Pathophysiology and Management of Decrease in Body Temperature During Surgical Procedures

Essay

Submitted for partial fulfillment of
Master Degree in Anesthesia

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2012

بسم الله الرحمن الرحيم

قَالُوا سُبْحَانَكَ لاَ عِلْمَ لَنَا إِلاَّ مَا عَلَّمْتَنَا إِنَّكَ أَنتَ الْعَلِيمُ الْحَكِيمُ

صدق الله العظيم

سورة البقرة آية (٣٢)

Acknowledgement

First and foremost, thanks to ***Allah*** *for giving me the will and the patience to finish this work.*

In a few grateful words, I would like to express my deepest gratitude and appreciation to ***Prof. Dr. Madiha Metwaly Zidan*** *Professor of Anesthesia and Intensive Care, Faculty of Medicine-Ain Shams University, for her great concern and generous help .Without her generous help, this work would not have been accomplished in its present picture.*

I am sincerely grateful to ***Dr. Noha Sayed Hussein*** *Lecturer of Anesthesia and Intensive Care, Faculty of medicine, Ain Shams University, for her kind help and constructive suggestions to achieve this work.*

I would also like to express my deep appreciation to ***Dr. Assem Adel Moharram*** *Lecturer of Anesthesia and Intensive Care, Faculty of Medicine-Ain Shams University, for his great kindness, constant assistance and guidance.*

Lastly, there are no words to express my gratitude to my family who charged me with love and encouragement.

Ahmed Abdelrahman Mohamed

Contents

List of Abbreviations

ACTH	:	Adrenocorticotropic hormones
ALP	:	Alanine aminotransferase
ASA	:	American society of Anesthiologists
AST	:	Aspartate aminotransferase
ATP	:	Adenosine triphosphate
Bpm	:	Beat per minute
CBF	:	Cerebral blood flow
CMR	:	Cerebral metabolic rate
CPB	:	Cardiopulmonary bypass
HAIs	:	Hospital acquired infections
ICP	:	Intra cranial pressure
ICU	:	Intensive care unit
L	:	Liters
NST	:	Non shivering thermogenesis
OR	:	Operating room
SSI	:	Surgical site infections
T	:	Temperature
TBI	:	Traumatic brain injury
TH	:	Therapeutic hypothermia
tPA	:	Tissue plasminogen activators
TSH	:	Thyroid stimulating hormone

List of tables

List of Figures

Introduction

Hypothermia is defined as the intentional or accidental reduction of core body temperature to below 35°C. **(Kenley, 1999)**.

Of the many classifications of hypothermia, it can be classified as mild, moderate and severe. Yet there is some disagreement (by one or two degrees) as to where the boundaries lie between the three stages. Generally, the categories are defined as follows. Mild: around 31-35°C; Moderate: approximately 29-31°C; and Severe: anything below 29°C. **(Epstein E and Anna K, 2006)**.

Inadvertent hypothermia is one of the most commonly and frequently reported complications in surgical patients **(Surkitt-Parr, 1992)**. Research into this subject matter clearly indicated that as early as 1880 hypothermia was a major concern for patients **(Surkitt-Parr, 1992)**. Since it has been estimated that seven tenths of all surgical patients experience it to some extent. **(Bellamy, 2007)**.

Body temperature is balanced by heat loss and heat production, thus maintaining normothermia between 35.6°C to 37.8°C **(Marieb, 2004)**. Although other brain regions contribute, the hypothalamus, which consists of a heat promoting and heat loss centre, is the brain's thermoregulatory centre **(Marieb, 2004)**.

Heat is lost mainly from the skin, but also from expired air, faeces and urine. Air passing over exposed parts of the body becomes heated and therefore rises, cool air then replaces it and convection currents are established. Exposed skin radiates heat away from the body and anything touching the skin will conduct the heat away from the body **(Waugh and Grant, 2001)**. Radiation is the largest contributor to heat loss as 60% of body heat is lost by infra-red heat waves **(Radford**

et al., 2004). Evaporation occurs through sweating and exposed tissues **(Waugh and Grant, 2001).**

Hypothermia produces numerous adverse effects and Consequences on the body which include altered cardiac performance, coagulopathy, altered action of commonly used anesthetic medications, increased incidence of wound infection, delayed emergence from anesthesia and increased rate of mortality **(Tander et al., 2005).**

Intentional hypothermia is used in medicine in both regional and total-body cooling. Total-body hypothermia slows the metabolic rate, protecting organs from reduced oxygen supply during the interruption of blood flow necessary in certain surgical procedures. **(Martinez, 1998)**.

The use of therapeutic hypothermia for a variety of therapeutic purposes has a long and erratic history. Ancient Egyptian treated high fevers; Hippocrates recommended the use of topical cooling to stop bleeding. It wasn't until 1950s, when the effects of hypothermia on systemic oxygen metabolism become better defined, that Systemic hypothermia becomes a commonly used modality particularly for cardiothoracic and neurological surgeries. **(Mackensen et al., 2009).**

Aim of the Work

This essay describes the stages, adverse effects, prevention and management of inadvertent hypothermia. The value and methods of intentional hypothermia will be also discussed.

Physiology of Thermoregulation

Human body is able to regulate internal body temperature within a narrow range near 37°C, despite wide variations in environmental temperature. The range of temperatures that living cells and tissues can tolerate without harm extends from just above freezing to nearly 45°c. (***Witzmann, 2009)***.

Tissue temperature is important for two reasons: First, temperature extremes injure tissue directly. High temperatures alter the three-dimensional structure of protein molecules, even though the sequence of amino acids is unchanged. Such alteration of protein structure is called denaturation. A familiar example of denaturation by heat is the coagulation of albumin in the white of a cooked egg. Because the biological activity of a protein molecule depends on its configuration and charge distribution, denaturation inactivates a cell's proteins and injures or kills the cell. Injury occurs at tissue temperatures higher than about 45°C, which is also the point at which heating the skin becomes painful. The severity of injury depends on the temperature to which the tissue is heated and its duration. Cold also can injure tissues. As a water-based solution freezes, ice crystals consisting of pure water form, so that all dissolved substances in the solution are left in the unfrozen liquid. Therefore, as more ice forms, the remaining liquid becomes more and more concentrated. Freezing damages cells as ice crystals mechanically injure the cell. The increase in solute concentration of the cytoplasm as ice forms denatures the proteins by removing their water of hydration, increasing the ionic strength of the cytoplasm and causing other changes in the physicochemical environment in the cytoplasm. ***(Rodney and David, 2012)***

Second, temperature changes profoundly alter biological function through specific effects on such specialized functions as electrochemical properties and fluidity of cell membranes and through a general effect on most chemical reaction rates. In the physiological temperature range, most reaction rates vary approximately as an exponential function of temperature (T); increasing T by 10°C increases the reaction rate by a factor of two to three. For any particular reaction, the ratio of the rates at two temperatures 10°C apart is called the Q_{10} for that reaction, and the effect of temperature on reaction rate is called the Q_{10} effect. The notion of Q_{10} may be generalized to apply to a group of reactions that have some measurable overall effect (such as O_2 consumption) in common and are, thus, thought of as comprising a physiological process. The Q_{10} effect is clinically important in managing patients who have high fevers and are receiving fluid and nutrition intravenously. A commonly used rule is that a patient's fluid and calorie needs are increased 13% above normal for each 1°C of fever. ***(Rodney and David, 2012)***

Body Temperature and Heat Transfer

The body is divided into a warm internal core and a cooler outer shell. Because the environment greatly influences the temperature of the shell, its temperature is not regulated within narrow limits as is the internal body temperature. This is true despite the thermoregulatory responses that strongly affect the temperature of the shell, especially its outermost layer, the skin. The thickness of the shell depends on the thermal environment and the body's need to conserve heat. In a warm environment, the shell may be less than 1 cm thick, but in a subject conserving heat in a cold environment, it may extend several centimeters below the skin. The regulated internal body temperature is the temperature of the vital organs inside the head and trunk which, together with a variable amount of other tissue, comprise the warm internal core. ***(Rodney and David, 2012)***

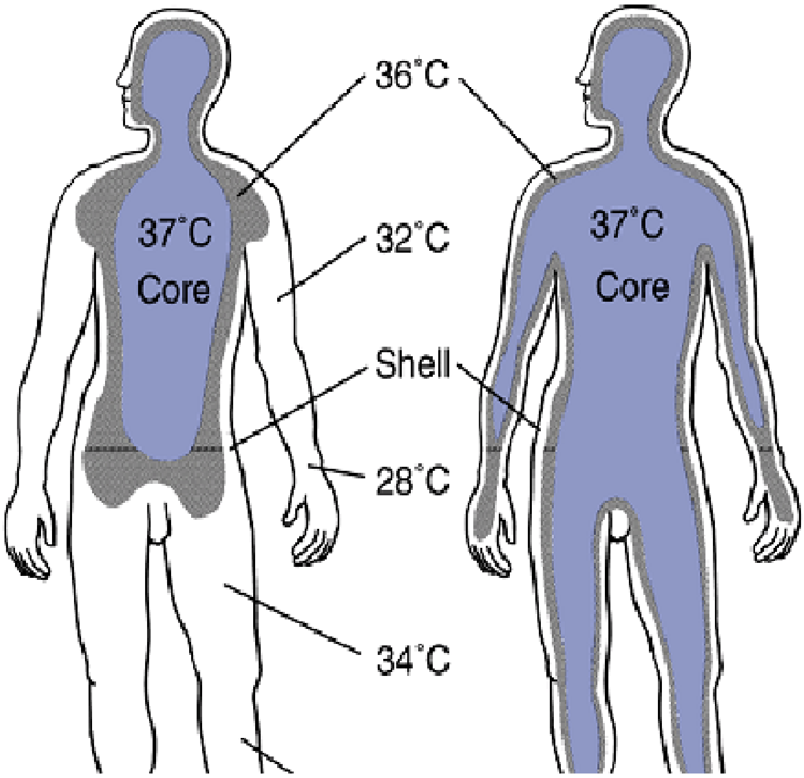

Fig.(1): Distribution of temperatures in the body's core and shell ***(Rodney and David, 2012***)

Heat is produced in all tissues of the body but is lost to the environment only from tissues in contact with the environment predominantly from the skin and, to a lesser degree, from the respiratory tract. We, therefore, need to consider heat transfer within the body, especially heat transfer (1) from major sites of heat production to the rest of the body and (2) from the core to the skin. Heat is transported within the body by two means: conduction through the tissues and convection by the blood, a process in which flowing blood carries heat from warmer tissues to cooler tissues ***(Rodney and David, 2012).***

Heat flow by conduction varies directly with the thermal conductivity of the tissues, the change in temperature over the distance the heat travels, and the area (perpendicular to the direction of heat flow) through which the heat flows. It varies inversely with the distance the heat must travel. The tissues are rather poor heat conductors. Heat flow by convection depends on the rate of blood flow and the temperature difference between the tissue and the blood supply. Because the vessels of the microvasculature have thin walls and, collectively, a large total surface area, the blood temperature equilibrates with that of the surrounding tissue before it reaches the capillaries. Changes in skin blood flow in a cool environment change the thickness of the shell. When skin blood flow is reduced in a cold environment, the affected skin becomes cooler and the underlying tissues which in the cold may include most of the limbs and the more superficial muscles of the neck and trunk become cooler as they lose heat by conduction to the cool overlying skin and, ultimately, to the environment. In this way, these underlying tissues, which in a hot environment were part of the body core, now become part of the shell. In addition to organs in the trunk and head, the core includes a greater or lesser amount of more superficial tissue mostly skeletal muscle depending on the body's thermal state. (***Witzmann, 2009)***

Because the shell lies between the core and the environment, all heat leaving the body core, except that which is lost through the respiratory tract, must pass through the shell before being lost to the environment. Thus, the shell insulates the core from the environment. In a cool subject, the skin blood flow is low, so conduction dominates core-to-skin heat transfer; the shell is also thicker, providing more insulation to the core, because heat flow by conduction varies inversely with the distance the heat must travel. Changes in skin blood flow, which directly affect core-to-skin heat transfer by convection, also indirectly affect core-to-skin heat transfer by conduction by changing the thickness of the shell. ***(Rodney and David, 2012)***

In a cool subject, the subcutaneous fat layer contributes to the insulation value of the shell because the fat layer increases the thickness of the shell and because fat has conductivity about 0.4 times that of dermis or muscle. Thus, fat is a correspondingly better insulator. In a warm subject, however, the shell is relatively thin and provides little insulation. Furthermore, a warm subject's skin blood flow is high, so convection dominates heat flow from the core to the skin. In these circumstances, the subcutaneous fat layer, which affects conduction but not convection, has little effect on heat flow from the core to the skin. ***(Chandra and Baumgart, 2005)***

Basic concepts

Core temperature

The body core consists of the essential organs: brain, heart, lungs, liver and kidneys. These organs are maintained at an almost uniform temperature. Core temperature is measured by temperature sensitive neurons in the great veins, spinal cord, abdominal viscera and the hypothalamus. Peripheral thermoreceptors (free nerve endings) are found mainly on the body surface; there are ten times more cold-sensitive nerve endings than heat-sensitive nerve endings. ***(Dan et al., 2011)***

Normal temperature

Normal body temperature is 37°C (±0.5°C). There is a diurnal variation of core temperature within individuals of a similar magnitude; in women, there is also a monthly variation because core temperature rises around the time of ovulation. Temperature rises with increasing physical activity. ***(Dan et al., 2011).***