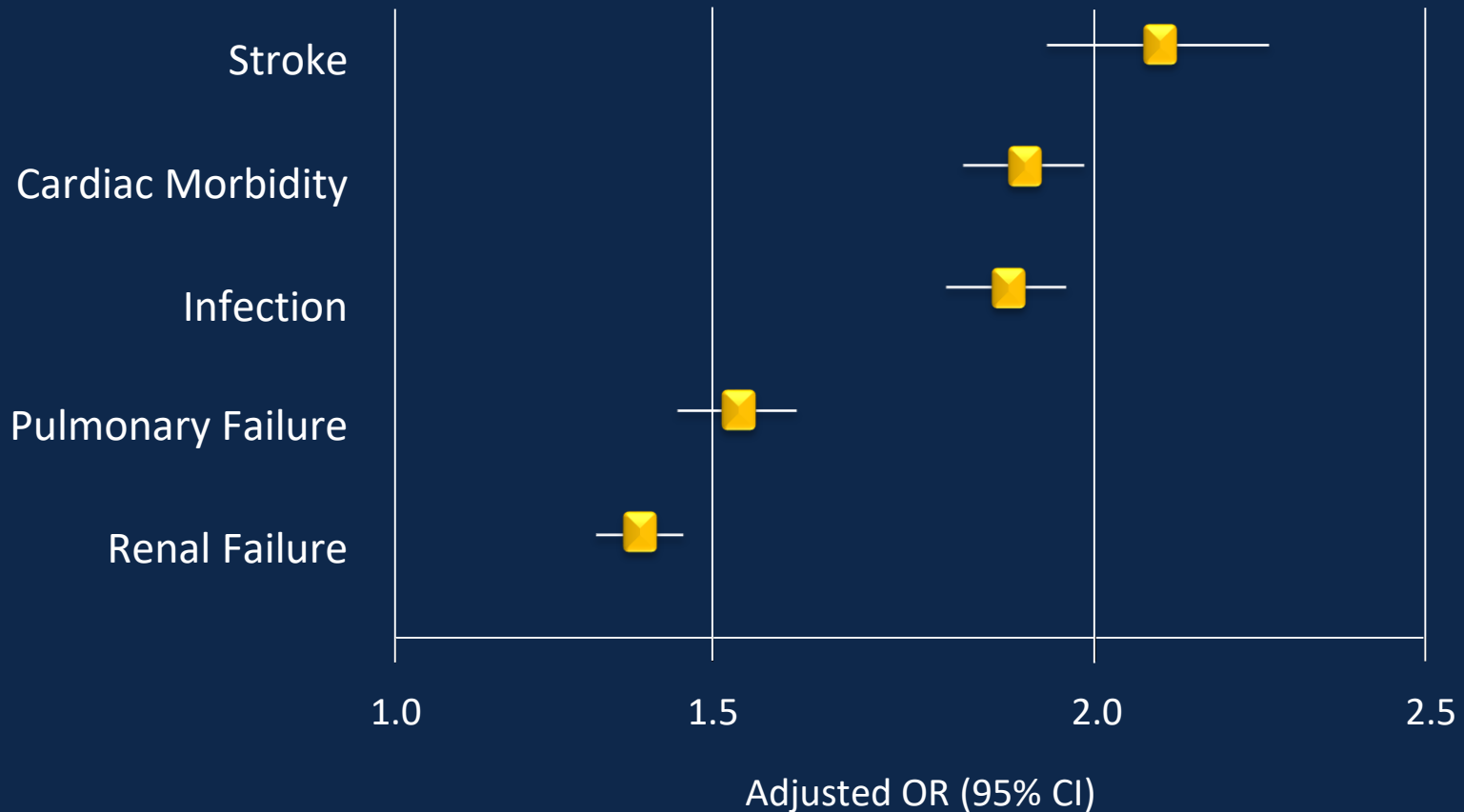
- Viral infection not major risk

Potential risk mechanisms

- Highly immunogenic
- Nitric oxide depletion



Transfusions Cause Complications

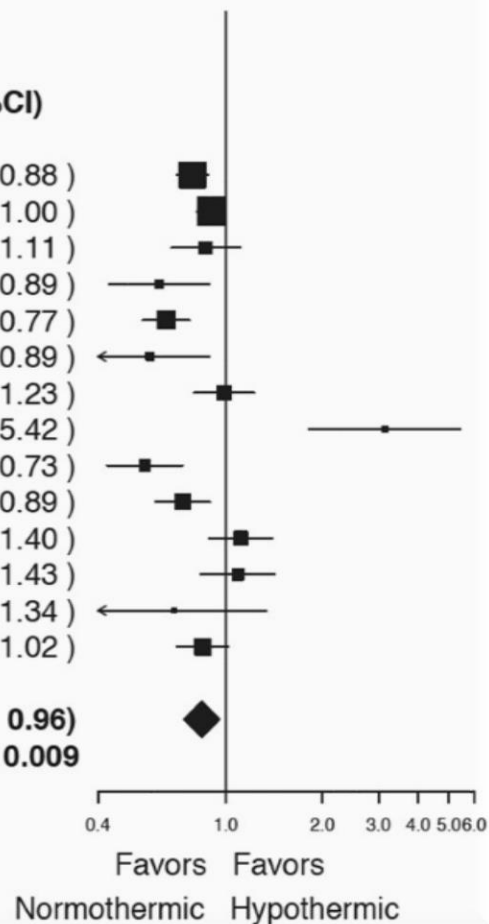


Hypothermia Increases Blood Loss

Study	Sample Size (N) N : H	Normothermic (N) mean (sd)	Hypothermic (H) mean (sd)	Outcome (N/H) mean (95%CI)
Schmied	30 : 30	1670 (320)	2150 (550)	0.79 (0.70 , 0.88)
Winkler	75 : 75	1531(1055,1746)	1678(1366,1965)	0.90 (0.82 , 1.00)
Widman	22 : 24	923 (410)	1068 (482)	0.87 (0.68 , 1.11)
Persson	29 : 30	186 (145)	308 (257)	0.62 (0.43 , 0.89)
Hofer	29 : 29	1497 (497)	2300 (788)	0.65 (0.55 , 0.77)
Bock	20 : 20	635 (507)	1070 (803)	0.58 (0.38 , 0.89)
Johansson	25 : 25	1047 (413)	1066 (441)	0.99 (0.80 , 1.23)
Smith	31 : 30	423 (562)	159 (268)	3.14 (1.82 , 5.42)
Frank	142 : 158	390 (834)	520 (754)	0.56 (0.43 , 0.73)
Mason	32 : 32	111 (40)	157 (73)	0.73 (0.60 , 0.89)
Casati	25 : 25	470 (170)	442 (216)	1.11 (0.89 , 1.40)
Murat	26 : 25	160 (61)	161 (100)	1.09 (0.84 , 1.43)
Hohn	43 : 73	660(230,1870)	956(340,5480)	0.69 (0.36 , 1.34)
Nathan	73 : 71	569 (356)	666 (405)	0.85 (0.70 , 1.02)

Summary

0.84 (0.74, 0.96)
Treatment effect P = 0.009



16% lower average blood loss in normothermic vs. hypothermic, p=0.009



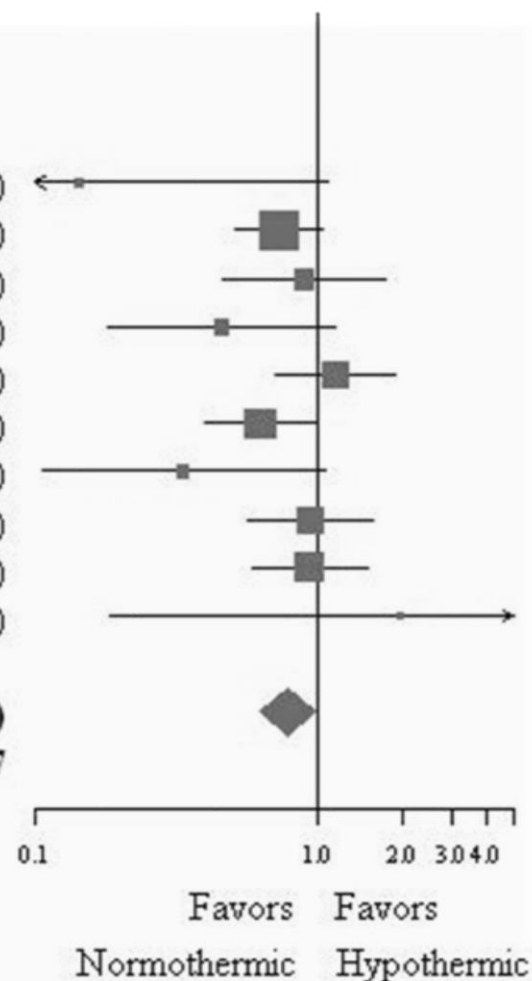
Transfusion Meta-Analysis

Study	Normothermic n/N (%)	Hypothermic n/N (%)	Outcome RR (95%CI)
Schmied	1/30 (3%)	7/30 (23%)	0.14 (0.02, 1.09)
Winkler	29/75 (39%)	40/75 (53%)	0.73 (0.51, 1.03)
Widman	9/22 (41%)	11/24 (46%)	0.89 (0.46, 1.73)
Hofer	5/29 (17%)	11/29 (38%)	0.45 (0.18, 1.14)
Johansson	15/25 (60%)	13/25 (52%)	1.15 (0.7, 1.89)
Kurz	23/104 (22%)	34/96 (35%)	0.62 (0.4, 0.98)
Bock	3/20 (15%)	9/20 (45%)	0.33 (0.11, 1.05)
Hohn	17/43 (40%)	18/43 (42%)	0.94 (0.57, 1.57)
Nathan	23/73 (32%)	24/71 (34%)	0.93 (0.58, 1.49)
Smith	2/31 (6%)	1/30 (3%)	1.94 (0.19, 20.24)

Summary

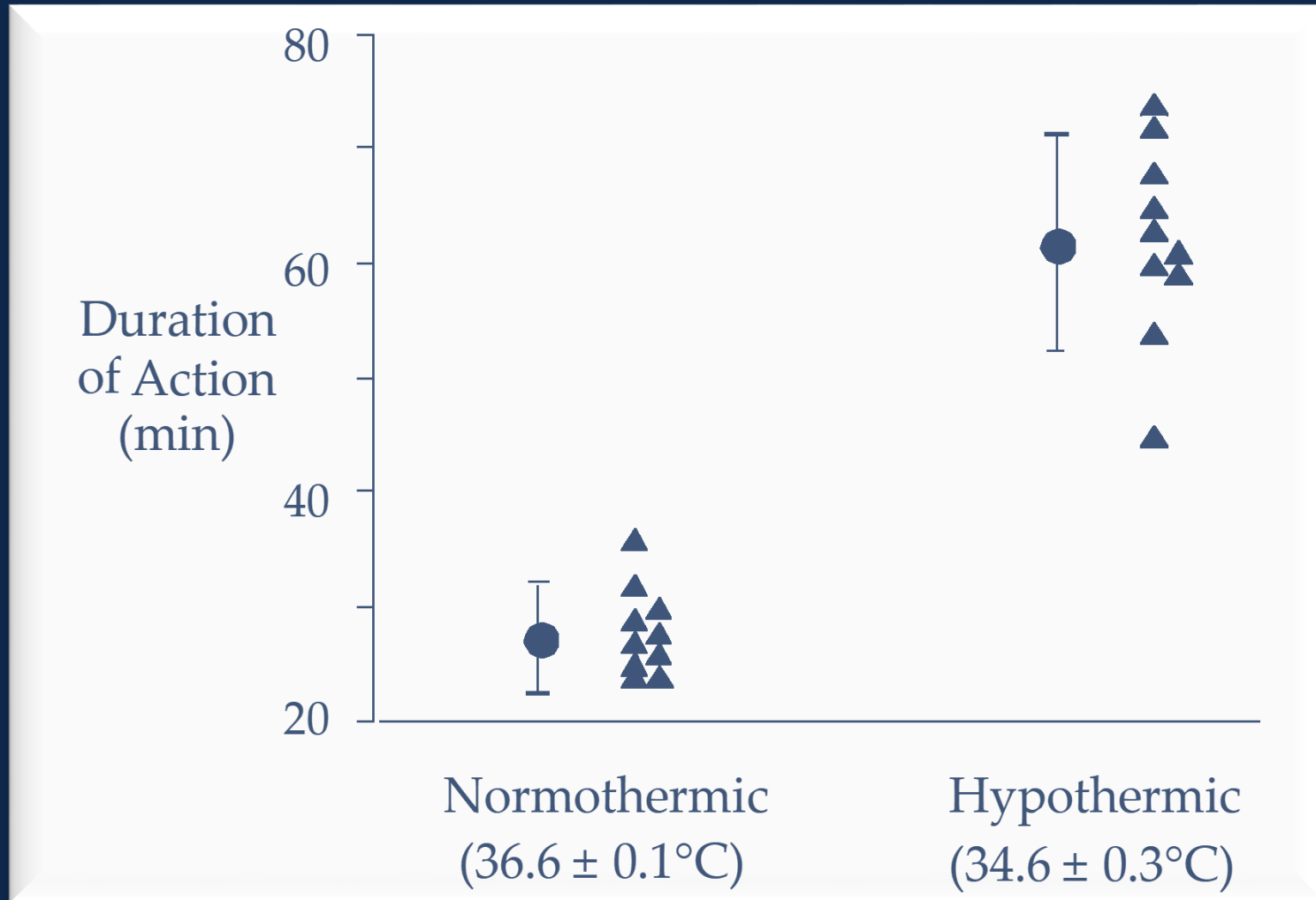
0.78 (0.63, 0.97)

Treatment effect P = 0.027



Normothermia is associated with 22% less risk of transfusion than hypothermia

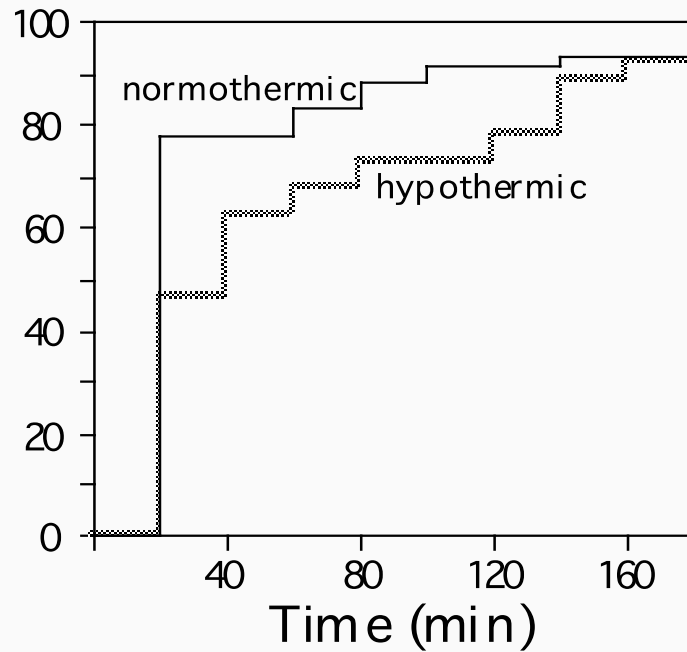
Duration of Vecuronium



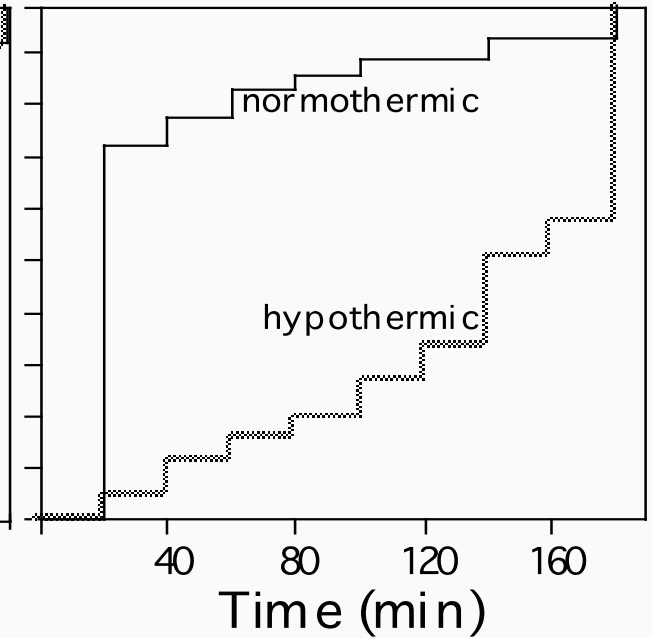
Hypothermia Prolongs Recovery

Discharge
From PACU
(%)

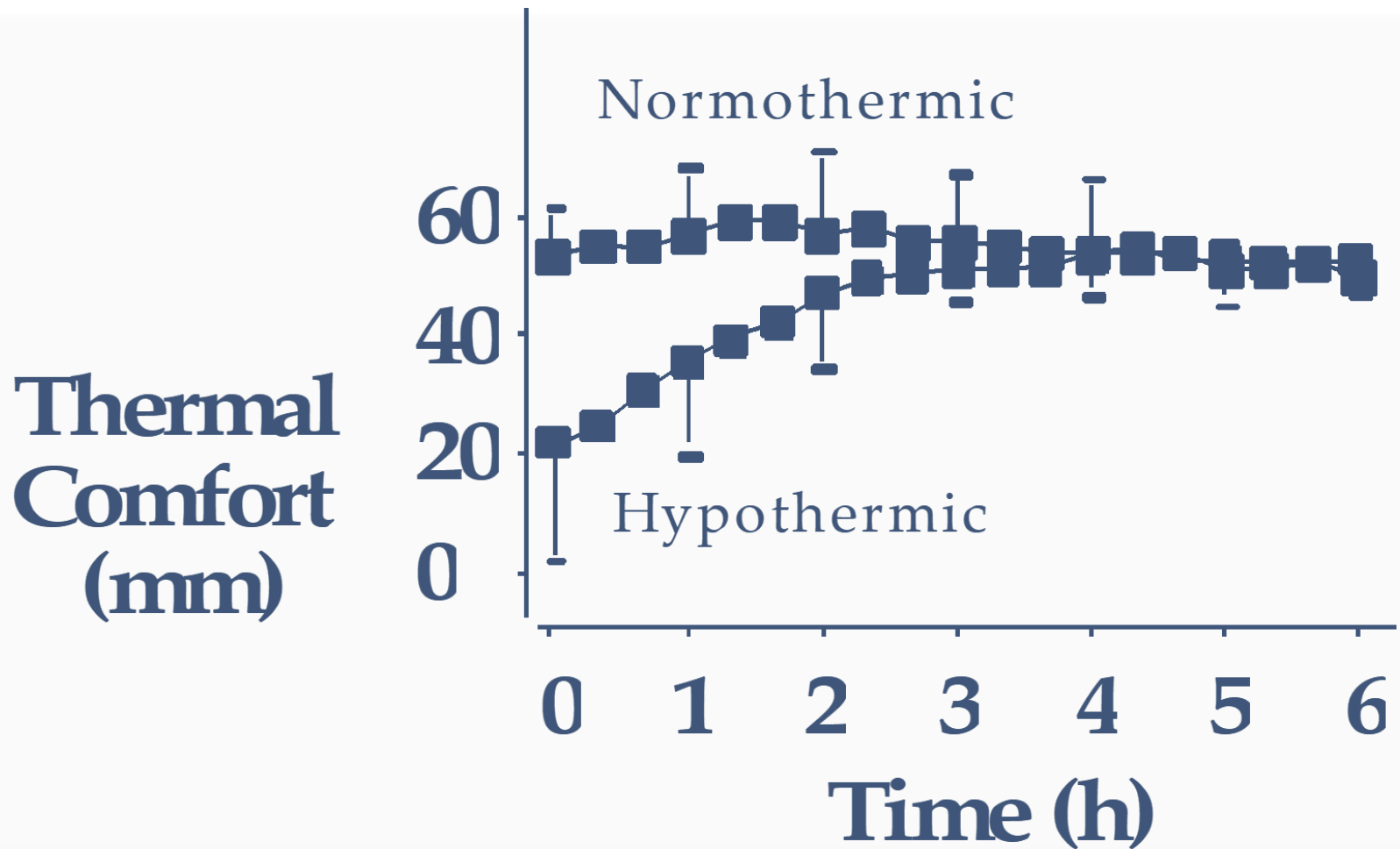
Fit For Discharge



Fit For Discharge
&
 $T_c \geq 36^\circ\text{C}$



Thermal Discomfort



Summary: Consequences of Hypothermia

Major complications

- Promotes *bleeding*
- Increases *transfusion requirement*
- Increases risk of *wound infections*
- *Prolongs hospitalization*

Other complications

- Decreased *drug metabolism*
- *Prolonged recovery* duration
- *Thermal discomfort*
- Increased *pain* sensation



What Now ?



Temperature Monitoring

Core Sites

- Pulmonary artery
- Distal esophagus
- Nasopharynx
- Tympanic membrane thermocouple

Other generally-reliable sites

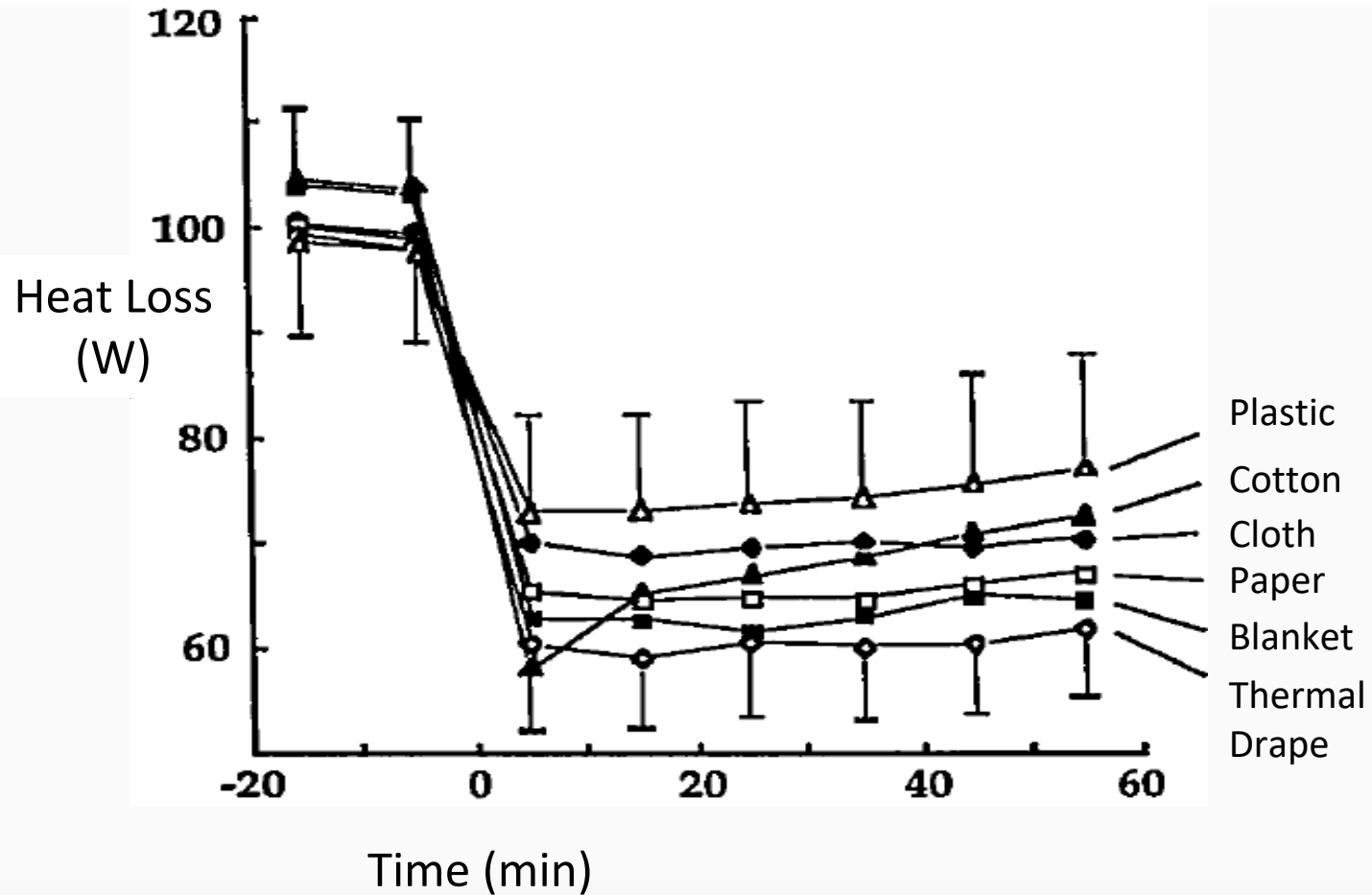
- Mouth
- Axilla
- Bladder

Sub-optimal

- Forehead skin
- Infrared “tympanic”
- Infrared “temporal artery”
- Rectal



Insulating Covers

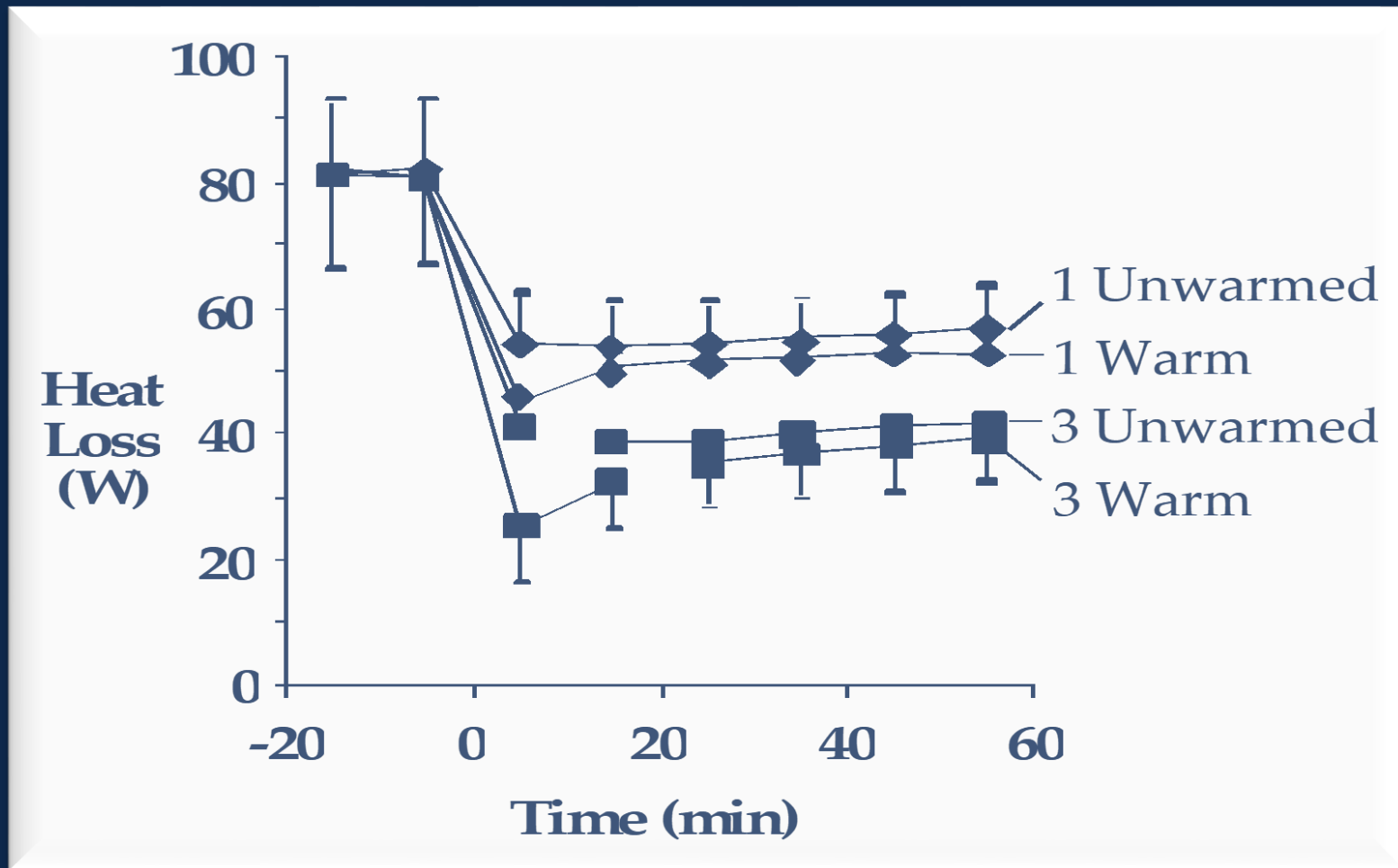


Cotton Blankets

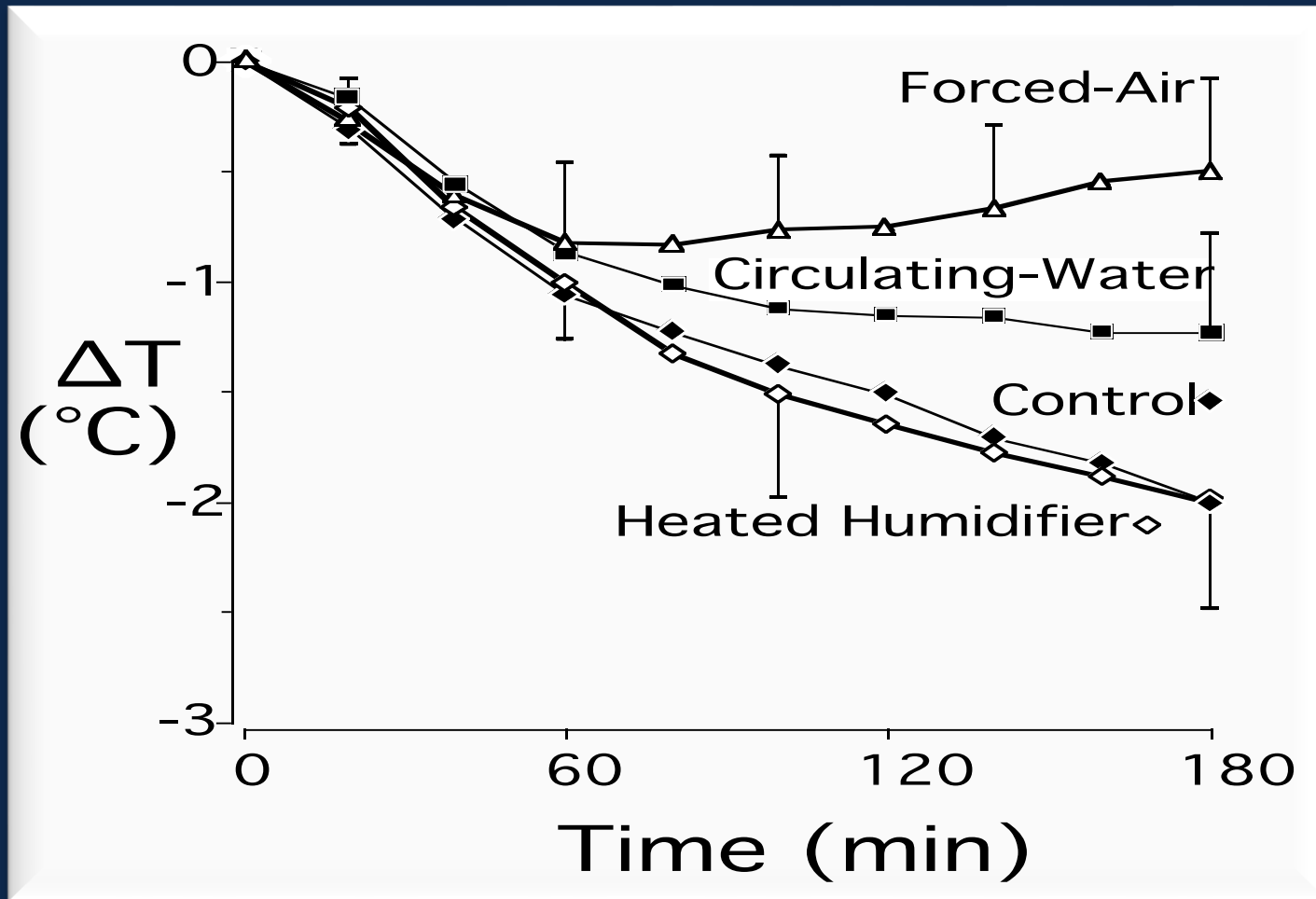
- Patients prefer the warmed ones.
- Heat contained in the warmed blankets is likely to dissipate rapidly to the environment.
- Warmed blankets reduced heat loss more than unwarmed ones, but the benefit dissipated in approximately 10 minutes.
- Rapid dissipation of the heat in warmed cotton blankets is due to the fact that the heat capacity of cotton is low.
- Even when blankets are replaced with freshly warmed ones at 10-min intervals cutaneous heat loss remains high compared with the best active warming systems.



More Layers Do Not Help Much



Active Warming Comparison



Fluid Warming

Cooling by intravenous fluids

- 0.25° C per liter crystalloid at ambient temperature
- 0.25° C per unit of blood from refrigerator

Cooling prevented by warming solutions

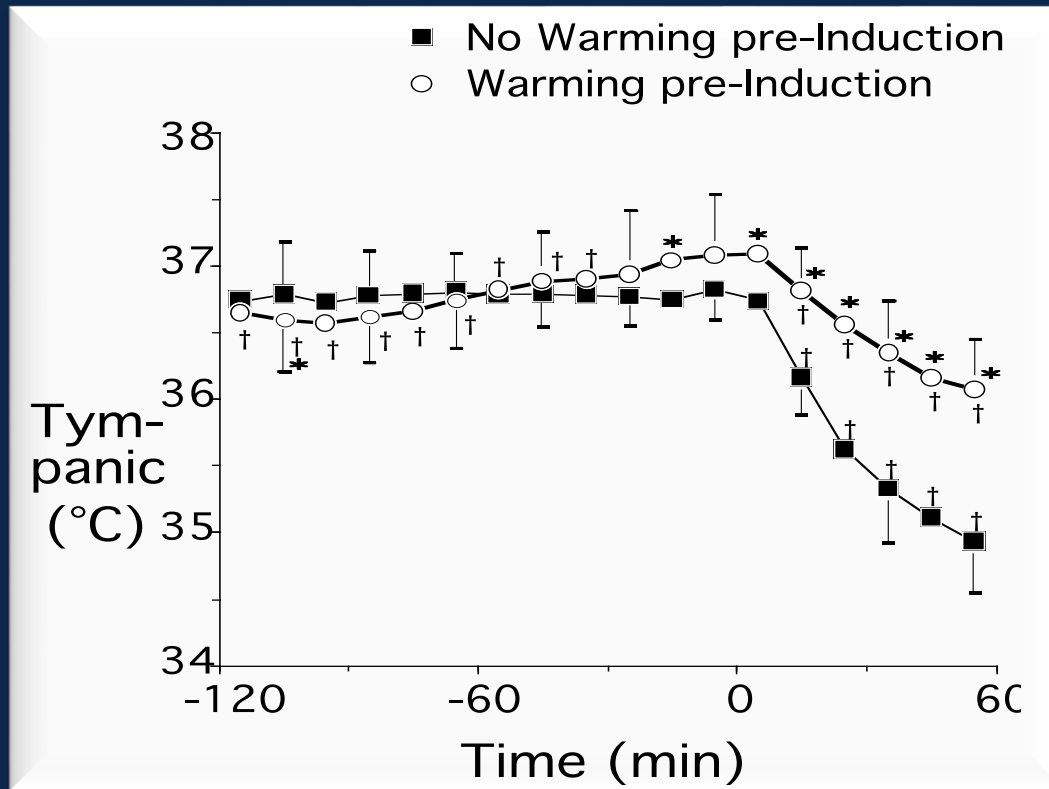
- Type of warmer usually less important
- Use high-flow systems for major trauma

Fluid warming does not prevent hypothermia!

- Most core cooling from redistribution
- 80% of heat loss is from anterior skin surface



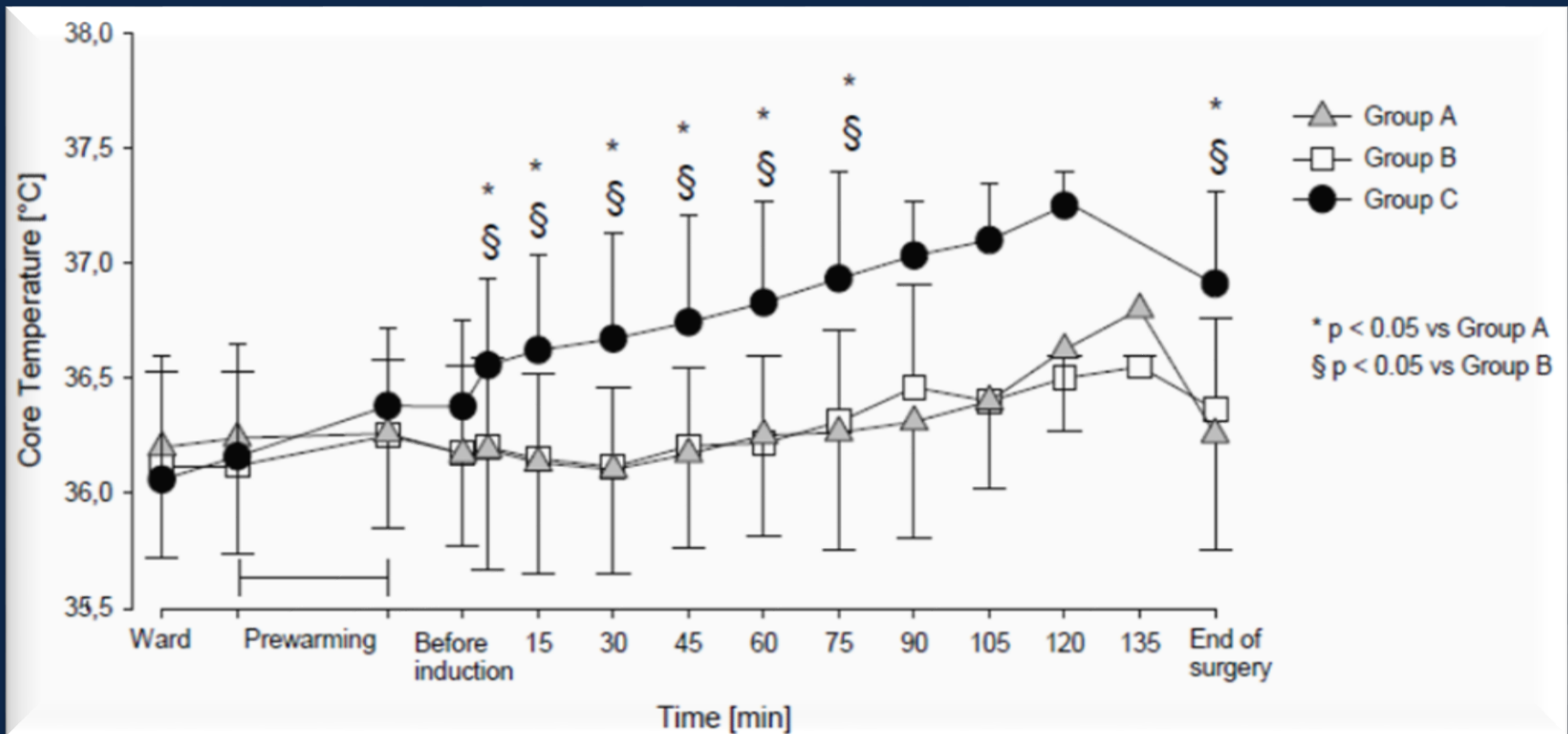
Pre-Warming Prevents Hypothermia



Short procedures

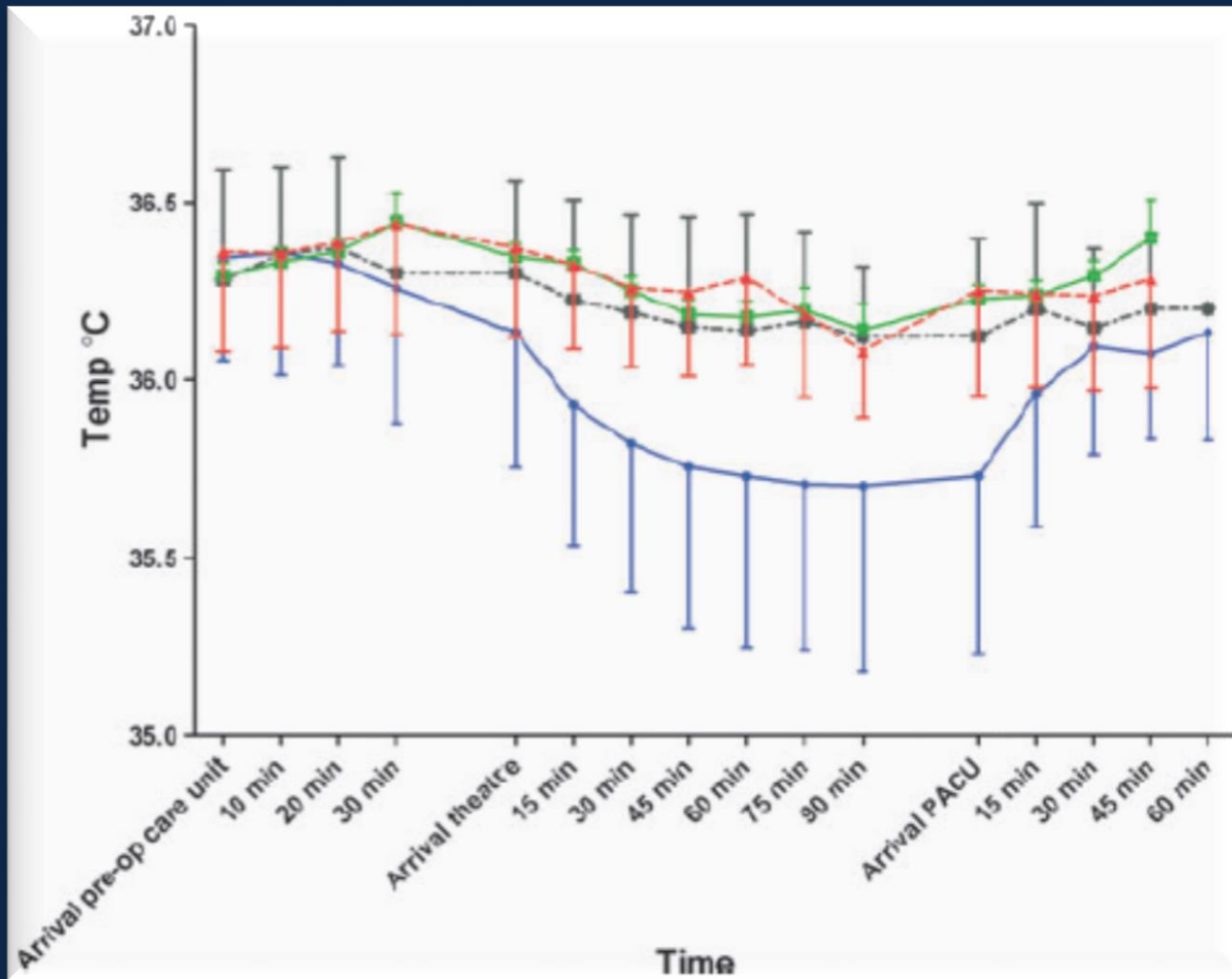
Complete avoidance of hypothermia

Prewarming & Hypothermia



Mean pre- and intraoperative temperatures of the control group A (Δ), the passive prewarming group B (\square) and the active prewarming group C (\bullet).

Duration of Prewarming



- No Prewarming
- 10 min Prewarming
- 20 min Prewarming
- 30 min Prewarming



Surgical Care Improvement Project (SCIP)

Patients included (denominator)

- Surgical procedure
- General or neuraxial anesthesia ≥ 60 minutes
- Not having documented intentional hypothermia

Criteria (numerator)

- Active over-body intraoperative warming, or
- Core temp $\geq 36^{\circ}$ C within 30 min before anesth end time, or
- Core temp $\geq 36^{\circ}$ C within 15 min after anesth end time

Comments

- A similar “pay-for-reporting” measure coming
- “Core temperature” sites and devices undefined



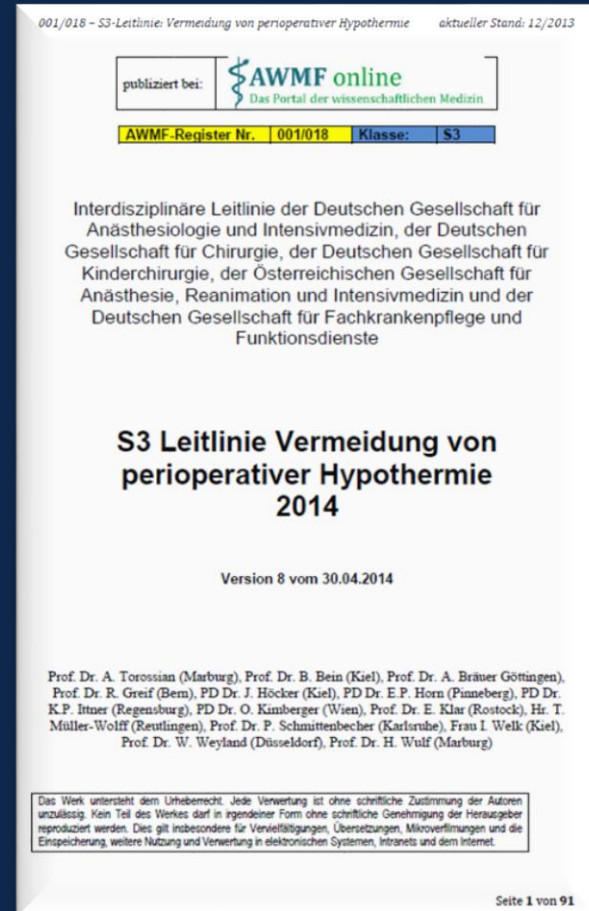
NICE Guidelines (UK)

- Temperature measured and documented before induction of anesthesia and every 30 minutes until end of surgery
- Warm intravenous fluids (>500 ml) and blood products to 37° C
- Warm patients at high risk of inadvertent perioperative hypothermia having anesthesia for < 30 minutes intraoperatively with forced air
- Warm patients having anaesthesia for longer than 30 minutes intraoperatively with forced air



S3 Guideline

- Active warming if anesthesia duration >30 min.
- Intraoperative Fluid warming if >500ml/h
- Pre-warming for patients scheduled for general anesthesia
- Convective warming for ca. 20 min (mind. 10 min.)
- Patients should be prewarmed before neuraxial anesthesia



ASPIRE an MPOG Quality Initiative

TEMP 01: Active Warming

Percentage of cases with increased risk of hypothermia that active warming was administered by the anesthesia provider

TEMP 02: Core Temperature Measurement

Percentage of cases with increased risk of hypothermia that the anesthesia provider documented a core or near-core temperature

TEMP 03 (MIPS 424): Perioperative Temperature Management

Percentage of patients, regardless of age, who undergo surgical or therapeutic procedures under general or neuraxial anesthesia of 60 minutes duration or longer for whom at least one body temperature greater than or equal to 35.5 degrees Celsius (or 95.9 degrees Fahrenheit) was recorded within the 30 minutes immediately before or the 15 minutes immediately after anesthesia end time

Summary

- Normal body temperature is 36.5-37.5° C
 - Temperatures less than 36° C considered hypothermia
- All patients become hypothermic
 - Redistribution hypothermia
 - Metabolic heat loss during surgery
 - Hypothermia depends on type and dose of anesthetic
- Consequences of hypothermia
 - Pharmacokinetics and dynamics of drugs
 - Increased blood loss and transfusion requirement
 - Increased incidence of adverse myocardial events
 - Increased duration of recovery
 - Increased duration of hospitalization



Summary

- Temperature monitoring
 - GA: esophageal, nasopharynx
 - RA: Zero-heat flux, bladder
- Warming: Active warming
 - Convective, conductive and internal heating
 - Pre-warming
- Also helpful with large fluid amounts
 - Fluid warming
- Recommendations and Guidelines
 - Measure core body temperature in patients given anesthesia for more than 30 minutes
 - Maintain intra-operative core temperature $>36^{\circ}\text{C}$



The Rule: Monitor and Warm

Monitor core temperature

- General anesthesia >30 minutes
- Large procedures under neuraxial anesthesia

Maintain normothermia: core temp $\geq 36^{\circ}$ C

Forced-air heating

- Best combination of efficacy, cost, and safety
- But any method(s) okay





Thank you very much!

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