10.0 TEMPERATURE CONTROL

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Accurate temperature monitoring and management is an essential component of a massive hemorrhage protocol. An increase in the core temperature of a hypothermic patient by 1°C is associated with a 10% reduction in red blood cell transfusion requirement.[1] Likewise, hypothermia is associated with increased blood loss and transfusion requirements and is an independent predictor of mortality.[2,3] Moreover, as blood components are stored at temperatures between 2°C and 6°C, massive transfusion of these components can worsen hypothermia.[4] The following section provides details on how to manage the temperature of the actively hemorrhaging patient addressing recommendation statement numbers 24-26 divided into three parts: (1) how to accurately monitor a patient's temperature, (2) techniques to maintain or increase a patient's temperature, and (3) practical tips and the application of these techniques.

10.1 Monitoring

- The gold standard for temperature monitoring is the thermistor of an intravascular pulmonary artery catheter.[5] However, given the technical skills required to place a pulmonary artery catheter and the potential complications associated with its use, we **do not recommend the pulmonary artery catheter** as the standard tool for temperature measurement during massive hemorrhage resuscitation.[6,7]
- We **recommend that patient temperature is measured using either an esophageal, rectal, or bladder thermometer**.[5,7,8,9] The choice of measurement modality should be based on the available hospital resources and clinician familiarity. However, given the discomfort associated with placement of an esophageal probe, it is recommended for use primarily in the intubated patient.
- Peripheral thermometers (including tympanic membrane, temporal artery, axillary, and oral) do not have acceptable accuracy and at extremes of temperature can report measurements up to 2°C higher or lower than actual core temperature.[8-10]
- If one uses a peripheral thermometer, we recommend the use of a tympanic membrane thermometer.[11-14] If a tympanic thermometer is to be used, the ear should be cleaned of wax and the tympanic membrane should be intact to allow for optimal measurement.[10-11]
- It is recommended that devices used to measure temperature be routinely calibrated as per vendor instructions.[5,8]
- Many thermometers are inaccurate at temperatures less than 34°C. Given the concern for hypothermia, a thermometer capable of reading low temperatures should be used to measure core temperature during massive hemorrhage resuscitation.[15]
- There is limited evidence regarding the frequency that temperature should be checked during resuscitation. However, during active warming temperature can change by greater than 3°C per hour.[16] As such it is reasonable to monitor temperature continuously. If continuous monitoring is not possible, we recommend that the patient's temperature be measured within 15 minutes of patient arrival or protocol activation and then at a minimum of every 30 minutes.

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10.2 Methods for patient warming

- We recommend hypothermia prevention and rewarming with multiple methods that include passive external warming, active external rewarming, and active internal rewarming.[1] Prevention of heat loss is essential given the challenges of rewarming patients that are already hypothermic.
- Passive rewarming strategies such as removing wet clothing, increasing room temperature, and applying warm blankets should be used to avoid heat loss. However, none of these interventions are effective in isolation to manage significant hypothermia.[2]
- The use of active rewarming with resistive heating devices can increase thermal comfort and keep stable core temperature in situations in which physical and logistical challenges limit warming methods, including out of hospital and intra-hospital transport.[3,4,5]
- We **recommend the use of forced-air warmers** as one of the active external rewarming methods;[6] the larger the area the blanket covers, the more effective it is. The use of forced-air warmers should be continued in the operating room. Forced-air warmers are safe and easy to use, they limit further heat loss and provide heat to the body.[7] The use of conductive warmer systems is less effective and has higher risk for burns and pressure ulcers.[7]
- We **recommend the routine use of intravenous fluid warmers** to avoid worsening of hypothermia from cold blood and fluid resuscitation. The ideal fluid warmer should be capable of safely delivering components at normothermia at both low and high flow rates.[8] The temperature should be set ideally at 41.5°C to effectively avoid hypothermia[3] but not higher than 43°C to avoid the risk of hemolysis and air embolism.[9]
- Patients that require intubation and induction of anesthesia have a higher risk for hypothermia.[10,11] Heat loss from the airway is a small but additive factor. We recommend that in addition to the previously mentioned strategies, heat and moisture exchange (HME) filters are utilized to reduce evaporative heat loss from the airways.[2]
- Patients with temperatures below 32°C have impaired thermogenesis such that the aforementioned therapies will likely be insufficient to increase their core temperature. If a patient's temperature is below 32°C clinicians should

refer to local guidelines for treatments of severe hypothermia. This degree of hypothermia should prompt the clinician to identify alternative causes aside from massive hemorrhage or transfusion.

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10.3 Practical strategies to apply rewarming techniques

10.3.1 Passive rewarming:

- As soon as is safe remove wet clothing, linens, dressings, and dry the patient thoroughly.[1] Shears can be utilized to cut away clothing.
- Cover the patient with warm blankets.[1,2] Locations in which patients are commonly resuscitated, such as the emergency department or operating room, should have easy access to a warmer in which blankets can be kept.
- When able the patient's head should also be covered (warm towel) to prevent additional heat loss.[1,2]

10.3.2 Active rewarming:

- Healthcare providers who are expected to be involved in acute resuscitations should ensure they are familiar with the location and utilization of the forced-air warmer.[1] Common challenges in using a forced-air warmer include limited access to the patient's core after application, and challenges to ensure the warming blanket stays on the patient.
- Ensure the warming blanket used with the forced air-warmer is in direct contact with the patient.[3]
- Ensure the blanket is placed as per the manufacturer's instructions, this includes ensuring that the perforated side is facing in the correct direction (towards the patient), and the blanket is secured to avoid it blowing off the patient as it inflates.

- When using a forced-air warmer ensure that the hose carrying the warm air from the heater to the patient does not come in direct contact with the patient's skin.[3] Likewise, **do not use the hose to blow warm air directly at the patient**, a practice referred to as "hosing".
- If a fluid circulating blanket is used for patient rewarming place a sheet between the patient and circulating water blanket. [2,4]
- Blood transfusions should be warmed using blood warmer.[2] Given the speed and volume of fluids transfused, if resources allow have two healthcare providers operating the fluid warming device.

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Pediatric

Please refer to section 15.0 and Appendix D regarding specific pediatric considerations and tips for temperature management in children, respectively.