



Prevention of Accidental Hypothermia in Pre-Hospital Care: The Critical Role of Head Protection

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Abstract: -

Introduction: Accidental hypothermia in pre-hospital care (PHC) worsens the prognosis of victims of trauma and environmental exposure, forming part of the "Lethal Diamond" of trauma (hypothermia, acidosis, coagulopathy, and hypocalcemia). Despite its severity, simple preventive measures—such as thermal protection of the head—are frequently neglected in clinical practice. **Objective:** To review the pathophysiological underpinnings, clinical impact, and prevention strategies for accidental hypothermia in PHC, with an emphasis on the critical role of head protection. **Methods:** This is a narrative literature review involving searches across the PubMed, Scopus, Web of Science, and Google Scholar databases, as well as an analysis of international guidelines (PHTLS, ERC, WMS), prioritizing publications dated between 2010 and 2025. **Results and Discussion:** Heat loss in PHC occurs rapidly through conduction, convection, radiation, and evaporation. The head—due to its rich vascularization and lack of significant cold-induced vasoconstriction—acts as a critical zone for heat dissipation; it can account for up to 50% of radiant heat loss when the rest of the body is insulated. The early use of ground insulation, vapor barriers, and head coverings interrupts heat loss, thereby preventing hemodynamic and hemostatic deterioration. **Conclusion:** Preventing hypothermia in PHC is more effective and feasible than attempting its delayed reversal. Thermal protection of the head is a low-cost, high-impact clinical intervention that should be systematically incorporated into initial care protocols to improve patient survival.

Keywords: Accidental Hypothermia; Pre-Hospital Care; Multiple Trauma; Body Temperature Regulation; First Aid.

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1. Introduction

Accidental hypothermia is a frequent and potentially serious clinical condition in pre-hospital care, especially in trauma scenarios, prolonged environmental exposure, drownings, and rescues in remote areas. Defined as the involuntary reduction of core body temperature below 35 °C, this condition has a direct impact on multiple physiological systems, interfering with cellular metabolism, cardiovascular function, coagulation, and neurological response, with significant repercussions on the prognosis of patients treated outside the hospital environment [1].

In the context of pre-hospital care, hypothermia should not be understood merely as a passive consequence of exposure to cold, but as a modifying factor of clinical outcomes, frequently preventable and yet undervalued in clinical practice. Accumulated evidence in recent decades demonstrates a consistent association between accidental hypothermia and increased mortality, worsening neurological outcomes, and a higher incidence of complications, particularly in patients with multisystem injuries, drowning, and cardiorespiratory arrest. In this scenario, hypothermia is part of the so-called lethal diamond of trauma, interacting synergistically with acidosis, coagulopathy, and hypocalcemia, which reinforces the need for its early prevention from the first contact with the patient [2].

In the context of pre-hospital care, hypothermia can also be aggravated iatrogenically, resulting from essential interventions that, in the absence of structured thermal conservation measures, contribute to the loss of body heat [3].

Despite the growing recognition of its pathophysiological relevance, the approach to hypothermia in pre-hospital care still focuses, in many services, on late treatment, with less emphasis on simple, low-cost, and high-impact clinical preventive strategies. Among these strategies, adequate thermal protection of the patient from the scene stands out, including isolation from the ground, control of wind exposure, use of thermal blankets, complete body protection, and reduction of environmental exposure time during care and transport [4].

In this context, the head represents a critical and frequently neglected region in preventing heat loss. Due to its high vascularization, proximity to the central nervous system, and intense heat dissipation through convection and radiation, the cephalic region can significantly contribute to overall body heat loss, especially in cold, windy environments, and in pediatric and geriatric populations. Neglecting the protection of this area can accelerate the onset or worsening of hypothermia, with possible neurological and hemodynamic implications, particularly in vulnerable patients.

Given this scenario, it becomes crucial to broaden the understanding of accidental hypothermia in pre-hospital care, not only as a clinical finding but as a priority target for prevention. The systematic adoption of preventive measures, including thermal protection of the head, should be considered an integral part of initial care, aligned with contemporary guidelines for trauma and emergency care.

Although widely recognized from a pathophysiological perspective, the prevention of hypothermia still lacks operational

standardization in pre-hospital care, especially with regard to thermal protection of the cephalic region.

Thus, this article aims to provide a narrative and up-to-date review of the importance of preventing accidental hypothermia in pre-hospital care, addressing its pathophysiological foundations, the prognostic impact associated with its occurrence, and the main practical strategies for prevention and management, with emphasis on the role of thermal head protection as an essential component of pre-hospital care.

2. Materials and Methods

This is a narrative review article, descriptive and analytical in nature, with a clinical-operational focus on pre-hospital care. The objective was to gather, analyze, and integrate current scientific evidence and technical recommendations related to accidental hypothermia, with emphasis on early prevention and thermal protection of the head in the pre-hospital environment. The methodology followed the general principles for narrative reviews in health, aiming to synthesize the available knowledge for practical application [5].

The bibliographic search was carried out systematically and in a targeted manner in national and international scientific databases, including PubMed/MEDLINE, Scopus, Web of Science and Google Scholar, in addition to consulting guidelines, manuals and reference textbooks in Emergency Medicine, Trauma and Pre-Hospital Care, such as the guidelines of the Wilderness Medical Society and the European Resuscitation Council [6,7].

Controlled descriptors and free terms were used, combined with Boolean operators, including: hypothermia, accidental hypothermia, prehospital care, emergency medical services, trauma, cold exposure, heat loss, head heat loss, thermal protection, and their Portuguese equivalents.

2.1 Inclusion and exclusion criteria

The following were included:

Original articles, narrative reviews and systematic reviews published preferably in the last 15 years, with priority given to studies that support current guidelines (2010-2025); documents that address pathophysiological, clinical, prognostic or preventive aspects of accidental hypothermia; internationally recognized guidelines and protocols related to trauma care (PHTLS, ATLS) and emergency care [8].

The following were excluded:

Studies focusing exclusively on controlled therapeutic hypothermia (post-cardiac arrest) in a hospital setting, when not related to the pathophysiology of accidental hypothermia; articles without clinical relevance to pre-hospital care; duplicate publications or publications with insufficient data for analysis.

2.2 Selection, Analysis and Organization of Content

The initial database search resulted in the identification of 142 potentially relevant articles. After removing duplicates and screening by title and abstract, 68 publications were selected for full-text reading. Of these, rigorously applying the inclusion and exclusion criteria, 27 references (including original articles, reviews, and international guidelines) were effectively used in the final construction of this manuscript.

The selected publications were critically analyzed and integrated in a narrative manner, considering: the pathophysiological mechanisms of hypothermia in the pre-hospital environment; the clinical and prognostic impact associated with heat loss; the relevance of the head as a critical zone for heat dissipation; and practical prevention strategies applicable to pre-hospital care, as recommended by advanced trauma life support guidelines [8]. The content was organized into progressive thematic axes, covering the definition and classification of hypothermia, pathophysiology, clinical impact, prevention, and pre-hospital management, in order to establish a logical relationship between scientific evidence and clinical practice.

2.3 Use of images and illustrative material

Illustrative images from the authors' collection were used, representing real techniques for preventing hypothermia in pre-hospital care, including ground insulation, use of aluminized blankets, and thermal head protection. The images were selected for their didactic value and practical applicability, and were used to complement the textual description of preventive strategies without interfering with the scientific analysis of the data.

3. Concept and Classification of Accidental Hypothermia

Accidental hypothermia is defined as the involuntary reduction of core body temperature below 35 °C, resulting from environmental exposure to cold or the body's inability to maintain thermal balance in the face of adverse conditions [7]. This definition is widely adopted in international guidelines, such as those of the American Heart Association and the European Resuscitation Council, which recognize hypothermia as a relevant clinical condition in initial care, especially in scenarios of trauma, cardiorespiratory arrest, sepsis, drowning and prolonged environmental exposure [7,8].

In the context of pre-hospital care, hypothermia can occur in isolation or associated with other clinical conditions, and is frequently underdiagnosed in the initial phase of care. Common factors in the pre-hospital setting such as exposure to wind, contact with cold surfaces, humidity, removal of clothing, administration of cold fluids, and prolonged care time contribute significantly to the development or worsening of hypothermia [9].

From a physiological point of view, maintaining body temperature depends on the balance between metabolic heat production and its loss to the environment. When compensatory mechanisms fail or are overwhelmed, hypothermia sets in, with progressive repercussions on the cardiovascular, respiratory, metabolic, hematological, and neurological systems [10]. These changes can begin even in mild hypothermia and worsen rapidly, especially in vulnerable patients or those with associated comorbidities.

Given the frequent impossibility of accurately measuring core body temperature in the pre-hospital setting, systematic clinical assessment and functional staging become essential tools to guide decision-making and risk stratification.

The classification of accidental hypothermia is based on core body temperature and directly guides clinical management in initial care. In general, the internationally validated Swiss Staging System is used [6,11]:

- **Mild hypothermia (35–32 °C):** It is characterized by the activation of compensatory mechanisms, such as peripheral vasoconstriction and tremors. The patient may present with tachycardia, tachypnea, mild alteration of the level of consciousness, and impaired motor coordination, generally maintaining relative hemodynamic stability. Although apparently benign, this phase is already associated with increased energy consumption and a risk of progression if preventive measures are not adopted early [7].
- **Moderate hypothermia (32–28 °C):** There is a progressive reduction in metabolic response and a decrease or cessation of tremors, with more evident neurological impairment. Bradycardia, reduced cardiac output, hypotension, respiratory depression, and increased susceptibility to arrhythmias, including atrial fibrillation, are described [9]. At this stage, improper handling and abrupt movements during pre-hospital care can precipitate severe instability.
- **Severe hypothermia (<28 °C):** It is associated with significant multisystem dysfunction, with a high risk of malignant ventricular arrhythmias, circulatory collapse, profound depression of the level of consciousness, and cardiorespiratory arrest. Minimal stimuli can trigger fatal events, requiring a careful, systematic, and integrated approach to prevention and management strategies in pre-hospital care [8].

In addition to classification based on temperature, accidental hypothermia can be distinguished according to its origin as primary or secondary. Primary hypothermia results predominantly from direct environmental exposure to cold. Secondary hypothermia, on the other hand, results from clinical conditions that compromise thermoregulation, including severe trauma, hemorrhagic shock, drowning, sepsis, and intoxications. In the pre-hospital setting, this distinction has significant practical relevance, since secondary hypothermia is usually associated with greater clinical severity and is part of complex pathophysiological processes, such as the lethal triad (or diamond) of trauma [12].

4. Pathophysiology of Hypothermia

The pathophysiology of accidental hypothermia in pre-hospital care is complex and multifactorial, resulting from the interaction between physical mechanisms of heat loss, compensatory physiological responses, and associated clinical conditions. In the pre-hospital setting, these changes tend to develop early and progressively, often before hypothermia is clinically recognized [10].

Body heat loss occurs through four main mechanisms: conduction, convection, radiation, and evaporation. In pre-hospital care, these mechanisms often act simultaneously. Conduction occurs through direct contact of the body with cold surfaces, while convection is related to the movement of air or water around the patient. In cold liquids, the thermal conductivity of water is approximately 25 times greater than that of air, which explains the rapid onset of hypothermia in immersion victims [13]. Radiation corresponds to the dissipation of heat to the environment without direct contact, being intensified when large body areas remain exposed.

Evaporation occurs mainly through skin moisture and respiration [10].

Initially, the body responds to cold exposure through compensatory mechanisms coordinated by the hypothalamus. Peripheral vasoconstriction reduces cutaneous blood flow, while increased thermogenesis raises endogenous heat production. The main thermogenesis mechanism in acute response to cold is involuntary muscle shivering, which can increase the metabolic rate by up to five times [13]. However, as core body temperature decreases, the effectiveness of these responses diminishes. Cessation of shivering, characteristic of moderate hypothermia (generally below 30-32°C), represents a critical pathophysiological milestone, indicating failure of active thermoregulation and signaling a high risk of rapid deterioration [6].

The cardiovascular system is particularly sensitive to hypothermia. A reduction in body temperature leads to progressive bradycardia and decreased cardiac output. As core temperature falls, changes in cardiac electrical conduction occur, such as the appearance of Osborn J waves and QT interval prolongation, increasing susceptibility to malignant ventricular arrhythmias, especially below 28 °C [14]. The hypothermic myocardium is extremely irritable; sudden movements can precipitate refractory ventricular fibrillation [8].

Hypothermia has a profound impact on metabolism and the hemostatic system. The reduction in body temperature directly interferes with platelet function and the coagulation cascade, whose enzymes are thermodependent. Studies show that hypothermia inhibits thrombin generation and fibrinogen synthesis, worsening bleeding in trauma patients [15]. In addition, functional hypocalcemia stands out, resulting from the reduction in calcium-dependent enzymatic activity, an essential element for coagulation and myocardial contractility. These alterations comprise the updated concept of "Lethal Diamond of Trauma" (hypothermia, acidosis, coagulopathy, and hypocalcemia) [16].

It is important to highlight that laboratory evaluations performed under normothermic conditions may not accurately reflect hemostatic disturbances present in hypothermia, contributing to an underestimation of the severity of coagulopathy in trauma patients.

In the central nervous system, a decrease in temperature reduces cerebral oxygen consumption (CMRO₂) by approximately 6% to 7% for every 1°C drop in temperature [17]. Although this effect may be neuroprotective in controlled situations, in pre-hospital care, uncontrolled accidental hypothermia is associated with worsening neurological outcomes, especially when associated with hypoxia and trauma, leading to decreased level of consciousness and loss of protective reflexes [12].

5. The Head as a Critical Zone for Heat Loss

The head plays a central role in thermoregulation and in the pathophysiology of accidental hypothermia, constituting a critical zone of heat loss. From an anatomical point of view, the cephalic region is highly vascularized, and the scalp vessels do not undergo significant vasoconstriction in response to cold, unlike the peripheral vessels of the limbs [18]. This occurs to ensure constant cerebral perfusion, but results in an open "thermal window" to the environment.

This peculiarity gives the head a disproportionate importance in the process of body heat loss, especially in immobilized patients exposed to cold environmental conditions.

Despite representing a relatively small fraction of the total body surface area (approximately 7-9% in adults, but up to 20% in young children), the head can account for a disproportionate share of heat loss, potentially reaching 50% of total radiant body heat loss if the rest of the body is insulated [19]. It is important to demystify the premise that the head loses heat more rapidly per square centimeter than other parts of the body. In reality, its thermal relevance stems from the fact that, while the trunk and limbs are usually protected by clothing or blankets and undergo intense peripheral vasoconstriction in the cold, the head often remains exposed and maintains its blood flow unchanged. Consequently, it acts as the body's main "thermal sink".

This phenomenon becomes even more relevant in pre-hospital care, where the patient frequently remains immobilized on rigid boards. The absence of adequate head covering eliminates one of the few barriers against heat loss. From a neurological point of view, the direct cooling of blood returning from the head can affect brain temperature and the hypothalamic thermoregulatory center. Therefore, thermal protection of the head should be understood as an active preventive intervention, with the use of thermal caps or improvised wraps recommended by the Wilderness Medical Society guidelines as an essential part of the "hypothermia package" [20].

The practical application of these pathophysiological concepts can be observed in full-body thermal insulation devices. Translating pathophysiological principles into practical conduct in pre-hospital care requires simple interventions, such as the use of vapor barriers and thermal insulation that includes the head, as demonstrated in studies on the management of victims in cold environments [21]. These resources allow for a significant reduction in heat loss by radiation and convection, without compromising airway access or neurological assessment, constituting an effective and operationally viable strategy in pre-hospital care (Figure 1).

Figure 1 – Complete body thermal insulation system with integrated head protection.



(Source: authors' collection.)

Patient wrapped in a thermal blanket appropriate for preventing hypothermia in pre-hospital care, with continuous coverage of the trunk, limbs, and head. The illustrated model demonstrates an effective strategy for containing heat loss through radiation and convection, highlighting head protection as an essential component for preserving core temperature, without compromising airway access and clinical monitoring.

Translating the pathophysiological principles of hypothermia into practical procedures in pre-hospital care requires simple, early, and systematic interventions. Among these, body thermal containment combined with head protection stands out, preferably performed at the scene. Figures 2 to 7 illustrate, sequentially, a practical and low-cost method using plastic sheeting and aluminized blanket, widely available in rescue scenarios, capable of significantly reducing heat loss through conduction, convection, radiation, and evaporation.

Figure 2 – Soil isolation with plastic sheeting.



(Source: authors' collection.)

A plastic sheet is placed between the patient and the ground to interrupt heat loss through conduction, one of the main pathways of thermal dissipation in pre-hospital care, especially in humid or cold environments. Creating this barrier interrupts the direct transfer of body heat to the environment and significantly reduces the rate of core temperature drop, particularly during prolonged care or in outdoor settings.

Figure 3 – Positioning of the aluminized blanket



(Source: authors' collection.)

An aluminized blanket is positioned over the tarp, forming an initial thermal barrier designed to reduce heat loss through radiation and convection, preparing the environment for the safe transfer of the patient.

Figure 4 – Transfer of the patient to the isolation system



(Source: authors' collection.)

Careful positioning of the patient on the tarp and aluminized blanket, with attention to minimal handling, is an essential strategy to avoid cardiovascular instability and arrhythmias in patients with moderate or severe hypothermia.

Figure 5 – Making an improvised head protection device

Construction of a thermal head wrap using aluminized blanket and plastic sheeting, highlighting the protection of the cephalic region as an essential component in the prevention of hypothermia, maintaining access to the airways and allowing neurological monitoring.



(Source: authors' collection.)

Figure 6 – Progressive closure of the aluminized blanket



(Source: authors' collection.)

Progressive closure of the aluminized blanket around the torso and lower limbs, reducing heat loss through radiation, convection, and evaporation, without compromising clinical assessment or necessary interventions.

Figure 7 – Complete thermal insulation system



(Source: authors' collection.)

Patient completely immersed in an improvised thermal insulation system, with integrated body and head protection, demonstrating a simple, low-cost, and highly effective strategy for preventing hypothermia in pre-hospital care.

The systematic application of these measures prematurely interrupts the main mechanisms of heat loss and acts directly on the pathophysiology of hypothermia, reducing the risk of progression to cardiovascular instability, coagulopathy, and neurological deterioration. Head protection, integrated with body thermal insulation, represents a high-impact clinical intervention in pre-hospital care and should be routinely incorporated into initial care protocols.

6. Recent evidence on head protection and reduced trauma mortality (2023-2024)

Classic studies and seminal meta-analyses had already established accidental hypothermia as an independent predictor of multiple organ failure and increased mortality in trauma, with significantly elevated odds ratios for death in hypothermic patients [22,23]. However, recent publications (2023-2024) have brought new perspectives on the urgency and methods of thermal protection in the pre-hospital environment, reinforcing that intervention should be immediate, prophylactic, and encompass the entire body, with critical attention to the cephalic region.

A comprehensive update on the management of accidental hypothermia, published by Paal et al. (2024), reiterates that active and passive thermal protection, initiated at the scene, is the cornerstone for preventing the development of the "lethal diamond" [24]. The study highlights that the early application of vapor barriers associated with complete thermal insulation,

including the head, is the most effective strategy to stop heat loss by convection and radiation. Current literature emphasizes that the head cannot be treated as a secondary area in pre-hospital care; due to the absence of significant local vasoconstriction, its continuous exposure negates much of the thermal conservation efforts applied to the trunk [25, 26].

Furthermore, recent investigations conducted by Strapazzon et al. (2024) highlighted the challenges and importance of measuring core temperature in pre-hospital care to guide thermal conservation therapies [27]. As obtaining accurate and non-invasive measurements at the trauma scene is often unfeasible, the authors reinforce the premise that total prophylactic isolation (body and head) should be instituted empirically and without delay, even before a documented drop in temperature.

Updated international guidelines, such as the 10th edition of Prehospital Trauma Life Support (PHTLS), align with this recent evidence. It explicitly recommends the removal of wet clothing, strict isolation of the patient from the ground, and full coverage, including the application of head wraps, as first-line interventions associated with improved survival outcomes [28, 29].

6.1 Thermal insulation techniques: comparison and applicability

Different devices and techniques for thermal insulation are available for pre-hospital care. The effectiveness of simple aluminized blankets, for example, lies in reducing heat loss through convection and evaporation, but they offer little thermal insulation (reduction of conductive loss) if not combined with wool blankets or active systems [30]. The use of "vapor barrier" systems (plastics) combined with thermal insulation is the most effective strategy in austere environments [2].

Table 1 – Comparison between thermal insulation techniques in pre-hospital care

Technique/Device	Mechanism of action	Effectiveness	Cost	Advantages	Limitations	Applicability in pre-hospital care
Aluminized blanket	Reduction of radiation and convection	Moderate to high	Low	Lightweight, compact, disposable, widely available	Fragile, can tear easily, does not actively heat up.	Very high – first line
Wool/cotton blanket	Convection reduction	Moderate	Low to moderate	Reusable, comfortable, available	It loses effectiveness if wet, bulky, or infrequently used.	Moderate
Plastic tarp	Reduction of conduction and evaporation	Moderate	Very low	Waterproof, protects against moisture and wind.	It does not reflect heat and is not a good insulator on its own.	Very high – initial barrier
Complete body isolation system	Reduction of conduction, convection, radiation and evaporation	High	Moderate to high	Full head protection, including head protection, maintains clinical access.	Requires training, less available.	Moderate – specialized scenarios
Active heating devices (hot air, chemicals)	Active heating	High	High	Actively raises temperature.	Requires a power source or chemical activation, higher cost.	Low to moderate – advanced features
Thermal hat	Reduction of radiation and cephalic convection	Moderate	Very low	Simple, effective, does not interfere with the airway.	Limited protection to the cephalic segment.	Very high – essential complement

7. Discussion

The implementation of rigorous hypothermia prevention protocols in pre-hospital care, although widely supported by pathophysiology, faces significant operational and cultural challenges. The main dilemma in trauma practice is the apparent conflict between the time spent at the scene for thermal insulation and the need for rapid transport to the definitive center (scoop and run). However, current literature suggests that the time invested—often less than two minutes with proper team training—in applying vapor barriers and head protection is largely offset by the prevention of coagulopathy and hemodynamic instability, justifying intervention at the scene of the incident [26, 31].

Another point of debate concerns the effectiveness and limitations of the materials used. While aluminized blankets are excellent at blocking heat loss through radiation and evaporation, they offer little resistance to conductive heat loss if the patient remains in contact with cold surfaces, such as rigid boards or the ground itself [24]. Therefore, the technique demonstrated in this study — combining plastic sheeting (lower insulation) with aluminized blankets and head protection — presents itself as a highly effective and low-cost compromise solution for austere scenarios. However, it is imperative to recognize that, in patients already in moderate to

severe hypothermia, these passive measures only stabilize heat loss, not replacing the need for active warming methods during prolonged transport [7].

Finally, the difficulty in accurately measuring core temperature in the pre-hospital environment [24] reinforces the need for a paradigm shift in rescue teams. Thermal protection, especially of the head, should not be conditional on thermometric confirmation of hypothermia, but rather instituted prophylactically and empirically in all at-risk patients, simultaneously integrating with initial hemorrhage control maneuvers and airway management.

8. Final Considerations

Preventing accidental hypothermia in pre-hospital care requires a proactive and systematic approach. Scientific evidence unequivocally demonstrates that heat loss exacerbates the lethal trauma diamond and increases mortality, making prophylactic intervention at the scene far more effective and feasible than attempting late reversal in the hospital setting.

In this context, thermal protection of the head is not an accessory measure, but a mandatory component of initial care, given its relevance as the main route of heat dissipation in patients with isolated trunks. The use of simple, low-cost, and quick-to-perform

techniques such as head and body wrapping with aluminized and plastic blankets demonstrates that excellence in pre-hospital thermal control depends less on expensive technologies and more on training, pathophysiological awareness, and strict adherence to care protocols.

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