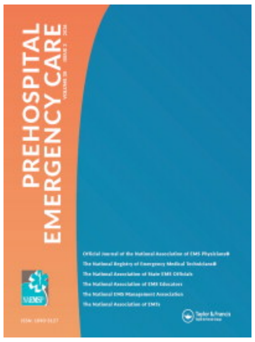

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ABSTRACT

Objectives: Heat stroke is a life-threatening condition requiring rapid recognition and immediate cooling. Cold water immersion (CWI) is the most effective cooling modality; however, its adoption and use by emergency medical services (EMS) agencies has been limited and described primarily in case reports. In 2024, the Phoenix Fire Department (PFD) implemented a novel rapid-cooling bag and protocol for prehospital CWI across a large urban area. This study describes the implementation, patient characteristics, cooling effectiveness, and clinical outcomes of the program.

Methods: This retrospective observational study included adults with heat stroke who were treated with the PFD prehospital CWI protocol between May 1 and September 30, 2024. Prehospital, emergency department (ED), and inpatient data were evaluated from EMS charts and electronic medical records across four hospital systems. Descriptive statistics summarized demographics, treatment characteristics, cooling duration, temperature change, neurologic trajectory, and outcomes.

Results: One hundred and eighty-three patients met study criteria as having a tympanic temperature of at least 40 °C with central nervous system dysfunction, attributable to or associated with environmental heat exposure. The median prehospital tympanic temperature was 41.4° ± 0.9 °C, and nearly one-third presented with temperatures above 42.2 °C. Median prehospital immersion time was 13.5 min (9–17.8, range 5–66). Prehospital time was defined as care provided outside the hospital prior to ED arrival and transfer of care. Temperature decreased from prehospital to emergency department arrival in 72.1% of patients with an average decrease of 2.0 ± 1.5 °C. The median GCS increased from prehospital, 8 (4–10), to hospital arrival, 9 (3–14), and hospital discharge, 15 (14–15). Survival decreased with increasing prehospital temperature and was lowest among those presenting at or above 42.2 °C. One hundred and twenty-seven (69.4%) patients were discharged neurologically intact (GCS = 15).

Conclusions: A prehospital CWI protocol is feasible in a large urban EMS system and provides rapid temperature reduction and improved neurologic status in patients with heat stroke. The findings suggest a meaningful clinical benefit and broad operational feasibility. Further prospective, multicenter studies are needed to define the resulting impact, optimize workflows, and guide wider adoption of prehospital immersion cooling.

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Introduction

Early recognition as well as rapid treatment and transport of patients with heat stroke in the prehospital setting is critical. Heat stroke is a medical emergency characterized by a rapid rise in core body temperature above 40 °C (104 °F) that overwhelms the body's thermoregulatory mechanisms, resulting in organ and central nervous system dysfunction (1,2). The pathophysiology of heat stroke is complex and involves a cascade of physiological alterations that affect multiple organ

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systems (3). The downstream damage of skeletal muscle, cytokine release, organ dysfunction, and coagulopathy in heat stroke underscores the importance of early intervention to prevent irreversible damage and mortality (4,5). Published estimates of heat stroke mortality vary widely due to the heterogeneity of the data used to derive these numbers, as well as variations in the type of heat stroke. Exertional heat stroke has a mortality rate of approximately 33% in the absence of prompt medical intervention. In comparison, classic heat stroke, which occurs after prolonged exposure to high ambient temperatures and is often associated with underlying chronic conditions, has mortality rates that may approach 80% (6).

Rapid recognition, assessment, and initiation of cooling are essential, as early diagnosis and immediate intervention, along with rapid cooling, are vital for reducing morbidity and mortality (7,8). The duration of exposure to elevated temperatures and the maximum body temperature are significant risk factors for heat-related mortality (9,10). Common techniques for reducing temperature include cold water immersion (CWI), cold IV fluids, soaked sheets or towels, use of misters and fans, directly pouring water on the patient, localized ice packs, or providing shade or rest (11). Compared with multiple cooling techniques, cold or ice water immersion results in the most rapid cooling (2,11,12).

Various methods for effectively performing CWI have been described across prehospital, emergency department, and event medicine settings, each shaped by available resources, patient access, and operational constraints. Traditional approaches include large-tub immersion, which provides excellent surface-area contact but requires significant space and setup, and Tarp-Assisted Cooling with Oscillation, which offers a flexible, low-cost option that can be rapidly deployed in austere or prehospital environments (2,13–16). In addition, enclosed systems ranging from traditional "body bags" to specifically designed products have been increasingly described, where a patient is placed within a waterproof container filled with ice and water to facilitate rapid conductive heat transfer while allowing continued access for monitoring and care (17–21).

The importance of CWI in sports medicine is widely recognized and has been reported, including descriptions of applications and consensus statements encouraging its use in the management of exertional heat stroke (2,16, 22–25). However, these same strategies must be used in all patients with heat stroke, even those who may have compounding complications, which are not exclusively due to exertion. Anecdotally, many of these techniques for prehospital cooling by emergency medical services (EMS) have been explored. However, CWI is increasingly recognized not only as a viable initial treatment option for heat stroke but also as the gold standard (26,27). Despite growing interest among EMS entities, information on the implementation and outcomes of EMS-based treatment and transport protocols centered on CWI, including hospital input and continuation of care outside athletic events or event medicine, is limited to case reports or case series (21,28).

The Phoenix Fire Department (PFD) is the fifth-largest fire-based EMS department in the United States (U.S.). It is the largest fire-based EMS agency in Maricopa County, with the highest service delivery demand for heat-related incidents requiring emergency care. Spurred by the need to find more effective cooling modalities for their patients and the lack of clear data on the effectiveness of current cooling methods, the PFD developed and piloted a prehospital CWI protocol in the summer of 2024. This study was designed to describe the deployment and impact of CWI for acute heat stroke on patient outcomes.

Methods

Study Design, Population, and Setting

This study is a retrospective observational description of acute prehospital heat stroke-associated adult presentations who received the PFD Ice and Cold Water Immersion Protocol between May 1st, 2024, and September 30th, 2024. Patient encounters were matched and tracked by the research team from the prehospital setting through hospitalization to outcome and disposition.

The study was conducted across four large, urban, multi-site health care systems, and data were collected only from patients who were transferred by PFD EMS to these facilities. Each ED employs a variety of approaches to patient cooling, including non-immersion (e.g., cold towels, ice packs, fans) and CWI. The selection, deployment, and cessation of cooling therapy in the ED were at the discretion of the treating emergency medicine (EM) physician and in accordance with each hospital's protocols. Each system received IRB approval, with some systems entering into an IRB Reliance Agreement with the Valleywise Health IRB Protocol #2024-043, while other systems' IRBs directly reviewed and approved the protocol.

Selection of Participants

Adult patients aged ≥ 18 years old, who met the PFD prehospital heat stroke CWI inclusion criteria from May 1 to September 30, 2024, were included as study participants. Heat stroke was defined as the combination of a tympanic temperature ≥ 40 °C and central nervous system dysfunction defined as a Glasgow Coma Scale (GCS) <15 attributable to or associated with environmental heat exposure. Pediatric patients less than 18 years of age at the time of ED presentation and adult patients with presentations that could not be attributed to heat stroke after chart review were excluded from analysis.

Demographic information and data on the prehospital, ED, and inpatient courses were collected through chart extraction. Information regarding the prehospital treatment and management, as well as on-scene event recording, was extracted from PFD EMS run sheets. We operationally defined prehospital time as clinical assessment and care delivered by the prehospital team outside the hospital setting, prior to arrival and transfer of care to the ED team. Study investigators extracted data from each institution's electronic medical record (EMR). The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines were used during study design and manuscript development (29). Clinically experienced EM physicians were identified from the study investigators and trained on the study protocol before data collection, with ongoing education and review as needed. Data collection utilized a standardized abstraction form. Study investigators extracted data from the encounters that met the study inclusion criteria, and investigators adjudicated discrepancies or disagreements. Data from each site were entered into a shared Research Electronic Data Capture (REDCap) repository and were accessible to the hosting hospital, Valleywise Health, and the statistician.

Recorded demographics included patient age, gender, housing status, primary heat illness diagnosis, and documented comorbidities. The prehospital course included dispatch time, vital signs, initial prehospital tympanic temperature, prehospital GCS score, presence of prehospital cardiopulmonary arrest, airway management, cooling duration, and narrative information regarding the circumstances of the heat exposure. The ED course included vital signs, arrival date and time, length of stay (LOS), maximum core temp obtained by rectal, esophageal, or urinary catheter measurement (Tmax), ED GCS, ED intubation, urine drug screen (UDS) results, whether cardiopulmonary arrest occurred in the ED, ED cooling methods and duration, and ED disposition (admit, discharge, death). Hospital course included admission location, including intensive care unit (ICU), disposition (discharge or death), LOS, and neurologic status at the time of hospital disposition (GCS). Hospital and EMS data were linked using the EMS patient identification number.

Implementation of Protocol by EMS

The development and implementation of widespread CWI therapy for acute heat stroke began in 2023, when PFD Paramedic Captains explored various techniques for rapidly cooling patients experiencing heat stroke. After consulting with local physicians and the PFD medical directors, crews initially began using ice and tarps to immerse and rapidly cool patients during heat-related emergencies. While this approach was practical, it introduced new challenges. Particularly, the difficulty in containing the resulting ice water slurry and managing the potential exposure to contaminated water. Training captains, with support from the PFD medical directors, next began researching commercially available rapid-cooling bags to enhance the field treatment for heat emergencies, while minimizing exposure and contamination. These products range from a “body bag”- style product to purpose-built devices designed to facilitate CWI and rapid cooling during heat stroke.

Several practical features were prioritized during the development process and refinement of the cooling product. The ideal product should be relatively inexpensive to purchase multiple units, given the likelihood of frequent seasonal use. It should be rapidly deployable with minimal assembly, easily stored within the limited space of an ambulance, and durable enough for repeated field use. Waterproof construction is essential to prevent leakage during transport, and a lightweight design supports efficient handling by crews while minimizing the burden of additional equipment. Finally, the product should be appropriately sized and shaped to accommodate most adults while still allowing effective patient access for monitoring, airway management, and ongoing resuscitation as needed. The team developed several prototypes until the Rapid Cooling Bag (Taylor Healthcare Products, Spring, TX) was finalized and adopted. The Rapid Cooling Bag measures seven feet in length and features reinforced zippers, durable handles, and double-welded seams. It is engineered to handle the combined weight of a patient, ice, and slurry, accommodating varying patient sizes and field conditions.

In addition to developing the Rapid Cooling Bag, updated treatment guidelines for hyperthermia and rapid cooling procedures were created. The procedures specify that any patient with an altered mental status and a tympanic temperature of 40˚C or higher is a candidate for immersion treatment. Patients meeting these criteria will have CWI initiated immediately in the prehospital setting prior to placement in the ambulance, absent scene problems or hazards, and will not remain on scene until cooling is completed. CWI, along with other standard treatment measures that are initiated on scene, will be continued during transport to the receiving hospital.

The PFD implemented the CWI guideline and infrastructure as the department’s standard of care in May 2024 (Figures 1 and 2). The PFD experiences a higher number of hyperthermic patients during peak summer heat. Infrastructure included freezers at fire stations and coolers on EMS vehicles to ensure continuous availability of ice and water in appropriate volumes for immersion. Before 2024, the use of cold water baths and ice water immersion was limited. In early 2024, the PFD delivered department-wide training on the Ice and Cold Water Immersion Protocol to all 2,000 members (Figure 3). This training was delivered prior to the 2024 heat season and included both classroom instruction and hands-on practice with the Rapid Cooling Bag.

The Ice and Cold Water Immersion Protocol was launched in the summer of 2024, which saw record-breaking temperatures in Phoenix: the highest average maximum environmental temperature (Tmax), 44.6˚C, and minimum temperature (Tmin) of 32.1 °C, occurred in July. The lowest average temperature occurred in May with Tmax of 35.9 °C, and Tmin of 21.6 °C (30). As a result of this large heat burden, Maricopa County identified a total of 608 heat-related deaths, three out of four of which occurred outdoors (31).

Analysis

This study was designed as a descriptive analysis of prehospital heat stroke presentations occurring during the study window. Patients with acute heat stroke were identified and described, including patient demographics, diagnostics, and therapeutic cooling interventions. Before study commencement, representatives from each hospital system met to discuss the study protocol, variables to be collected, and the start and end dates for the study period. Data sharing

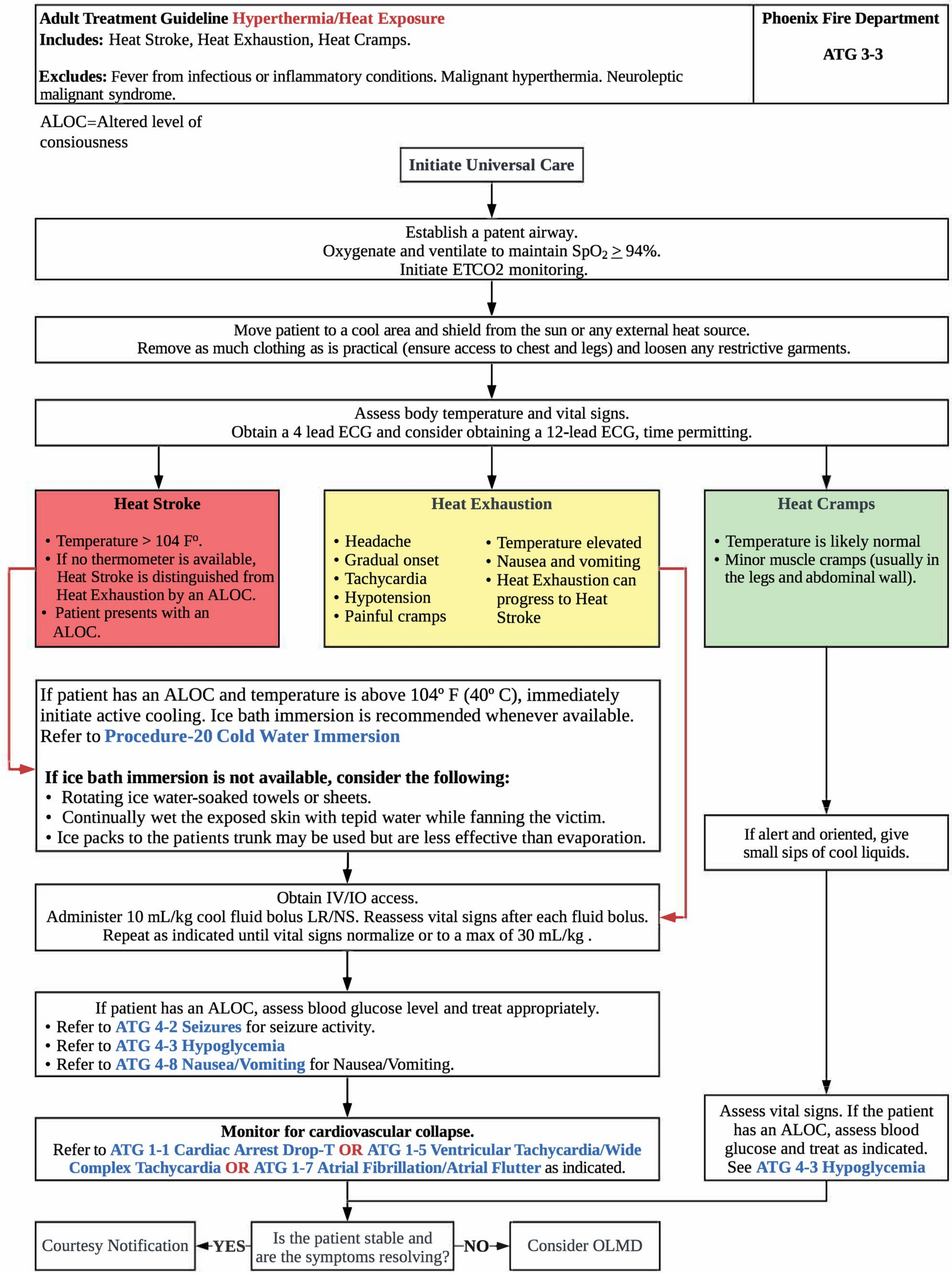

Figure 1. Phoenix fire department treatment guideline hyperthermia 2024.

agreements were approved by each hospital system as well as the PFD. The principal investigator's hospital system served as the data coordinating center.

Data were reported using means with standard deviations for continuous variables or medians with 25th and 75th quartiles when skewed. Counts with percentages were reported for

Procedure Cold Water Immersion **Indications:** Heat Stroke • Temperature > 104° F (40° C) (tympanic) • Patient presents with an ALOC (altered level of consciousness) • If no thermometer is available, Heat Stroke is distinguished from Heat Exhaustion by an ALOC	**Phoenix Fire Department** **Procedure 20**

If patient temperature is above 104° F (40° C) and has an ALOC, immediately initiate active cooling.
Cold Water Immersion is recommended whenever available.

↓

Refer to **PTG 3-3 Hyperthermia/Heat Exposure** **OR** **ATG 3-3 Hyperthermia/Heat Exposure**

↓

If Cold Water Immersion is indicated, begin the process as quickly as possible.
Utilize ice from any nearby apparatus. Ideally aim for as many as 6 - 8 bags of ice if available.
If you are special calling a rescue, ask the alarm room to send a message to the dispatched rescue requesting they bring additional ice to the scene. Be resourceful when needed; gas stations, shelters, bars, restaurants, hotels etc.

↓

Fully expose the patient's chest and legs prior to placing the patient in the Rapid Cooling Bag.

↓

When possible, don't wait for the rescue to be on scene to initiate rapid cooling measures.

1. Place your Rapid Cooling Bag on the ground/gurney and fully open the zipper.
2. Pour a base layer of 3 - 4 bags of ice into the Rapid Cooling Bag.
3. Place patient in the Rapid Cooling Bag in a supine position.
4. Pour an additional 3 - 4 bags of ice on top of, and around the patient, leaving the chest and face exposed.
5. Close the zipper up to the patients mid chest, (allowing for cardiac monitoring). Submerge arms in ice. Remove for IV access or monitoring
6. Lifting the patient from the ground onto the gurney using the handles of the Rapid Cooling Bag is acceptable.
7. Raise the head of the gurney approx 30° and keep the chest area clear/dry (allowing for cardiac monitoring).
8. If cardioversion/defibrillation is indicated, clear as much ice/water as possible off of the patient before energy delivery.

Pour a base layer of 3 - 4 bags of ice into the Rapid Cooling Bag. →

Place patient into Rapid Cooling Bag and add an additional 3 - 4 bags of ice on top of, and around the patient, leaving the chest and face exposed. →

Ice bag sizes may vary. Add as much ice as needed to cover the patient's body surface area

Raise the head of the gurney approx 30° and keep the chest area clear/dry to allow for cardiac monitoring. →

Figure 2. Phoenix fire department CWI protocol 2024.

Figure 3. Phoenix fire department CWI training.

ordinal and dichotomous variables. For cooling duration, data were presented using means, medians, minimum, and maximum values. Prehospital temperature and GCS at hospital arrival were missing for one case each. Spearman's rank correlations were used to assess the association between cooling duration, GCS score, and prehospital temperature. Statistical analyses were completed with SPSS version 29 (IBM Corp.; Armonk, New York, USA).

Results

From May 1 to September 30, 2024, 304 patients underwent prehospital CWI with PFD. Of these, 196 were transported to the participating hospital systems. Fifteen of these patients did not meet study inclusion criteria due to an initial prehospital GCS of 15, leaving 183 total patients for study inclusion.

Table 1 outlines the demographic characteristics and selected key outcomes. A majority of patients were male (84.7%) with an average age of 47.5 ± 18.5 years. 10.4% of patients were aged 65 years or older. 55% of patients were experiencing housing insecurity. Urine toxicology results were most commonly positive for methamphetamine (60.1%), followed by opiates/fentanyl (50.8%) and Marijuana (21.9%). Notably, it was not possible to consistently determine if opioids or benzodiazepines were administered by EMS or ED staff before testing, which may result in over-reporting of these drugs. A documented history of substance abuse (30.3%) or behavioral health disorders (13.7%) was frequently found in this patient population. Ninety-seven (53%) patients were intubated, 8 in the prehospital setting and 89 in the ED. Prehospital and hospital cardiac arrest was observed in 16 (8.7%) and 28 (15.3%) patients, respectively. Fourteen of the 28 patients who had a cardiac arrest in the hospital also arrested in the prehospital setting.

Table 1. Patient demographics.

Demographics	$N = 183$, count (%) or mean ± SD
Gender, male	155 (84.7%)
Age	47.5 ± 18.5 (range, 20:81)
Housing insecurity	102 (55.7%)
Urine toxicology results	
Benzodiazepine	34 (18.6%)
Cocaine	8 (4.4%)
Methamphetamines	110 (60.1%)
Opiate/fentanyl	93 (50.8%)
Marijuana	40 (21.9%)
Documented comorbidities	
Cancer	2 (1.1%)
Diabetes	8 (4.4%)
Cardiac disease	21 (11.5%)
Behavioral health disorder	25 (13.7%)
Obesity	19 (10.4%)
Other	18 (9.8%)
Renal disease	3 (1.6%)
Respiratory disease	9 (4.9%)
Smoking history	7 (3.8%)
Substance abuse history	72 (39.3%)
Intubation	
Prehospital	8 (4.4%)
Hospital	89 (48.6%)
None	86 (47.0%)
Cardiac arrest	
Prehospital	16 (8.7%)
Hospital	28 (15.3%)

Prehospital EMS dispatch occurred most frequently between the times of 1200–1759 (66.1%), followed by 1800–2359 (18.0%), 0600–1159 (13.1%), and 0000–0559 (2.7%). A description of temperature management is included in Table 2. The median prehospital (tympanic)

Table 2. Prehospital and emergency department temperature management.

	Descriptive analysis
Temperature (mean ± SD °celsius)	
Initial Prehospital	41.4 ± 0.9 °C
Initial Hospital	40.1 ± 2.0 °C
Temperature Improvement, Count (%)	132 (72.1%)
Average Temperature Improvement, Overall	2.0 ± 1.5 °C
Average Temperature Improvement, Prehospital	1.3 ± 1.8 °C
Average Temperature Improvement, Hospital	1.0 ± 1.7 °C
Cold Water Immersion	
Total Cold Water Immersion Duration (Median, 25th-75th Percentile)	26 (18–35)
Prehospital Cold Water Immersion Duration (Median, 25th-75th Percentile)	13.5 (9–17.8)
Hospital Cold Water Immersion Duration (Median, 25th-75th Percentile)	11 (3.3–19.8)

Prehospital temperature = tympanic and Hospital temperature = Rectal or temperature-sensing urinary catheter.

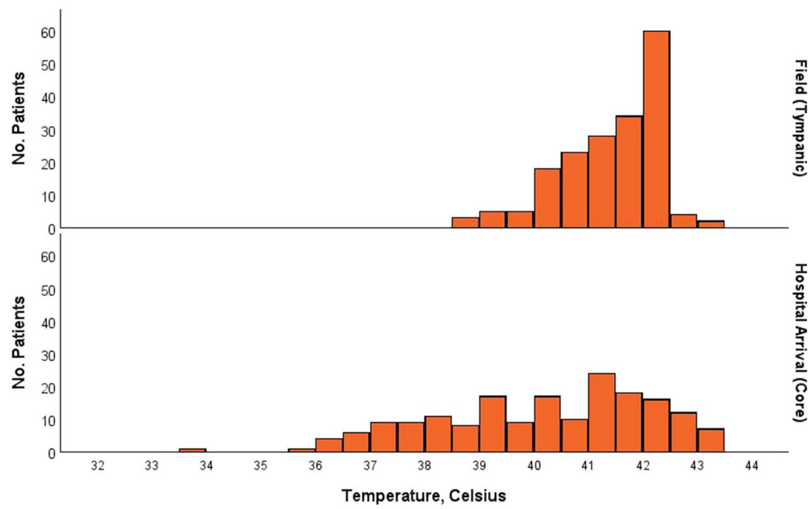

Figure 4. Prehospital to emergency department temperature.

and hospital (core) temperatures were 41.4 ± 0.9 °C and 40.1 ± 2.0 °C, respectively. There were 59 (32.4%) patients who had a prehospital temp of >42.2 °C. Prehospital-to-ED temperature reduction was calculated in 178 patients and revealed improvement in 132 (72.1%) patients, with an average decrease of 2.0 ± 1.5 °C ($p < 0.05$). Prehospital, hospital, and total median CWI duration were 13.5 (9–17.8, 25th-75th percentile (5–66), 11 (3.3–19.8, 25th-75th percentile 1–37), and 26 (18–35, 25th-75th percentile 1–48), respectively. Patient cooling duration was negatively correlated with prehospital GCS score $r(182) = -0.271$, $p = 0.004$, and positively correlated with prehospital temp $r(182) = 0.348$, $p < 0.001$. Prehospital-to-ED temperature distribution is shown in Figure 4.

Patient outcomes are demonstrated in Table 3. The median ED and hospital length of stay (LOS) were 5.5 (3.5–12.5) hours and 4.0 (2.0–7.0, range 1–102) days, respectively. There were 64 (35.0%) patients who were admitted to the ICU, where the median LOS was 3.0 (1.3–5.0, range 1–26) days. The median hospital LOS was 4.0 (2.0–7.0) days. A majority of patients were discharged home (41.5%), followed by skilled nursing facility, rehabilitation, or long-term care facilities (24.0%). A total of 35 (19.1%) patients died. Zero patients who experienced prehospital intubation or cardiac arrest survived to hospital discharge. Survival was lowest in those with a prehospital temp of ≥ 42.2 °C (67.8%) but improved as prehospital temp decreased (≥ 41.6 °C 75.8%, ≥ 41.1 °C 78.0%, ≥ 40.6 °C 80.1%). 127 (69.4%) patients were discharged neurologically intact (GCS of 15).

Table 3. Patient outcomes.

	Descriptive analysis (count, percentage)
Intensive care unit admission	64 (35.0%)
Hospital disposition	
Against Medical Advice	20 (10.9%)
Died/Hospice	35 (19.1%)
Home	76 (41.5%)
Other	8 (4.4%)
Skilled Nursing Facility, Rahab, or Long-Term Care Facility	44 (24.0%)
Outcome	
Death	35 (19.1%)
Survival	148 (80.9%)
Glasgow Coma Score 15 at Disposition	127 (69.4%)

Forty-three (23.5%) patients had a prehospital GCS of 3. The median GCS increased from prehospital, 8 (4–10), to hospital arrival, 9 (3–14), to hospital discharge, 15 (14–15). Notably, 12.5% of patients had a prehospital GCS ≥ 13 compared with 77% at hospital disposition. Figure 5 demonstrates the shift in GCS distribution from the left (poor GCS) to the right (high GCS) from the prehospital setting to hospital disposition.

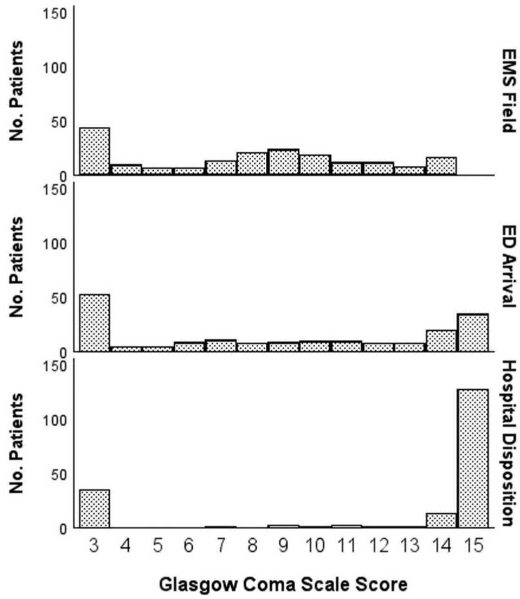

Figure 5. Prehospital to hospital disposition Glasgow Coma Scale distribution.

Discussion

This study provides the first large-scale evaluation of prehospital CWI for heat stroke in a major U.S. metropolitan city. One hundred eighty-three adult patients with heat stroke met the inclusion criteria and were treated through implementation of the PFD CWI protocol. The findings demonstrate successful reduction in body temperature, improvement in GCS scores during their hospital stay, and favorable survival outcomes in patients with heat stroke.

The demographic profile of the cohort reflects the evolving epidemiology of urban heat stroke, with a majority of patients being middle-aged men and more than half experiencing housing insecurity. The high rate of positive urine toxicology for methamphetamines and opioids suggests that substance use may be an additional cofactor contributing to both exposure risk and physiological vulnerability. Rapid and aggressive cooling is strongly linked to better outcomes in heat stroke. Faster reductions in core body temperature within the first hours of care are associated with lower mortality and fewer organ injuries in clinical cohorts and modalities that achieve rapid cooling are far more likely to result in survival without medical complications than slower cooling methods. These findings highlight the value of early, prehospital intervention rather than waiting for hospital-based management (32,33).

Nearly one third of patients had prehospital temperatures above 42.2 °C, and 43 patients (23.5%) presented with a GCS of three, reflecting significant CNS dysfunction. Despite significant clinical severity at presentation, prehospital CWI resulted in a measurable physiological improvement, with an average prehospital-to-ED temperature difference of 2 °C, and evidence of continued cooling throughout hospital care. In addition, most patients (72.1%) demonstrated a reduction in temperature during EMS care, supporting the operational efficacy of immersion cooling under field conditions. However, given that prehospital temperatures are primarily obtained peripherally and likely underestimate accurate core temperature, we feel that the actual degree of physiological benefit from cooling is probably greater than our reported data show. Furthermore, since many patients were removed from the CWI process when they reached the ED but still showed consistent improvements in GCS across the care continuum, prehospital CWI effectively stopped the continued heat effect and decreased the total time the patient was experiencing elevated body temperature.

Median GCS improved from 8 in the prehospital phase to 9 upon ED arrival and to 15 by hospital discharge, with nearly 70% of patients discharged neurologically intact. However, in the context of this study, GCS was used as a longitudinal measure of neurologic recovery; it should not be used alone to diagnose heat stroke or to guide cooling decisions (34). Instead, it should serve as a supplement to core temperature measurement, as GCS can vary widely, correlates poorly with core temperature, and altered mental status manifestations in heat stroke present with substantial variability (35,36).

Mortality was highest among those with the most severe initial presentations, particularly those with temperatures greater than 42.2˚C or those with prehospital cardiac arrest, none of whom survived to discharge. This further supports early temperature reduction as a key modifiable factor. Survival improved steadily as the presenting temperature decreased. This gradient of survival relative to hospital presentation provides additional evidence of the protective effect of prehospital CWI.

Available data on hospital or ICU LOS in heat stroke are limited. A meta-analysis of 63 studies evaluating cooling techniques for heat stroke and exertional hyperthermia found that hospital LOS was largely unreported in the literature (7). One subsequent study analyzing an extensive inpatient database reported a median hospital LOS of 2 days (37). In contrast, our cohort demonstrated a median hospital LOS of 4 days. Several factors may account for this discrepancy, most notably differences in illness severity between study populations. In the inpatient database study, Kaewput et al reported invasive mechanical ventilation in 686 of 3372 patients (20.3%), whereas in our cohort, 97 of 183 patients (53.0%) required intubation (37). Given that our patient population was presumably more critically ill, an extended hospital LOS is not unexpected. Further research incorporating a broader range of disease severity is warranted to clarify the relationship between rapid cooling and hospital outcomes in heat stroke.

CWI Implementation

During implementation, several operational challenges were identified. The most notable was access to sufficient ice. A fire apparatus typically carries only 15–20 pounds of ice, which melts quickly during summer months and requires frequent restocking. This issue was mitigated in several ways. Crews often obtained ice from local convenience stores, either through donation or rapid reimbursement after treatment completion. Ice storage was also an issue, and portable coolers were added to EMS trucks to enable rapid ice transport. As a part of implementation, the PFD Dispatch Center (alarm room) began proactively identifying potential heat emergencies during call processing. Prehospital telecommunicators notified crews that a call was heat-related, enabling them to load additional ice from station freezers before responding. In some cases, first-arriving units also requested that responding ambulances bring extra ice when needed.

Importantly, agencies adopting CWI protocols should recognize that there are multiple feasible ways to mitigate these challenges while still obtaining effective cooling performance. Options include using water at modest temperatures or ice packing without added water, both of which can achieve clinically meaningful rectal temperature cooling rates (17,38). Departments should evaluate locally available resources, storage constraints, and workflow to determine the most practical fill method and should consider structured training and quality review to optimize cooling performance within their operational context.

Another challenge involved temperature monitoring. Standard tympanic thermometers carried by crews can overheat in extreme conditions and may not register critically high patient temperatures. It is known that there are significant barriers to using peripheral temperature identification strategies, including underestimation of the core temperature. Rectal temperature remains the gold standard for identification of heat stroke (12,16,26). However, several reasons have been cited for challenges in obtaining rectal temperature in the prehospital setting, including the need to undress patients in uncontrolled environments, limited space in ambulances, patient discomfort or refusal, and the invasive nature of the procedure, particularly in conscious patients (39,40). These limitations are not unique to PFD. Many ambulances lack equipment designed for accurate core temperature measurement, further limiting feasibility in the field (40). In one review, only 10% of respondents in a study had access to a rectal thermometer in their emergency response vehicle (41). In this protocol, tympanic temperature measurement was selected to support a theoretical high utilization rate across the entire department, ensuring that the focus of the CWI process was on the adoption of the immersion process rather than on the temperature measurement component. Esophageal monitors were considered; however, due to challenges with prehospital placement, this method was not widely adopted. To address challenges in temperature measurement, the protocol allows immersion treatment based on clinical presentation, specifically for patients with signs of heat stroke, such as hot skin and altered mental status.

Furthermore, the use of GCS for identification has significant challenges as discussed previously. It was incorporated into protocol development as a pragmatic and widely understood tool to promote high sensitivity for identifying altered mental status and trigger rapid cooling in a time-critical disease, recognizing that early treatment outweighs diagnostic precision in the field. While GCS lacks specificity and should not be used as a sole diagnostic marker for heat stroke, it provides a common language for EMS to identify concerning neurologic dysfunction and initiate cooling early and rapidly. Improving mental status or GCS should not be used in isolation to establish the diagnosis of heat stroke, but instead as a supportive element alongside the core definition of elevated body temperature with altered mental status. Additionally, neurologic improvement alone should not be used to justify discontinuing active cooling, as clinical recovery may precede an adequate reduction in core temperature. As this protocol goes through further development and refinement, additional core temperature strategies, as well as other descriptors of altered mental status, are being explored and tested to better align with guideline recommendations.

Finally, concerns were raised regarding the ability to monitor and treat patients while immersed. However, due to the bag's design, access to the head, torso, and arms was maintained, allowing continuous care. The bag effectively contains ice and slurry without leakage, thereby preventing exposure to biohazards from contaminated water. As EMS systems vary widely in call volume, staffing, transport times, available storage space, and medical oversight, agencies interested in applying similar protocols are encouraged to evaluate available options and select a product that best aligns with their operational needs, budget, and clinical scope.

The implementation of this protocol was well-received and quickly adopted within the PFD and represents a treatment truly born of the experience and innovation of field members. Each use of the Rapid Cooling Bag was evaluated for both appropriateness and effectiveness. Additionally, incidents in which the treatment was indicated but not utilized were reviewed to determine the reason. The most common limiting factor was access to ice. Patients treated for heat-related emergencies were typically transported to the nearest facility. The abundance of local hospitals and the engagement of major urban medical centers enabled crews to deliver patients rapidly to the most appropriate destination for continued care. Furthermore, the continuation of CWI in local EDs and collaboration on patient care through information sharing and process meetings with both EMS and ED stakeholders enabled further evaluation and outcome reporting.

Limitations

This study has several limitations related to the retrospective study design that may reduce confidence that these improvements are directly attributable to the intervention. For example, unmeasured confounding variables such as the time the patient was under duress, illness severity, response times, or concurrent treatments may have impacted patient outcome.

The determination of the GCS score relies on clinical judgment and has some degree of subjectivity. In this study, we were unable to assess the intra-rater or inter-rater reliability of prehospital or hospital staff. Future studies should address these psychometric properties.

Additionally, the retrospective chart review process conducted at four separate hospitals and across multiple electronic health record systems introduces potential variability. Data abstraction depended on hospital and EMS documentation, which may vary in completeness and terminology.

Temperature measurement itself was a significant challenge throughout the data collection period, as tympanic prehospital readings obtained in the field likely underestimate the core body temperature. As a result, the correct patient temperature and the degree of temperature reduction achieved from prehospital to in-ED core temperature measurements are challenging to report with confidence. Some patients with heat stroke physiology may register temperatures below treatment thresholds and be misclassified as having less severe illness, potentially contributing to undertriage and delayed cooling initiation. While these values were analyzed descriptively, this limitation makes the precise determination of cooling duration challenging. This measurement limitation is likely the reason several patients experienced a temperature increase upon hospital arrival after prehospital CWI. However, a potential underestimate of accurate core body temperature underscores the striking findings in the efficacy of prehospital CWI, as illustrated by the rate of patients who did not require additional cooling on ED arrival. Furthermore, there is a risk of overcooling if a patient is immersed for too long due to inaccurate temperature readings. Based on the protocol and study design, data on continued cooling after removal from CWI were not reported by the participating hospitals and are an area for future study. To address temperature measurement challenges, protocol modifications to incorporate evidence-based temperature assessment methods and techniques that more accurately reflect true core temperature are under review.

Ultimately, our results can be generalized to urban areas with Phoenix-like climates during summer months and short hospital transport times. It is our goal to expand this work to generalize findings to rural settings and to cities with different heat and humidity patterns.

Taken together, these limitations underscore the need for future prospective, multicenter studies using standardized core temperature monitoring, objective outcome assessment, and adjusted analytic models to better define the causal relationship between prehospital CWI and improved survival and neurologic recovery in heat stroke.

Conclusions

Prehospital CWI can be safely and effectively implemented within large urban EMS systems, producing clinically meaningful improvements in temperature reduction, neurologic recovery, and survival following heat stroke. The operational success of this program within the PFD underscores that prehospital immersion is both feasible and sustainable, if supported by protocol development, personnel education, and interagency collaboration with hospital and nearby EMS partners. Further studies involving multiple EMS agencies and prospective evaluations of outcomes can better define the impact on patients, system efficiency, and cost-effectiveness. Adaptations of similar field-based protocols have the potential to significantly decrease patient morbidity and mortality, where heat stroke and elevated ambient temperatures continue to be a challenge faced by EMS agencies and clinicians.

Authorship Statement

All authors meet the authorship criteria of the International Committee of Medical Journal Editors by contributing substantially to the study design or data, drafting or critically revising the manuscript, approving the final version, and accepting accountability for the accuracy and integrity of the work.

Data Sharing Statement

Due to the research model and various participating hospitals, data is not available.

Declaration of Generative AI in Scientific Writing

The authors did not use a generative artificial intelligence (AI) tool or service to assist with the generation or editing of this work. The author(s) take full responsibility for the content of this publication.

Disclosure Statement

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