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Heat Stroke in Emergency Department: Diagnosis and Management

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Abstract

Background: Heat stroke is a severe health concern with the potential for multi-organ failure, necessitating rapid and effective management. With rising global temperatures, there is increasing concern regarding the vulnerability of populations in high-heat areas, notably in Saudi Arabia, especially during the annual Hajj pilgrimage. Objective: This paper aims to review the epidemiology, evaluation and management techniques of heat stroke, emphasizing the situation during Hajj pilgrimages in Saudi Arabia, and to outline the best practices for emergency management. Methodology: A comprehensive review of literature and studies related to heat stroke, both globally and specific to Saudi Arabia, was undertaken. An in-depth analysis of emergency management, including initial assessment, cooling methods, organ support, medication, and prevention strategies, was conducted. Results: Heat stroke remains a significant cause of emergency department visits, with specific groups, such as men and the elderly, being more susceptible. During the Hajj in 2016, 267 patients were diagnosed with heat-related illnesses, with heatstroke accounting for 29% of these cases. With the threat of global warming, studies indicate a potential tenfold increase in heat stroke risk with a 2°C rise in temperatures. Swift and comprehensive cooling is pivotal for recovery. Management emphasizes rapid recognition, assessment, and varied cooling methods, along with targeted treatments for organ dysfunctions. Prevention strategies play a vital role, given the higher efficacy and practicality over treating organ dysfunctions. Conclusion: Heat stroke is a pressing health challenge, particularly in high-risk environments like Saudi Arabia during the Hajj pilgrimage. While effective emergency management protocols exist, an emphasis on prevention is crucial. It is imperative to incorporate a comprehensive approach to address both the immediate threat and long-term risks of heat stroke, especially with the looming challenge of global warming.

Keywords: *Management Technique, Rapid recognition*

1. Introduction

Heat stroke is a severe and potentially fatal condition characterized by an elevated core body temperature of greater than 40°C (104°F) accompanied by central nervous system abnormalities such as delirium, convulsions, or coma resulting from prolonged exposure to high environmental temperatures or from strenuous physical exercise [1]. As global temperatures rise and the frequency of heatwaves increase due to climate change, cases of heat-related illnesses, including heat stroke, have been on the rise [2]. This alarming trend underscores the urgency and importance of adequate understanding, timely diagnosis, and appropriate management of heat stroke in clinical settings, particularly in emergency departments.

Heat stroke is classified into two types: classical (or non-exertional) and exertional [3]. Classical heat stroke typically affects vulnerable populations such as the elderly, infants, and those with chronic illnesses during prolonged heatwave conditions. It is often the result of exposure to high ambient temperatures without adequate hydration or ventilation [4]. In contrast, exertional heat stroke typically afflicts young, active individuals who engage in intense physical activity in hot environments, such as athletes or military personnel [5]. Despite the differences in their predisposing factors, both types can lead to multi-organ dysfunction and demand swift intervention.

The underlying pathophysiology of heat stroke is complex and multifactorial. Elevated body temperature overwhelms the body’s thermoregulatory mechanisms, leading to a cascade of inflammatory responses, release of endotoxins, coagulation abnormalities, and ischemia-reperfusion injuries, resulting in damage to vital organs [6]. The brain, kidneys, liver, and muscles are especially susceptible to injury [7].

Despite the advancements in the field of medicine, the primary method of treating heat stroke remains the rapid reduction of body temperature [8]. However, achieving this without causing further harm requires a nuanced understanding of various cooling methods, their efficacy, and their potential risks [9]. Additionally, secondary complications such as rhabdomyolysis, acute renal failure, and disseminated intravascular coagulation might arise, further complicating the clinical management of these patients [10].

Emergency departments are often the first line of medical intervention for patients presenting with heat stroke, and as such, they play a pivotal role in the outcome of these patients. Understanding the latest diagnostic criteria, recognizing early warning signs, and employing evidence-based management strategies are imperative in ensuring optimal patient outcomes. This paper aims to shed light on the current best practices in the diagnosis and management of heat stroke in the emergency department setting.

Etiology of Heat Stroke:

Understanding the etiology of heat stroke is paramount in both its prevention and management. Heat stroke ensues when the body's intrinsic mechanisms to dissipate heat are overwhelmed by external and internal heat sources, causing a sharp rise in core body temperature [11]. Multiple factors, both intrinsic and extrinsic, contribute to this critical failure in thermoregulation.

1. **Environmental Factors:** High ambient temperatures and humidity levels are prime extrinsic contributors. High humidity can impede the evaporation of sweat, one of the primary mechanisms by which the human body dissipates heat [12]. This is exacerbated in conditions with limited air movement, which further hinders efficient evaporation. Urban settings, with their heat-retaining concrete structures and limited green spaces, can exacerbate heat exposure, creating what's known as urban heat islands [13].
2. **Physical Exertion:** Engaging in strenuous physical activities, especially during high temperatures, can lead to exertional heat stroke. This type of heat stroke is more common in young, otherwise healthy individuals, such as athletes or soldiers undergoing rigorous training in hot conditions [14].
3. **Clothing and Acclimatization:** Wearing heavy or non-breathable clothing can trap heat, increasing the risk of heat stroke. Similarly, individuals who have not had adequate time to acclimatize to hotter temperatures—like tourists visiting a hotter climate or workers from cooler regions deployed to hotter ones—are more susceptible [15].
4. **Medical Conditions and Medications**: Certain medical conditions, such as obesity, diabetes, heart disease, and skin disorders that affect sweating, increase susceptibility to heat stroke. Furthermore, medications like beta-blockers, diuretics, and anticholinergics can affect the body's

ability to regulate temperature [16]. Alcohol and recreational drug use can also impair the body's heat regulation and increase dehydration risk [17].

5. **Age-Related Factors**: Both the very young and the elderly are at increased risk. In infants and young children, the central nervous system is not fully developed, making them less capable of managing significant temperature fluctuations. On the other hand, elderly individuals may have compromised cardiovascular systems, take medications that affect heat regulation, or suffer from chronic medical conditions that increase susceptibility [18].

heat stroke is multifactorial in origin, with both intrinsic and extrinsic factors playing a pivotal role. Recognizing these etiological factors can be instrumental in crafting prevention strategies and early interventions.

Epidemiology:

Gauging the effects of extreme heat on public health is challenging since medical professionals aren't mandated to record illnesses caused by heat. In the U.S., between 2006 and 2010, over 3,300 deaths were linked to heat stroke. Yet, many believe this count is significantly understated. The death rate is closely associated with how much the body temperature rises, how quickly cooling measures are started, and the number of vital organs impacted. [18-20]

Heat Stroke remain among the high causes of emergency department visits. According to Wu, X., et al (2014) research conducted Between 2009 and 2010, the U.S. experienced an estimated 8,251 emergency department (ED) visits for heat stroke, translating to an annual incidence rate of 1.34 visits per 100,000 population. Men, the elderly aged 80 years and above, and residents of the southern region faced significantly higher risks. Most of these visits (63.1%) took place during the summer months of June through August. More than half (54.6%) of these ED visits resulted in hospitalization, and 3.5% of the patients passed away either in the ED or during their hospital stay. This data indicates that heat stroke leads to around 4,100 ED visits annually in the U.S., with specific groups being more susceptible. [21]

Heat Stroke in Saudi Arabia & Pilgrimage:

The annual Muslim pilgrimages to Makkah (Hajj and Umrah) are among the world's largest religious gatherings, attracting millions from 180 countries. Heat stress during summer has previously caused health issues, including deaths, and this may intensify with global warming.

Hajj is a mandatory religious duty for adult Muslims who have the financial and physical means, requiring them to make the pilgrimage at least once in their lifetime. Every year, millions converge in a specific, limited space to perform various religious acts, making it a challenging event to oversee, especially under adverse weather conditions. Pilgrims predominantly stay in closely packed tents in the plains of Mina, near Makkah. Yet, on the second day, known as 'The day of Arafat', there's a significant movement as pilgrims walk about 15 km from Mina to the plains of Arafat from morning until afternoon. After sunset, they move to Muzdalifa, a 9 km journey, only to return to their Mina tents later. Undertaking these activities, especially during the summer, is both physically and mentally strenuous for the participants.

Heat Stroke in Saudi Arabia is critical issue, especially During the Makkah Pilgrimage. There was no up to date data that we could find about incident of heat stroke in Saudi Arabia during Hajj. A data we could find was from **Khogali M. (1983)** who indicated that In September and October of 1980, 176 heat stroke cases were reported across locations including Arafat, Makkah, Medina, and Mina. During the same period in 1981, 467 cases were recorded which makes it 2 and half fold's increase. [22]

More recent Data from **Abdelmoety, D. A., et al. (2018)** showed that During the Hajj in 2016, 267 patients were diagnosed with heat-related illnesses. Of these, 29% had heatstroke and 67.75% had heat exhaustion. The mortality rate for those with heatstroke was 6.3%, while no deaths were reported for heat exhaustion cases. The average age of the patients was 54 years. Most patients presented with high body temperature and electrolyte imbalances and were treated according to heat illness guidelines. Despite efforts to prevent health issues during the Hajj, the mortality rate from heatstroke remains significant, with many patients exhibiting hyperthermia, various symptoms, elevated creatinine levels, and electrolyte disruptions. [23]

Another study that considered the global warming effects, examined the potential heat stress impact on Makkah during summer under the Paris Agreement's global warming targets of 1.5°C and 2°C. The findings indicate significant increases in dangerous (wet-bulb temperature >24.6°C) and extremely dangerous (wet-bulb temperature >29.1°C) heat thresholds, especially during August, September, and October. Specifically, September could experience up to 13 times the dangerous threshold in a 2°C warmer world. Risk analysis showed a tenfold increase in heat stroke risk in a 2°C warmer scenario and a fivefold increase if limited to 1.5°C. Thus, keeping global warming to 1.5°C could halve the risks associated with a 2°C increase. The study highlights that strict global warming limits can significantly reduce heat-related risks during these pilgrimages. [24]

Preventing heat illness involves careful planning and protective measures. It's observed that even a slight temperature rise, such as from 20°C to 21°C, can cause an 11% surge in people needing medical care. Furthermore, when the temperature exceeds 27°C, more individuals seek medical attention. To combat this, the Saudi Arabian government, in partnership with the Hajj Ministry, has implemented strategies to safeguard participants during the Hajj event. Pilgrims are advised to take shelter, apply sunscreen, maintain good hand hygiene, and drink plenty of water. They are also encouraged, when feasible, to perform rituals at night to avoid the heat. Despite these measures, the study found that out of 267 individuals, 80 (or 29%) suffered from heatstroke, the most severe type of heat-related ailment, with a fatality rate of 6.3%. [23,25-28]

Pathophysiology:
the pathophysiology is intricate, stemming from a combination of direct heat-induced cellular injury and systemic inflammatory responses.

At the core of heat stroke's pathophysiology is the body's inability to dissipate the heat it produces, leading to a progressive rise in core temperature [1] The human body, under normal circumstances, maintains a steady core temperature through a combination of metabolic heat production and heat dissipation mechanisms, primarily radiation, conduction, convection, and evaporation. The hypothalamus, which serves as the body's thermostat, orchestrates these processes [29].

During periods of extreme heat or intense physical exertion, the body's heat production can outpace its heat dissipation mechanisms, especially when external conditions reduce the efficacy of evaporative cooling, such as in high humidity environments [30]. This imbalance leads to a rapid increase in core body temperature.

Cellular function becomes compromised when internal temperatures exceed physiological limits. Heat-induced cellular damage occurs as proteins denature and cellular membranes become destabilized. These cellular injuries can lead to the release of heat shock proteins and inflammatory cytokines, triggering a systemic inflammatory response [31]. This systemic inflammation can result in multi-organ dysfunction, encompassing a range of symptoms from liver enzyme abnormalities to coagulopathies and acute kidney injury [32].

The central nervous system (CNS) is particularly vulnerable to elevated temperatures. Neuronal injury in the brain due to hyperthermia can lead to cerebral edema, increased intracranial pressure, and, subsequently, the neurological symptoms observed in heat stroke patients [33]. The cardiovascular system also reacts to hyperthermia, manifesting as increased heart rate, low blood pressure, and eventually shock due to the dilation of peripheral blood vessels as the body tries to dissipate heat [34].

Heat stress leads to a shift in blood flow towards the skin and its underlying layers, subsequently reducing the flow to other parts of the body such as the brain, heart, liver, spleen, and kidneys. This adjustment aids in more efficient heat release. It has been observed that rising temperatures can reduce the time taken for blood clotting and the number of platelets while increasing the activity that breaks down blood clots. As a result, the body's clotting system is activated sooner during heat stress. [35]

Occasionally, hyponatremia can develop in marathon runners and those affected by exertional heat stroke due to excessive intake of low-sodium fluids. Heat stroke has been linked to high potassium levels in the blood, resulting from the release of potassium during muscle breakdown or acidosis which causes potassium to move from cells to the bloodstream. Potassium plays a crucial role in dilating blood vessels in skeletal and heart muscles, and significant reductions can cause cardiovascular instability and decreased blood flow to muscles, making them prone to rhabdomyolysis. The complications of rhabdomyolysis can vary, from slightly low calcium levels to severe kidney damage. Elevated potassium and reduced calcium levels combined can cause heart rhythm disturbances, including changes in the QT interval and ST-segment, and in rare cases, might result in life-threatening heart rhythm issues. [36]

Prognosis:

During the August 2003 heat wave in Paris, researchers studied patients to identify factors predicting outcomes. In a study by Hausfater et al., patients who had core temperatures above 38.5°C and were admitted to emergency departments were analyzed. Factors like prior diuretic use, being over 80 years old, living in an institution, having cardiac issues or cancer, core temperatures above 40°C, and low systolic blood pressure were associated with an increased risk of death from nonexertional heatstroke. Another study by Argaud et al. on 83 patients with temperatures above 40°C found that institutional living, taking long-term antihypertensive medications, and presenting with specific symptoms significantly affected 2-year mortality rates. A third study by Misset et al. determined that factors like location of heatstroke occurrence, severity scores, high initial body temperatures, certain medical interventions, and receiving care in an ICU without air conditioning increased the risk of hospital death. [37-40]

Evaluation:

When patients present with potential heat stroke, rapid and accurate evaluation in the emergency department is essential to initiate prompt treatment and improve outcomes.

Based on the surrounding temperature and other environmental elements like humidity and airflow, as well as heat-producing factors, the efficiency of heat-release processes, and personal heat regulation influenced by multiple risk factors, heat illness can present itself in a range from mild to severe conditions.

When examining patients suspected of having heat stroke, it's essential to regularly check their vital signs and take a rectal temperature. Lab tests such as CBC, CMP, PT/PTT, blood gases, serum CPK, and urine myoglobin should also be conducted. Depending on the clinical evaluation, some might need a toxicology test, a chest x-ray, and an EKG. EKG results could reveal signs like ST depression, QT extension, and T-wave changes linked to ischemia. Every heat stroke patient will exhibit rapid breathing and heartbeat. Their arterial CO_2 levels typically fall below 20 mmHg, and many might have low blood pressure. It's crucial to review the medical history of patients suspected of classic heat stroke, particularly looking for the use of diuretics, beta-blockers, and anticholinergic medications. [36]

1. Clinical Presentation: Patients with heat stroke commonly present with an altered mental state which may range from confusion to coma [1]. Other symptoms can include nausea, vomiting, headache, rapid heart rate, hyperventilation, and muscle cramps [3].
2. Physical Examination: On examination, patients may display hot and dry skin, although sweating may still be present in exertional heat stroke [9]. Neurological examination may reveal seizures, ataxia, or even focal neurological deficits. Cardiovascular assessment might show tachycardia and hypotension [4].
3. Laboratory Tests: Laboratory evaluation often reveals abnormalities such as:

- Elevated liver enzymes indicating hepatic injury [7].
- Elevated creatinine levels suggesting acute kidney injury [7].
- Elevated creatine kinase (CK) indicating muscle breakdown or rhabdomyolysis [5].
- Abnormal electrolyte levels like hyponatremia or hyperkalemia [5].
- Arterial blood gas might show metabolic acidosis [41].

4. Imaging: While imaging is not always necessary in the initial assessment of heat stroke, if other conditions are suspected, CT or MRI might be performed. For example, a head CT might be ordered if there's suspicion of an underlying central nervous system condition [42].
5. Core Body Temperature Measurement: Measuring the core body temperature is critical. Peripheral thermometers (e.g., oral, axillary) are not accurate in this setting. Instead, rectal or esophageal probes should be used.

In classical heat stroke, there's a primary presence of respiratory alkalosis, while exertional heat stroke can also be accompanied by lactic acidosis. The changes in electrolytes differ between these two forms. Notably, exertional heat stroke often shows signs of muscle damage, such as low calcium, elevated phosphate, and high potassium levels. Muscle breakdown, or rhabdomyolysis, is more frequent in exertional heat stroke, indicated by a significant rise in CPK markers. In comparison, classical heat stroke frequently exhibits increased AST and ALT levels. Both types can lead to kidney and liver issues, as well as damage to other vital organs. [36]

Prompt recognition and treatment of heat stroke can prevent significant morbidity and mortality. Once heat stroke is suspected based on clinical evaluation, immediate cooling measures should be initiated even before laboratory confirmation [43].

Management:

Heat stroke can lead to the failure of multiple organs. Thus, swift and efficient cooling, combined with careful observation and targeted treatment for affected organs, is crucial for effective recovery. Rapid recognition, assessment, and treatment are crucial to prevent severe complications and mortality. Here's a summary of the management of heat stroke in the emergency department:

Initial Assessment and Stabilization:

- Assess the patient's airway, breathing, and circulation (ABCs) immediately upon presentation. Initiate resuscitative measures as necessary.
- Obtain a rectal temperature to accurately measure core body temperature [1].

Rapid Cooling:

- Cooling should be initiated immediately. Methods include cold water immersion, evaporative cooling (wet the patient's skin and use fans), and applying ice packs to the axilla, groin, and neck [10].
- Monitor the patient's core temperature continuously and stop cooling once it drops to approximately 38.9°C (102°F) to prevent overcooling [44].

While there isn't a universally agreed-upon target temperature for initial cooling in heat stroke cases, a rectal temperature of 39.4 °C has been shown to be safe in several instances. There are various cooling methods used in clinical settings, such as immersion, evaporation, cold water bladders, gastric and rectal lavage, and noninvasive cooling systems. Yet, no single method has been proven to be the best for treating heat stroke. The intravascular balloon catheter system, typically used for cooling during specific surgeries in the USA, has been employed in a few instances for heat stroke. One study reported rapid and efficient cooling of a patient with this system. Another study found that using a convection-based intravascular cooling device in combination with traditional cooling methods could potentially prevent organ failure and yield better neurological results. Extracorporeal circulation with hemodiafiltration circuits has also been used for cooling with noted efficiency. However, there's no definitive research establishing one method as superior. The intravascular method doesn't cause skin blood vessel narrowing like external methods, but it necessitates the insertion of a cooling balloon. [45]

Cooling on the spot is crucial in remote areas. While urban populations are more commonly discussed than rural ones, some cooling techniques mentioned might be best suited for distant locations. For instance, locations with air transport capabilities can leverage the downward air current from a helicopter to act as a fan, aiding the evaporation of cold water. [41]

Fluid and Electrolyte Management:

Administer intravenous fluids to address dehydration. Use isotonic saline initially and adjust based on laboratory results [46].

Monitor for electrolyte imbalances, particularly hyperkalemia, hypocalcemia, and hyperphosphatemia, which can result from muscle breakdown [47].

For heat illness, on-site oral rehydration with water or a drink containing electrolytes can begin. Research has indicated that oral rehydration and IV rehydration are equally effective in treating heat-related illnesses. It's important to avoid overhydrating patients, as some might react adversely to major changes in fluid levels, especially those with reduced heart function. [32]

Monitor and Manage Organ Dysfunction:

- Multiorgan dysfunction, including liver, kidney, and coagulation abnormalities, can develop. Monitor laboratory values closely and initiate appropriate interventions [48].
- Consider transferring patients with severe complications to intensive care units for close monitoring and specialized care [3].

Consideration for moving to a liver transplant center is also important because of multiple instances of acute liver failure resulting from heatstroke. In one particular case, a young individual passed away due to acute liver failure and widespread internal clotting, without receiving a transplant. In a review, out of three identified cases where patients received a transplant, two athletes with activity-induced heatstroke needed a transplant by the third day of their stay, while another was transferred to a transplant facility on the third day and then received a transplant on the sixth day. [41]

Several cases have been documented where patients survived multiorgan failure due to heat stroke after receiving blood purification treatments, which included continuous venovenous hemofiltration and plasma exchange. This type of therapy can eliminate harmful inflammatory molecules linked to heat stroke. In another study involving a group of patients with severe exertional heat stroke, the clinical impacts of continuous renal replacement therapy (CRRT) were compared with standard treatment. The results showed a notably reduced 30-day death rate in the CRRT group compared to the standard treatment group, even though the initial severity scores of the patients were similar in both groups. [44]

Medications:

There are a few drug options to consider when treating heat stroke. Dantrolene, a muscle relaxant, is known to reduce heat from ongoing muscle contractions and is used to treat malignant hyperthermia. Yet, it doesn't seem to influence the outcomes in heat stroke cases. Antipyretics aren't recommended for heat stroke treatments as they could potentially harm the liver. [36] Also they're ineffective for heat stroke-induced hyperthermia [49].

Treating seizures with benzodiazepines is suggested by some studies [50]. A minor study proposed that a high dose of benzodiazepine might suppress the shivering reflex, reducing oxygen use, which could be beneficial theoretically. However, patients with heat stroke might not have the typical response mechanisms like shivering. As a result, it's not universally advised to use benzodiazepines, but it might be suitable for patients who are shivering intensely or are agitated. [36]

In some studies, Both rocuronium and succinylcholine were administered to patients, with no stated preference for one over the other. There's a theoretical reason to consider using rocuronium, as it might prevent potential heat production during muscle twitches and provides a more extended muscle relaxation that could lessen heat production. However, there's no concrete proof suggesting rocuronium is better than succinylcholine. [41]

2. Conclusion

Follow-up:

Once stabilized, patients should receive counseling on avoiding future heat-related illnesses, the importance of acclimatization, and early recognition of heat illness symptoms [51].

Death may result from heat stroke, often due to heart failure. The primary treatment is lowering the body temperature to support the cardiovascular system. Around a third of survivors from the initial impact face multiple organ failures. In cases of impending or actual shock, the ABCDE protocol should be implemented, emphasizing airway, breathing, and circulation management, along with swift cooling. If cooling happens within 30 minutes of collapse, death risk is nearly eliminated. However, individuals arriving at the emergency room with a body temperature of 41°C or more, especially if sustained, can have death rates as high as 80%. [35]

Prevention:

Instead of focusing on treating organ dysfunctions, which had limited therapeutic options even as of today, it's more practical to emphasize prevention. After all, heat-related illnesses and deaths can be avoided. Effective prevention tactics for heat stroke include using air conditioning, reducing outdoor activities during peak sunlight hours, drinking plenty of fluids, wearing loose and light-colored clothing, being aware of medications that might lead to dehydration or reduced sweating or heart rate, and ensuring that vulnerable adults or children are never left alone in a car. [44, 52].

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