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Pre-hospital use of intravenous in-line fluid warmers to reduce morbidity and mortality for major trauma patients: A review of the current literature

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Review

Pre-hospital use of intravenous in-line fluid warmers to reduce morbidity and mortality for major trauma patients: A review of the current literature

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Abstract

Introduction
In-line fluid warmers are an established treatment for delivering warmed intravenous fluid in the hospital setting. Recently their potential application within the pre-hospital setting has been highlighted to potentially reduce mortality and morbidity. Currently ambulance paramedics only administer warmed fluid to patients assessed as hypothermic, and this fluid is subject to further cooling on exposure to ambient environmental conditions. This review examined the peer-reviewed literature to determine the available evidence for in-line fluid warmer effectiveness and potential inclusion in pre-hospital emergency care.

Methods
A review of the electronic literature, including the MEDLINE and EBSCOhost databases was conducted using the terms 'intravenous fluid warmers', 'hypothermia', 'trauma', 'fluid', 'coagulopathy', 'acidosis', 'hypothermia and trauma patients', 'accidental hypothermia', 'lethal triad' and 'trauma care'. Articles were included if they represented a study of in-line fluid warmers within the surgical, general hospital or pre-hospital emergency care settings. Articles not available in English or as full text were excluded.

Results
The review identified 23 relevant articles for analysis. Of note, up to 40% of trauma patients with signs of hypoperfusion were reported to arrive at hospital in a hypothermic state post-incident. Hypothermia plays a significant role in contributing to the 'triad of death' - a condition that results in poor patient outcomes and high mortality rates.

Conclusion
This review identified that current pre-hospital practice does not prescribe warmed fluid to the normothermic trauma patient. The review also identified that there is a need for in-line fluid warmers in ambulance practice to prevent or limit hypothermia and reduce patient morbidity and mortality associated with trauma.

Keywords
fluid warmer; pre-hospital; trauma

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Introduction

In-ambulance warmed fluid is indicated for use in the hypothermic patient, but not indicated for the trauma patient to prevent potentially life-threatening conditions, including the development of hypothermia. A literature review examining factors for morbidity and mortality in trauma patients was undertaken. The review considered the need for and efficacy of pre-hospital in-line fluid warmers for use during intravenous fluid administration to reduce morbidity and mortality for major trauma patients. Currently, warmed fluid is not indicated as a preventive pre-hospital treatment for normothermic patients to prevent the development of hypothermia.

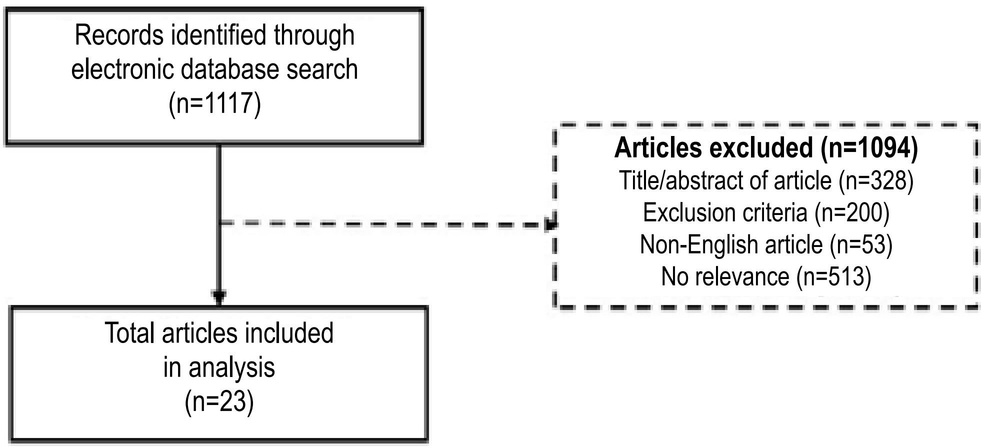
Methods

A review of the literature was undertaken utilising electronic databases including MEDLINE and EBSCOhost. Review articles and non-peer reviewed articles were excluded, as were those unavailable as full text or in the English language. Articles were accessed using the search terms ‘intravenous fluid warmers’, ‘hypothermia’, ‘trauma’, ‘fluid’, ‘coagulopathy’, ‘acidosis’, ‘hypothermia and trauma patients’, ‘accidental hypothermia’, ‘lethal triad’ and ‘trauma care’. The effectiveness of these in-line fluid-warming devices in preventing or limiting hypothermia was considered alongside the predicted effects on patient outcomes. All articles included were within 7 years of their publication date.

Results

A total of 23 articles were found to be relevant to the review (Figure 1). The included studies reported a likely progression to hypothermia in patients already compromised by trauma in ambient environmental conditions. The review also identified hypothermia as an independent factor in increasing morbidity and mortality among patients. Hypothermia was highlighted as a major contributing factor to the triad of death - a mortal condition where the patient is affected by hypothermia, metabolic acidosis and coagulopathy. The available literature demonstrated the need for, and the availability and practicality of some types of portable, compact in-line fluid warmers. These devices can reportedly be assembled and in use within minutes, and subsequently contribute to decreased morbidity and mortality in the trauma patient.

Figure 1. Search results



Discussion

Trauma is one of the leading contributors to worldwide morbidity and mortality rates and can be inflicted on a patient by a wide range of mechanisms in varied environmental settings (1). It is within these settings that paramedics are responsible for providing effective, timely and appropriate management to allow for transport to definitive care. Trauma care involves the use of both invasive and non-invasive interventions with the aim of restoring or maintaining physiological homeostasis wherever possible (2). The leading cause of trauma-related death is uncontrolled haemorrhage and its resultant hypovolaemic shock effects (3,4). This state of hypoperfusion induces a decompensating physiologic response to the reduced volume of circulating blood otherwise known as the ‘lethal triad’ (5).

The ‘lethal triad’ is defined by the presence of acidosis, hypothermia and coagulopathy, and as the name suggests, it plays a devastating role in patient mortality rates (6). Decreased circulating blood volume reduces cellular oxygen delivery, which in turn induces anaerobic metabolism and results in excessive production and build-up of lactate. This excessive volume of lactate causes systemic acidosis that impairs the coagulation cascade by inhibiting thrombin and clot formation (7). The acidotic state also has devastating effects on the cardiovascular system, renal and hepatic blood flow and can lead to multi-organ failure if not rectified (7,8). The addition of hypothermia to this situation severely exacerbates the negative effects of acidosis. Conversely, acidosis is reported to have little effect on the clotting cascade when normothermia exists (7).

Thermoregulation is also affected after a traumatic injury as the normal temperature threshold for hypothalamic intervention is lowered. The shivering reflex that occurs after significant progression of hypothermia is less effective in generating heat and hence hypothermia progresses further (5). The addition of hypothermia to an acidotic state complicates the final coagulopathic stage of the 'lethal triad'. Coagulopathy is defined as the presence of abnormal coagulation processes and is either due to a lack of available clotting factors or enzyme dysfunction caused by reduced temperature (4). It is accepted that trauma induced coagulopathy is directly affected by hypothermia and can commence at the time of injury or within 20 minutes of the injury (6,8). Severe traumatic injuries, including burns, can also invoke disseminated intravascular coagulation. This abnormal process causes small clots to form throughout the systemic vasculature that damage vessels and vital organs (5). The process consumes all available clotting factors and inhibits the body's ability to control haemorrhage (6). Hypothermia in the coagulopathic patient then predisposes the individual to other post-trauma conditions such as systemic inflammatory response syndrome, multiple organ dysfunction syndrome (MODS) and sepsis, all of which contribute to higher mortality rates (9).

A global consensus on the definition of hypothermia does not exist, however, the majority of studies agree that a core body temperature of less than or equal to 35°C signifies hypothermia (10). Trauma is a major risk factor for the development of hypothermia, however there are many more causes that can induce a hypothermic state, including hypoxia, hypotension, tachycardia and an altered Glasgow Coma Scale (11). Hypothermia among these patients may also result from a combination of environmental exposure (including body heat conduction when the patient is lying on the ground), blood loss from injury, heat loss through lessened motor activity of the injured patient and other factors such as patient clothing removal, energy loss and cool (ambient temperature) fluid administration (7,12). Lapostelle et al reported that infusion fluid temperature is a significant risk factor for hypothermia in trauma patients (13).

In the pre-hospital setting, prevention of hypothermia or limitation of the progression of hypothermia is often unrecognised or not well managed during treatment of a severely injured trauma patient. Those particularly at risk of developing hypothermia are patients with head injuries, moderate to severe burns, upper spinal cord injuries, penetrating injuries, the elderly, and patients under the influence of alcohol and/or drugs (2,14). Children have an inherently higher metabolic rate than adults and their body surface area to weight ratio is also higher which makes them more vulnerable to heat loss and subsequent hypothermia (15). Severely injured patients in the pre-hospital setting are often candidates for invasive airway management procedures such as intubation. This often involves temporary paralysis during rapid sequence induction procedures that predispose the patient to increased risk of body heat loss. Importantly, Langhelle et al and Lapostolle et al reported that patients who had been intubated before arriving at the hospital emergency department consistently had lower core body temperatures than those who had not been intubated (13,16). According to Andrzejowski et al, the administration of anaesthesia (including agents used for sedation and paralysis) for intubation can reduce the patient's core body temperature by 1.6°C via thermal redistribution (17). Additionally, the administration of room temperature intravenous fluids can add to this reduction in core temperature by 0.25°C each half hour period (18). This highlights another common area of paramedic practice that presents as a risk factor for the development or exacerbation of hypothermia. A study by Aitken et al reported that hypothermic trauma patients are not purely limited to presenting in cold climate environments (19). The study found that hypothermia affected a comparable portion of trauma patients in desert, sub-tropical or tropical climates as well, giving further credence to the direct correlation between trauma and hypothermia.

Hypothermia is common in trauma patients and the incidence increases with increased injury severity. It is reported that up to 40% of patients with signs of hypoperfusion post-trauma will go on to develop hypothermia (20). Lapostolle et al suggest that even if the level of hypothermia is moderate, the prognosis can be poor and the risk of mortality higher (13). This is of particular importance for patients who require surgical intervention, given that general anaesthesia inhibits the patient's endogenous control of thermoregulation and the associated behavioural reactions usually implemented to avoid heat loss (21). Peri-operative hypothermia has been stated to result in complications such as myocardial ischaemia, coagulopathies, increased infection of wounds, and increased length and cost of hospital stay (17).

The importance of maintaining patient normothermia is clearly recognised and embraced as the standard of care in hospitals. The relatively controlled setting of an operating theatre helps to limit the risk factors for patient hypothermia development or exacerbation. The National Institute for Health and Clinical Excellence (NICE) guidelines stipulate that the ambient theatre temperature should be at least 21°C when the patient is exposed (18). It is also recommended by Monzón et al that ambient theatre temperatures between 20–25°C mitigate the risk of hypothermia (21). Additionally, the NICE guidelines recommend that all administered fluids be warmed to 37°C, hence most theatres have access to warming cabinets or use in-line fluid warmers to achieve this. The use of forced-air warming blankets is also standard practice in many hospitals (18,21).

The current use of non-warmed fluid for trauma patients in the pre-hospital setting, along with the multitude of other previously mentioned risk factors demonstrate the high likelihood of the trauma patient developing life-threatening hypothermia.

It is accepted that the temperature of non-warmed fluid being infused to trauma patients is classed as a risk factor in causing the development of hypothermia (13). It is also reported that environmental conditions once thought to contribute to hypothermia in patients are in fact more likely to be causing hypothermia through the influence they have on fluid temperature (13). Preventing the onset of hypothermia is paramount to providing best outcomes for patients. This prevention must begin as closely as possible to the time of injury, must aim to keep body temperature above 35°C, and relies on all providers in the chain of care (2,7). At the forefront of this chain of care is the ambulance service. The administration of warmed fluid in the setting of paramedic management of severe trauma patients would constitute an improvement to clinical practice. Paramedic use of in-line fluid warmers would provide reduction of risk (mortality and morbidity) through enabling the temperature of fluid to be accurately controlled and maintained.

A stable working environment and controlled ambient temperature is not something that can easily be achieved in the pre-hospital setting to maintain patient body temperature. The use of forced air-warmers does not present as a viable option in paramedic care as the machines require a constant power source, they are bulky and not readily portable (21). Current paramedic practice for management of the hypothermic patient comprises both passive techniques such as the use of blankets, space blankets, removal of wet clothes and heating the ambulance, and active techniques such as the administration of warmed fluid (22). A Norwegian study suggested that the vast majority of ambulance vehicles, helicopters and fixed-wing aircraft have heated storage cabinets in which the fluids are kept, however, it was found that ambient temperature changes had a significant impact on heat loss from both the infusion bag and intravenous giving set during administration and resulted in fluid cooling (20). It was further concluded by Karlsen et al that even warmed fluid would not reach the patient at near body temperature without special equipment (20). This is supported by Wheeler et al who suggested that blood administration during helicopter transfers correlated to a six-fold increase in the incidence of hypothermia, compared to those who did not receive blood (12). This is primarily due to an inability to maintain adequate insulation of the infusion bag and an inability to monitor fluid temperature at the cannulation site (23). The use of intravenous in-line warmers such as the enFlow™ or buddy lite™ systems could help to eliminate these issues as the unit can be inserted into the giving set within centimetres of the cannulation site. Warmed fluid administration can be achieved in seconds by the enFlow™ system at flow rates of to keep vein open to 200 mL/min. Warmed fluid administration can also be achieved in seconds by the buddy lite™ system at 80 mL/min, which could be of particular use for management of paediatric patients who often require significantly smaller fluid infusion volumes and rates (18). The fluid is heated to 42°C to allow for minor cooling between the unit and cannulation site (dependent on ambient temperature) to deliver fluid at a minimum of 35°C. Both the enFlow™ and buddy lite™ units are compact, portable, quick to set up and easy to use. The advantage of the buddy lite™ system is that it does not need a mains power source and is able to operate from cartridges (18). This makes it ideal for the pre-hospital setting where available space and time are limited (22). This evidence suggests that in-line fluid warmers are a viable option to provide consistent and accurate administration of warmed fluid to the normothermic or hypothermic trauma patient (with the exception of barotrauma), resulting in beneficial outcomes (24).

Attempts were made to contact manufacturers for a unit price for devices suited to the pre-hospital setting; however none had responded by completion of this review. The retail price of a disposable warmer pack is approximately A$25. Further investigation is required to identify accurate costings, and it is likely that bulk orders and improvements in technology will create potential for a reduction in this figure.

Limitations of this study

This review did not evaluate the cost considerations of the provision of in-line warmers by the ambulance service or the ongoing costs of maintaining the units, nor does this review address the costs of training ambulance staff in the operation of the in-line fluid warmers.

Conclusion

This review identified that hypothermia in the major trauma patient increases morbidity and mortality both in conjunction with, and independently of, other risk factors. Correcting or hindering the progression of hypothermia is not currently at the forefront of ambulance management of the severely injured trauma patient. Emerging research is demonstrating that this crucial aspect of trauma management should be receiving more attention, as the implications of not managing or preventing hypothermia can be devastating. The early resolution or prevention of hypothermia in these patients through the use of in-line fluid warmers would reduce patient morbidity and mortality by providing consistent and accurately warmed fluid. The portable, battery operated in-line fluid warming devices are ideal for use in the pre-hospital field and present as a viable option to initiate appropriate and timely care for the trauma patient.

Conflict of interest

Gavin Smith is an Associate Editor of the Australasian Journal of Paramedicine.

The authors declare they have no competing interests. Each author of this paper have completed the ICMJE conflict of interest statement.

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