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Guidelines of the Polish Society of Anaesthesiology and Intensive Therapy regarding prevention of inadvertent intraoperative hypothermia

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RATIONALE BEHIND AND EXTENT OF THE ISSUE

Core body temperature is strictly regulated (± 0.2 °C) and coordinated at the level of central nervous system located in the hypothalamus via several protective effector mechanisms that prevent overcooling and overheating. The central regulation permits both circadian and monthly variations of even 1°C; under normal conditions, however, the activation of effective protective mechanisms prevents even the slightest overcooling and core temperature elevation at any moment of the day.

Anaesthesia (both general and block) limits the protective capacities of the body in this regard, increasing the range of temperatures accepted by the thermoregulation centre from several tenths to even several degrees Celsius, which is one of the factors favouring intraoperative hypothermia. The peripheral vasodilation, caused either by the direct effects of general anaesthetics or sympathetic nerve blocks, is responsible for the initial rapid decrease in core temperature. The higher rate of heat loss, as compared to heat production further reduces the thermal reserves of the body during the next hours of surgery, which results in a decrease in core temperature even by 2–3°C. The above changes can lead to coagulation disorders, higher risk of perioperative transfusions, increased incidence of surgical site infections resulting in longer hospital stays and higher costs of hospitalisation [1]. Intraoperative hypothermia is defined as the drop in core temperature below 36°C at any point of anaesthesia.

The temperature measurements during both general anaesthesia and nerve blocks are an essential element of intraoperative monitoring to detect, treat and prevent this most common anaesthesia-associated complication [2].

The epidemiological data from Europe and Australia regarding the incidence of inadvertent intraoperative hypothermia (IIH) and intraoperative monitoring indicate the need of recapitulating the available scientific reports and transforming them into clinical recommendations, whose implementation should improve the quality of perioperative care in Poland [3, 4]. The provision of thermal comfort to patients is a crucial element of perioperative management contained in the enhanced recovery after surgery (ERAS) protocol [5].

METHODOLOGY FOR PREPARATION OF GUIDELINES. STRENGTH OF RECOMMENDATIONS AND LEVELS OF EVIDENCE

To find the most relevant and recent literature reports, the authors searched several medical databases (PubMed, Cochrane Library, Elsevier ClinicalKey, Web of Knowledge) using the key words they conjointly defined. Out of several thousand results found, the authors selected those relevant for individual parts of the present document, prioritising systematic reviews of the randomised trials. Eleven meta-analyses and systematic reviews were identified, which directly regard the issues of intraoperative hypothermia.

Moreover, the measures were taken to identify the recommendations regarding intraoperative hypothermia already published by national and international organisations; the references of the available publications were analysed, and the above-mentioned databases and Internet were manually searched. Several publications containing recommendations were found, which were issued by governmental institutions and national scientific

TABLE 1. The current scale of the strength of recommendations

Authors's opinion on favourable – unfavourable outcome balance of a particular intervention	Level of evidence	Strength of recommen-dation	Strength of recommendation – practical implications
One of the management options clearly dominates (1)	The decision based on reliable RCTs with consistent results (A)	1A	A strong recommendation; the management should be commonly used unless there are strong contraindications
One of the management options clearly dominates (1)	The decision based on RCTs with inconsistent results or questionable reliability* (B)	1B	A strong recommendation but with less certainty; probably correct in most individual cases
One of the management options clearly dominates (1)	The decision based on non-experimental studies (C), in some cases, clinically very convincing	1C	A moderate recommendation that can change once more reliable data are obtained; probably correct
None of the management options clearly dominates (2)	The decision based on RCTs with consistent results (A)	2A	A moderate recommendation; its acceptance is a matter of choice and can depend on local and individual conditions; the intervention does not have to be applied
None of the management options clearly dominates (2)	The decision based on RCTs with inconsistent results (heterogeneity) or questionable reliability* (B)	2B	A weak recommendation; an alternative management can be equally good or better
None of the management options clearly dominates (2)	The decision based on non-experimental studies	2C	A weak recommendation, an alternative management is probably equally acceptable

*Reduced reliability of RCT may result from a high percentage of patients who did not complete the trial, lack of double-blind trials and subjective assessment of final points (outcomes), unconcealed randomisation and a small sample size (arbitrary threshold – 100 individuals).

societies [6–9]. The British recommendations of the National Institute for Health and Care Excellence, Clinical Guideline *65* of 2008, updated in 2016 and commonly cited (also in the remaining guidelines available) were fundamental to the development of the present guidelines.

Considering the nature of the available scientific data, the individual recommendations were developed based on the Oxford Centre of Evidence – Based Medicine (OCEBM) strength of recommendations (five grades I-V) [10]. The levels of evidence were defined according to the three-degree scale, i.e. A – reliable methodology of studies, consistent results; B – less reliable methodology or inconsistent results; C – incoherent methodology, mostly observational studies [11].

GUIDELINES

Physiology of thermoregulation and perioperative thermoregulation

The core body temperature is one of the parameters which are strictly regulated. At any time, the deviation from the assumed level even by several tenths of a degree activates the defence mechanisms based on the principle of feedback between the afferent signals from the thermoreceptors (delivering information to the centre of thermoregulation in the preoptic hypothalamus) and the efferent impulsation to the effector organs, triggering the changes aimed at decreasing heat loss and increasing heat production or increasing heat loss depending on the body thermal demands [12].

The reactions to maintain thermal homeostasis of the body can be divided into autonomic and behavioural; at the same time, voluntary behaviours abolished during anaesthesia, such as clothing adjusted to weather conditions or staying in shadowed or sunny places, are much more effective, as compared to involuntary peripheral vasodilation and perspiration (prevents overheating) or peripheral vasoconstriction (prevents overcooling) and muscle tremor [13].

The action of the hypothalamic centre of thermoregulation can be briefly described using two phenomena, i.e. the set point (temperature oscillating around 37°C) and the interthreshold range, usually 0.2°C below or above the set point. Under normal conditions, this range of temperatures within which the defence mechanisms are not yet activated is 0.4°C. The interthreshold range changes during anaesthesia [14].

The supply of both inhalational and intravenous anaesthetics used during general anaesthesia significantly impairs the central control of temperature, mainly by reducing the lower value of the interthreshold range, the temperature below which anti-cooling mechanisms are activated, i.e. peripheral vasoconstriction and muscle tremors [15]. The typical examples of the adverse effects of anaesthetics are desflurane and propofol, which at standard doses lower the activation threshold of the above mechanisms to below 34°C. The mechanism of this action is not known, but due to it, the body of an anesthetised patient behaves like a poikilothermic organism: despite a decrease in core body temperature, the body does not activate defence processes in a considerable temperature range [14].

Central blocks (subarachnoid and epidural) lead to thermoregulation disorders of comparable intensity, although the mechanisms are different. As in general anaesthesia, the threshold for activation of the mechanisms preventing cooling decreases. In this case, however, it does not depend on direct central effects of agents used for central blocks but is rather caused by blockage of sensory conduction pathways (including temperature) from the area blocked. It seems that the lack of cold impulsation is interpreted by the hypothalamic centre as the feeling of warmth; therefore, conscious patients undergoing central block anaesthesia report thermal comfort, even when their core temperature decreases [16]. In addition, blocking of the conduction of nerve impulses to and from the anaesthetised area prevents both peripheral vasoconstriction and muscle tremors, shutting down the autonomic defence mechanisms in a considerable area of the body. As a result of the above disorders, the risk of intraoperative hypothermia in patients undergoing surgical procedures under neuraxial and general anaesthesia is similar. In cases of regional anaesthesia, this risk depends on the level of blockade, and hypothermia increases with its extent [17].

Perioperative heat balance

The human body can be divided into two thermal compartments: core (the head and internal organs) and peripheral (extremities and body surface tissues). Thermal stability of the core compartment determines homeothermy in humans; hence, the core temperature is a very precisely regulated parameter, uniform in the entire compartment and relatively stable in a quite wide range of ambient temperatures. The characteristics of the peripheral compartment are significantly different. The peripheral compartment is usually colder by 2–4°C than the core compartment and its temperature is variable (e.g. toes and arms). Moreover, the compartment in question is the area of heat exchange between the core compartment, where the heat is produced, and the environment [17]. The rate of exchange is considerably regulated by the peripheral blood flow, which is autonomically regulated by the hypothalamic centre of thermoregulation [19]. It has been accepted that 95% of the heat produced by the human body is transferred to the environment by the skin, and only 5% by the respiratory system [14].

A high percentage of patients developing intraoperative hypothermia results from overlapping of several unfavourable phenomena: 1) anaesthesia-induced thermoregulation disturbances, 2) low temperatures in operating theatres, 3) use of infusion fluids of ambient temperatures, 4) heat loss through the surgical wound [20]. The above factors reduce the core temperature in the majority of anaesthetised and non-warmed patients according to the defined scheme [14].

After the induction of general anaesthesia or central block, the core temperature rapidly decreases by even 1–1.5°C within 30–60 minutes. Such a rapid decrease cannot be explained exclusively by the heat loss through the skin. It is believed that it is mainly caused by an increase in peripheral blood flow due to vasodilation, which transfers heat from the core to the peripheral compartment; during this period, the body thermal reserves remain relatively stable [18, 21]. The above changes result from the functional imbalance of the thermoregulation centre and are associated with a substantial decrease in temperature, below which the peripheral vessels constrict. Additionally, most general anaesthetics act directly on peripheral vessels, increasing the peripheral blood flow, which is comparable to block-induced sympathectomy and dilation of the vascular bed within the blockage area [22]. The studies in volunteers have demonstrated that blood redistribution in the initial period of anaesthesia is the essential factor responsible for intraoperative hypothermia, as in over 80% of cases, as it is main contributor to the initial rapid temperature drop within one hour after the induction of general anaesthesia or central block [18, 21]. The management effective in reducing intraoperative redistribution of heat from the core to the peripheral compartment is active warming before the induction of anaesthesia or central block **(level of evidence 1; strength of recommendation A)**.

During the next 2-3 hours of anaesthesia, increasing intraoperative hypothermia results from higher heat loss than heat production. During this period, the temperature decrease is slower; without active warming of the body surface the heat loss is almost linearly dependent on the differences in temperatures between the skin surface and the environment. Therefore, the unfavourable conditions in the operating theatre (air conditioning set at 19–21°C) as well as the extent and duration of surgery are crucial. The active methods of preventing hypothermia, such as forced-air warming (FAW), electric mattresses and blankets (resistive heating) and warmed infusion fluids, are vital for limiting intraoperative hypothermia **(level of evidence 1; strength of recommendation A).**

After 2-3 hours of anaesthesia, the temperature stabilises and does not show any downward tendency even during surgical procedures lasting many hours. The activation of thermoregulation centre-dependent peripheral vasocontraction and smaller differences between the skin and environmental temperatures reduce heat loss, which is sufficient for maintaining balance, despite significantly lower heat production.

Risk factors of inadvertent intraoperative hypothermia

Intraoperative hypothermia is common; however, its incidence and severity depend on many factors related to the patient, type of procedure and anaesthesia and operating theatre conditions. The identification of the above factors invaluably helps to take suitable decisions regarding the application of preventive methods and appropriate use of materials and agents. The analysis of the available studies enabled the identification of the most common risk factors [23–20]:

- age > 60 years;
- low BMI/poor nutritional status;
- the core temperature prior to induction lower than the physiological one;
- concomitant diseases and therapies predisposing to intraoperative hypothermia (hypothyroidism, diabetes with diabetic polyneuropathy, antiepileptic drugs, and anxiolytics);
- general anaesthesia combined with central block;
- low temperature in the operating theatre.

A higher risk of perioperative hypothermia in older patients most likely results from age-related thermoregulation disorders, e.g. impaired defence mechanisms and substantially lower heat production [23]. Compared to young patients, they are also more exposed to intraoperative hypothermia during surgeries with nerve blocks [24]. The causes of perioperative thermoregulation disorders in patients with low BMI and obese patients are different [25]. In obese individuals, the extent of heat redistribution is lower due to better fatty tissue isolation, hence smaller decreases in core temperature in the initial stage of anaesthesia and lower heat losses during its further stages [14]. The body heat reserves in the initial stage of anaesthesia, in the phase of blood (and heat) redistribution, do not change; therefore, the higher the amount of heat in the body (together in the core compartment and the peripheral compartment which is usually cooler by 2–3°C), the more difficult the lowering of core temperature is, so patients with initially low core temperatures develop hypothermia more easily, and the pre-induction temperatures below 36°C are a relevant risk factor of anaesthesia-related hypothermia. Moreover, there is convincing evidence for increased incidence of this complication in patients with concomitant systemic diseases, such as hypothyroidism, diabetic polyneuropathy, and those undergoing treatment with drugs causing thermoregulation disorders, such as anxiolytics and antiepileptic drugs [28].

Furthermore, the combination of general and regional anaesthesia is of particular interest. In addition to intensified systemic and redistribution disorders, the defence mechanisms in the form of peripheral vasoconstriction and muscle tremors are not activated in the anaesthetised region, even when the activation threshold is intraoperatively reduced (usually < 35°C). Despite the unquestionable benefits of the general and block anaesthesia combination, the patients anesthetised in such a way are at a significantly increased risk of intraoperative hypothermia [16].

The operating theatre temperature is usually strictly controlled and kept between 19 and 21°C to ensure comfort of the operating theatre personnel. The temperature gradient between the patient's body surface area and the environment is thus increased, which has slight effects on the anaesthesia-related redistribution, but considerably facilitates heat loss in the subsequent stages of surgery [24, 30]. Therefore, it is suggested to keep the operating theatre temperature above 21°C, at least until active warming of the patient is provided [6, 9] **(level of evidence 1; strength of recommendation B)**.

Consequences of inadvertent intraoperative hypothermia

The adverse consequences of perioperative hypothermia described most frequently are coagulation disorders, higher risk of infection and cardiovascular complications. Scientific evidence for the above cause-and-effect relationship was collected in meta-analyses and systematic reviews of clinical trials, most of which date back to the 90s, when the prevention of IIH was not yet part of standard perioperative care and such studies were ethically acceptable. Due to growing awareness about harmful effects of IIH, the research of the last decade involves mainly retrospective analyses and observational studies. Thus, more recent meta-analyses focus on the results of studies evaluating the effectiveness of the methods used to prevent hypothermia and its adverse consequences [31–33].

The coagulation changes caused by an intraoperative decrease in core temperature by 1–2°C are probably the most recognizable complication of IIH due to an increased risk of intraoperative haemorrhage. The platelet dysfunction is highlighted, which results in a reduced release of thromboxane A2 and a decrease in the rate of enzymatic reactions as the phenomena responsible for a considerable proportion of haemostatic alterations [34]. Numerous randomised clinical trials (whose results were summarized in a meta-analysis) have demonstrated the relationship between hypothermia, increased blood loss and transfusion requirement [35]. This relationship is supported by current multivariate analyses of postoperative outcomes in very large populations [36, 37].

Intraoperative hypothermia has been shown to adversely affect many aspects of the immune system, such as: leukocyte migration, lytic ability, chemotaxis of neutrophils, as well as production of cytokines and antibodies. In addition, peripheral vasoconstriction, a defence mechanism accompanying a decrease in body core temperature, reduces the supply of oxygen and blood components to the surgical site [34], which eventually leads to increased susceptibility to infections, including surgical site infections (SSIs). Considering the number of surgical procedures currently carried out and the fact that about 15% of all nosocomial infections are SSIs, the expenditure on treatment of the consequences of this common complication is significant. According to a double-blind study analysing the outcomes of 200 colorectal surgery patients, patients with normothermia maintained during surgery had a significantly lower risk of SSIs than those in whom hypothermia of 2°C was allowed [38]. Most of the available studies confirm the above correlation [39, 40]; although the reports of its dubious significance have also been published, intraoperative normothermia is considered one of the essential factors determining the appropriate body's responses to surgical site contamination.

Inadvertent intraoperative hypothermia is associated with cardiovascular disorders due to increased activity of the sympathetic system with increased concentrations of catecholamines, hence, increased vascular resistance, elevated blood pressure and propensity to arrhythmia [41]. The above changes result in a substantially higher cardiovascular risk in the postoperative period, which translates into higher incidences of adverse cardiac events and affects the overall outcomes of surgical interventions, as demonstrated in a large, randomised trial. In hypothermic patients, the incidence of ischaemic lesions was found to be twice higher and that of ventricular tachyarrhythmia episodes 4 times higher in postoperative ECG monitoring (as compared to normothermic individuals) [42]. These results allow us to conclude that at least some cardiac complications can be prevented by maintaining intraoperative normothermia. This is particularly important in the light of modern biochemical diagnostic procedures; the wide use of high-sensitivity troponin tests has enabled a better insight into the actual incidence of myocardial damage in the perioperative period. Approximately 9% of patients aged ≥ 45 who underwent elective surgical procedures had elevated cardiac troponin levels. Although the majority of such cases showed no clinical symptoms, the 30-day mortality rate in this group reached 10% [43].

Moreover, a well-documented consequence of IIH is altered pharmacodynamics of the agents used during anaesthesia. By decreasing the rate of enzymatic reactions, the reduced temperature significantly affects the duration and potency of action of drugs used during general anaesthesia, which lengthens the recovery period [44]. Substantially longer effects of relaxants and increases in plasma concentrations of propofol at hypothermia of 2°C have been demonstrated [45, 46]. Other agents used during general anaesthesia, including inhalational anaesthetics, also show altered characteristics of action [47].

Temperature monitoring

The presence of two thermal compartments – core with a homogeneous temperature and peripheral, within which this parameter can vary up to several degrees – means that temperature measurements differ depending on the method used and the place of measurement. Proper intraoperative monitoring:

- should enable core temperature measurements;
- a sensor should be placed in the area where core temperature changes can be quickly detected.

Monitoring of intraoperative body temperature is indicated for early diagnosis of thermal disturbances. Despite its low incidence, malignant hyperthermia is a disease with very poor prognosis. An increase in core temperature preceded by a rapid increase in end-expiratory CO_2 pressure, muscle stiffness, and tachycardia enables early diagnosis and treatment of this syndrome [48]. Temperature measurements during anaesthesia are also an important parameter for monitoring patients with fever and in conditions predisposing to developing fever. Inadvertent intraoperative hypothermia is undoubtedly the most common anaesthesia-associated complication, the detection of which is not possible without intraoperative monitoring of core temperature.

The pulmonary artery is considered the gold standard for measuring core temperature. Less invasive accesses, such as the distal oesophagus, nasopharyngeal cavity, tympanic membrane, and rectum, are also sufficiently accurate.

The most reliable and minimally invasive location seems to be the distal oesophagus. The sensor inserted to the appropriate depth gives measurements comparable to those in the pulmonary artery, and its position can be correctly determined using an oesophageal stethoscope (the place with the best audibility of heart tones) or following the developed principles [49, 50].

The tympanic temperature corresponds to the core temperature, yet accurate and repeatable measurements in this location are difficult to achieve. The use of sensors in direct contact with the tympanic membrane enables measurements with correct characteristics; however, very small, disposable devices, the proper placement of which on the tympanic membrane requires patient cooperation and may be felt as unpleasant, should be used with caution [51]. The commonly used infrared thermometers for measuring the tympanic temperature, although easy to use, do not ensure adequate quality. Even the correct placement of the tip of such a thermometer usually results in the measurement of skin temperature of the internal auditory meatus and does not reflect changes in core temperature suitably for the intraoperative period, which is also associated with significant discrepancies depending on the thermometer type and low repeatability of measurements [52].

Thanks to the proximity of the CNS structures, sensors located in the nasopharyngeal cavity reflect well core temperature. When properly placed, the accuracy of measurements is about ± 0.2°C, as compared to oesophageal measurements, yet this method is characterized by larger inertia [50].

Perioperative temperature measurements from locations other than those mentioned above are not recommended in the intraoperative period due to either highly delayed changes (bladder and rectum) or inability to measure core temperature in a technically simple way (tympanic membrane using infrared, axilla, forehead skin, oral cavity), as indicated by the results of a meta-analysis regarding studies on the accuracy of temperature monitoring using peripheral thermometers [52]. **(level of evidence 1; strength of recommendation A).**

An alternative method of measuring core temperature involves zero-heat-flux sensors; placed on the forehead, they produce values that perfectly correlate with core temperature. The method described in the 70s and implemented for clinical use only recently, consists in reading the temperature of the heated insulated layer contacting the forehead skin until it reaches the same temperature as the underlying tissues and stops exchanging heat with them [53]. Recent studies have confirmed the reliability of the above method; due to non-invasiveness of measurements, the method can also be successfully used in the perioperative period in conscious patients undergoing surgeries with nerve blocks [54] **(level of evidence 1; strength of recommendation B)**.

METHODS OF PREVENTION AND TREATMENT OF INADVERTENT INTRAOPERATIVE HYPOTHERMIA

Redistribution of blood from the core to peripheral compartment, heat loss through the skin and intravenous supply of preparations with temperatures below 37°C are the key phenomena leading to intraoperative hypothermia. Counteracting them should be considered a goal in the fight against IIH. The loss associated with warming and humidifying the respiratory gases and the use of cold carbon dioxide during laparoscopic procedures additionally contributes to the total heat loss (approx. 5%). Attempts to reduce redistribution and skin loss as well as the use of warmed infusion fluids are the procedures that can prevent this adverse surgery- and anaesthesia-related phenomenon.

The methods of counteracting intraoperative hypothermia can be divided into passive, without heat supply from the outside, and active, where devices providing the temperature higher than the ambient temperature are used [55].

The use of passive warming techniques, i.e. adequate covering of the patient`s body surface, reduces heat loss through the skin; however, in the vast majority of cases the use of even three layers of surgical coverings does not prevent intraoperative hypothermia. According to the Cochrane systematic review regarding this method, additional covers do not significantly affect intraoperative core temperature [56] **(level of evidence 2; strength of recommendation A)**. Appropriate covering for thermal insulation should be used over the intraoperatively accessible body surface that is not actively warmed [6, 7].

The active techniques of intraoperative warming of the body surface include forced-air warming (FAW) systems, electric mattresses and blankets as well as water mattresses; the most popular and thoroughly studied are FAW systems [3]. They consist of a heating unit and a disposable blanket, into which heated air is blown through micro-perforations on the surface of the blanket facing the patient. Heat is therefore transferred mainly by convection (convective heating). Based on the results of available research and international guidelines, it can be concluded that this method is recommended due to its high effectiveness [6–9]. Another asset of the above method is its safety – a significant amount of heat produced is distributed over a large area, bypassing places exposed to pressure, which significantly reduces the risk of burns and bedsores. Appropriate filters in the heating unit, combined with disposable blankets ensure an adequate level of epidemiological safety. According to the current extensive Cochrane meta-analysis, the reports of possible complications associated with the use of active body surface warming systems are rare; therefore, there is no evidence that their use poses any risk to patients [31].

The systems based on the phenomenon of converting electric energy into heat energy, used to prevent intraoperative hypothermia, are an important alternative to the most popular FAW systems. Electric mattresses and blankets provide heat through direct contact with the heated surface (patient's skin), so heat is mainly transferred by conduction (conductive heating). Despite their slightly lower effectiveness, electric sheets and blankets have many supporters, which is related to the fact that disposable materials do not have to be purchased and that the devices emit virtually zero noise, as compared to FAW systems. The contact surface of the heating mattress limited to the area of the patient's skin in contact with the operating table quite significantly reduces the effectiveness of using only such mattresses [57]. Therefore, the electric systems also include heating blankets; used together with mattresses, they show the effectiveness comparable to FAW systems [58]. A novelty on the market is an electric mattress with a polymer heating mat; its elasticity provides larger contact with the patient's skin. The ongoing clinical trials demonstrate that the effectiveness of a heating mattress built and used in this way may be comparable to that of FAW systems [59, 60]. It is recommended to use body surface warming during surgery, as this reduces the incidence of IIH or limits its extent **(level of evidence 1; strength of recommendation: A).**

The discrepancies in the results of the available studies comparing the effectiveness of intraoperative warming methods are significant, which is reflected in meta-analyses. According to them, there is no sufficient evidence to consider one of the devices explicitly superior; nevertheless, the FAW method seems to be best studied, its effectiveness widely recognised and can be a refence point for other technologies [32, 33, 61, 62].

Pre-emptive warming (prewarming)

Heat redistribution related to the induction of general or block anaesthesia is the basic mechanism decreasing the temperature in the initial stage of anaesthesia, associated with a thermal gradient of several degrees between the core and peripheral compartment; as a result, after peripheral vasodilation, heat is transferred to the area with a lower temperature. A reduction in the heat gradient can therefore limit the incidence of this adverse phenomenon. An effective method of decreasing the inter-compartment temperature difference is to supply heat from the outside to the colder peripheral compartment using prewarming prior to the induction of anaesthesia. The randomised clinical trials and meta-analyses have shown convincing evidence for the effectiveness of this type of management both in preventing intraoperative hypothermia [31, 32, 62, 63] and decreasing the extent of this complication [64]. Active warming of the patient's body surface using recognized methods before the induction of anaesthesia, even for 10–15 minutes, effectively prevents redistribution-related decreases in the patient's core temperature during the first period of anaesthesia [63, 65–67] **(level of evidence 1; strength of recommendation A).**

Considering the above, in the procedures carried out under general anaesthesia with the anticipated duration not exceeding 60 minutes, pre-emptive warming may prove to be the basic and sufficient intervention to prevent intraoperative hypothermia. In the majority of the available studies on pre-emptive warming, the FAW method is used. One study regarding warming with a chemical heating blanket has demonstrated better but clearly unsatisfactory results of such a warming method, as compared to additional layers of passive insulation, (incidence of intraoperative hypothermia 39% vs. 60%, respectively) [68].

It is recommended to counteract intraoperative hypothermia in the subsequent stages of surgery, as this prevents heat loss from the skin surface, which eliminates the temperature difference between the patient's body surface and the environment. It is also suggested to use active methods of intraoperative warming throughout the surgical procedure [6, 7, 9]. The recommended method is to use FAW systems with disposable heating mattresses placed under the patient or coverings over the intraoperatively accessible area (disposable heating blankets). Alternatively, electrical systems may be used, the effectiveness of which is sufficient when a heating blanket placed over the patient and a heating mattress are simultaneously applied [6, 7] **(level of evidence 1; strength of recommendation A).**

Warming of infusion fluids and blood products

Perioperative use of significant volumes of infusion fluids at ambient temperature (in the operating room) contributes to a reduction in core temperature, as body heat has to be expended to warm the intravenously transfused volume to core temperature [14]. Warming of infusion fluids to 37–41°C facilitates the maintenance of normothermia when used together with warming of the intraoperatively accessible body surface area; the benefit of using fluid warming alone is about 0.5°C. Based on a meta-analysis of 19 available clinical trials, it is recommended to use warmed infusion fluids to maintain perioperative normothermia [68] **(level of evidence 1; strength of recommendation B).** The results of meta-analysis of studies on restricting hypothermia during Caesarean sections are similar; in 8 out of 13 analysed studies, the use of warmed infusion fluids was the only form of active prevention of hypothermia, significantly reducing intraoperative temperature decreases and incidences of muscle tremor [70].

The currently available devices for warming intravenous fluids are based on many technologies – from warm air circulation to microwave technology. Each system certified for perioperative use is capable of providing appropriate protection against overheating, often also regulation of the set temperature. It is recommended to use the devices in which the infusion fluid or blood preparation has the shortest possible way to the intravenous cannula after warming, which prevents re-cooling during the flow through the transfusion apparatus. Fluids warmed in warmers to 39°C supplied by the transfusion apparatus of standard length (160–180 cm) are cooled to a temperature of approx. 30°C during their supply at a speed of 1000 mL h^{-1} at an operating room temperature of 23°C, which significantly reduces the benefits of earlier warming [71]. Furthermore, a randomised trial comparing the use of previously warmed preparations (stored at 41°C for 8 hours) and flow fluid warming systems has shown similar effectiveness of these two methods when the supply of crystalloids is rapid (1000 mL for 30 min) [72].

The data reported in the studies concerning the use of warmed irrigation fluids to prevent the development of intraoperative hypothermia have shown dubious benefits of such an intervention when used alone. However, due to a small number of relevant publications, its effectiveness cannot be explicitly assessed, especially when the use of warm irrigation fluids is combined with other methods to maintain normothermia [69] **(level of evidence 2, strength of recommendation B).**

Despite the extensive discussion on possible factors affecting the quality of blood preparations, both the storage time and the method of administration, the appropriate and exclusive use of dedicated devices is a standard in the light of applicable law [73].

SUMMARY

Preoperative period

1. Attention should be paid to possible benefits of informing the patient about possible exposure to hypothermia during the perioperative period.
2. It is recommended to measure core temperature before anaesthesia in each case.
3. In the case of measurements from locations other than those recommended for core temperature measurements, it should be remembered to properly compare the reading with core temperature, except for the use of devices in which such reading changes are made automatically.
4. The preoperative assessment should identify relevant risk factors for intraoperative hypothermia and its possible consequences for an individual patient:
   - ASA ≥3;
   - preoperative body temperature < 36°C;
   - BMI;
   - the extent of the procedure*/the procedure over 1 hour;
   - planned combination of general and block anaesthesia;
   - anticipated blood loss above 500 mL.

Intraoperative period

1. Continuous core temperature measurements or at least every 30 minutes are recommended during anaesthesia; the continuous measurement is preferable.
2. It is recommended to use active warming since the induction of anaesthesia, e.g. forced air warming systems or electric heating mattresses and blankets, when the anticipated duration of the procedure exceeds 60 minutes.
3. It is recommended to maintain core body temperature within the range of values accepted for normothermia.
4. The time when a significant part of the body surface of the anesthetized patient is not covered in the period preceding draping should be kept to a minimum.
5. The operating theatre temperature should not be lower than 21°C until the active warming systems have been activated.
6. If it is planned to transfuse more than 1000 mL of infusion fluids, they should be warmed to 37°C using the devices designed for this purpose.
7. Warming of whole blood, red blood cell concentrate, and other blood preparations to 37° C is indicated in transfusions with a rate above 50 mL min^{-1} and only with the devices designed for this purpose.
8. It is advisable to warm the fluids used for intraoperative rinsing of body cavities (irrigation) to 37–40°C.

Postoperative period

1. Postoperative monitoring of body temperature, which is one of the main vital signs, is recommended.
2. During the patient's stay in the recovery room and in the postoperative ward, forced-air warming should be provided to maintain core body temperature above 36.5°C.

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*Medium procedures (inguinal hernia repair, lower limb varicose vein surgery, tonsillectomy or adenotonsillectomy, knee arthroscopy), major procedures (abdominal hysterectomy, endoscopic prostate resection, lumbar discectomy, thyroidectomy, total joint replacement, lung surgeries, bowel resections, extensive neck surgeries).

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