ABSTRACT

Background: Heat induced illnesses are variable from a mild heat exhaustion to a severe heat stroke and its systemic complications. Millions of pilgrims annually perform the Islamic obligatory mission of Hajj, are vulnerable to heat induced illnesses, especially when Hajj falls in the summer period. This is a retrospective study of the renal and electrolyte abnormalities in heat stroke patients during Hajj.

Method: We selected randomly 472 patients out of 2044 patients diagnosed as heat stroke over 5 years from 1986-1991 for this study. The diagnosis of heat stroke was based on: 1) Rectal temperature > 40°C, 2) Hot dry skin and 3) Neurological deficit presenting as delirium, coma with or without convulsions. The renal function and electrolytes of all these patients were obtained.

Results: All the 472 patients revealed significant electrolyte abnormalities: hypophosphatemia 98%(P+0.55±0.05mmol/l), hyponatremia Na+ 70% (128 +1 mmol/l),hypocalcemia 70%(Ca+ 2.01 ± 0.02 mmol/l), hypokalemia 32% (K+3.3±01mmol/l), and hypomagnesaemia (Mg 0.06 ± 0.01mmol/l) in 30%. Metabolic acidosis and compensatory respiratory alkalosis was seen in most patients. Acute renal failure that required dialysis developed in 180 (8.8%) patients. In 100 patients, the most common cause was Rhabdomyolysis (68%). The rest had ischemic acute tubular necrosis (32%) with a mortality of 15% compared to 20% in all the 472 patients. The risk mortality was higher in patients with a temperature of 42°C, comatose at presentation and older than 50 years.

Conclusion: During Hajj, electrolyte abnormalities in heat stroke were found to be fairly common. Acute renal failure was mainly due to Rhabdomyolysis, which carry better prognosis compared to other causes of acute tubular necrosis.

Keywords: Hyponatremia, Hypocalcemia, Hypokalemia, Rhabdomyolysis, Acute renal failure, Hajj, Acute tubular necrosis.
INTRODUCTION
Exposure to a very hot environment may result in a variety of heat illnesses, like heat cramps, heat exhaustion and heat stroke. Heat stroke is the most serious form as its onset is usually acute[1]. Lack of acclimatization to heat includes failure to achieve maximal sweating capacity. Therefore, individuals who are not exposed to repetitive heat stress, either they live in cold temperature regions or spend much time in artificially cooled habitats are unable to tolerate excessive heat. Every year almost 2-3 million people perform Hajj in Makkah (pilgrims). These people are exposed to a very hot environment when the hajj period arrives during the summer time. The same activities are performed in a limited time which causes overcrowding. Many of these people are coming from cold climates, thus are not acclimatize to the hot environment.

During this short time, many cases of heat illnesses are reported. These cases range from a mild degree of dehydration, pre-renal azotemia due to heat exhaustion, and acute renal failure (ARF) due to a heat stroke.

The objective of this retrospective study is to review the renal and electrolyte abnormalities in heat stroke. Many papers reviewed the incidence of electrolyte abnormality in heat stroke, however, the cause, the incidence and the outcome of ARF in these patients has not been addressed on a large scale[2-4].

METHODS
A retrospective cohort study:
The results of all patients seen over a five year period between 1986 and 1991 were reviewed. All these patients had a diagnosis of heat stroke based on the following criteria:

1. Rectal temperature >40°C
2. Hot dry skin
3. Neurological deficits presenting as delirium and coma with or without convulsions[5]

A total of 2044 patients were presented to different hospitals in the Makkah region during the Hajj period from 1986 – 1991. Hence, they all met the above criteria for heat stroke[5], 472 patients were randomly selected for the study. For each patient, detailed result of electrolyte and renal functions abnormalities were obtained.

All of these patients were evaluated and their electrolytes, urea and creatinine, liver function tests and blood sugars, as well as urinalysis were examined.

A low serum phosphorus was defined as below 0.8 mmol/l (2.5 mg/dl) and a low serum sodium (Na+) was defined as Na+ below 130 mmol/l. A low serum potassium (K+) was defined as below 3.4 mmol/l. A low serum Mg+ was defined as below 0.7 mmol/l (1.3 mg/dl).

Out of the 2044 patients, 180 patients required dialysis for which 100 were randomly selected and studied in detail to determine the cause and outcome of their renal impairment, including rhabdomyolysis and other causes.

The criteria of the diagnosis of rhabdomyolysis were based on the following:

A. High serum creatine kinase (CPK) 2570 ± 500
B. Presence of myoglobinuria
C. High uric acid
D. Low calcium

The diagnosis of ischemic acute tubular necrosis (ATN) was made in the presence of:

1. Inactive urine sediment
2. Absence of myoglobinuria
3. Low urine Na+

RESULTS
The results showed that these patients had various forms electrolyte and renal abnormalities. These included hypophosphatemia, hyponatremia, hypokalemia, hypomagnesemia, hypocalcaemia, high uric acid and disturbed liver enzymes.

The most common electrolyte abnormalities (Table 1) were hypophosphatemia (98%), hypocalcaemia (70%) and hyponatremia (34%).

Additionally, 98% of patients were diagnosed with hyperglycemia with a blood sugar level above 240 mg/dl (13.3 mmol/l). Similarly, a large number of patients had deranged liver enzymes and elevated serum bilirubin (Table 2).

It was noted that 70% of patients had leukocytosis with white blood cell count above 11,000. The blood gas values showed that 29% of patients had predominantly metabolic acidosis and 18% had predominantly respiratory alkalosis. A low CO2 was seen in most patients.

A high urea (above 50 mg/dl) was seen in 27%; a high creatinine (> 1.5 mg/dl) was seen in 54% of patients and only 8.8% of the total 2044 needed dialysis. 50% of patients, however, had a uric acid above 8mg/dl which is higher than normal.

The mortality rate of the 472 patients was 20%. The most important factors associated with a worse outcome were:

1. Very high temperature of 42°C.
2. Coma on admission.
3. Age older than 50 years.

A temperature above 44°C was recorded in 57 patients for whom 37 of them died during hospitalization; they were all presented in a coma.

Renal failure requiring dialysis was not associated with poor outcome or high mortality.

The cause of renal impairment that required dialysis of the 100 patients who were reviewed over 5 years was also investigated. Rhabdomyolysis was found to be the cause of the renal impairment in 68 patients. The remaining 32
patients had a diagnosis which was compatible with ischemic ATN. Urinalysis showed that most patients had an acid urine pH of 5.0. Hence, the average cooling time was 2 hours and 30 minutes.

**DISCUSSION**

Various studies have shown that heat stroke is associated with different electrolyte and acid base abnormalities\cite{6-9}. Hyponatremia, hypocalcaemia, and hypophosphatemia had been observed by different authors. However, this report was performed in a large scale and addressed electrolyte abnormalities in more details.

In this series, it was apparent that hypophosphatemia was the commonest electrolyte abnormality seen, which has not been observed before on a large scale. In spite of the presence of dehydration, hyponatremia was seen only in 34% of the patients.

The patients were treated in a cooling environment and given IV fluids\cite{10}, mainly normal saline (0.9%).

The average blood glucose concentration exceeded 240 mg. This may be related to catecholamine release which inhibits on the insulin release from the pancreas, and therefore, decreases glucose uptake by peripheral tissue resulting in hyperglycemia\cite{11}. Catecholamine also releases stimulates glycogenolysis in the liver and muscles. This contributes to lactic acid production which augments the observed hyperglycemia through hepatic gluconeogenesis\cite{12}. When heat stress is relieved by cooling and rehydration, insulin secretion is resumed, promoting glucose and K+ entry into peripheral tissue resulting in lowering of their concentrations.

Primary alveolar hyperventilation can be attributed to the direct stimulating effect of hyperthermia on the respiratory centre\cite{13}. This may contribute to the presence of hypophosphatemia and hypocalcaemia.

Heat stimulates sweat which leads to hypovolemia. Hypovolemia will lead to rennin and aldosterone release and thus, increase Na+ re-absorption by the kidneys in exchange for potassium. Simultaneously, heat induced by hyperventilation decreases PCO2 and the resulting alkalosis shifts K+ into the intracellular compartment, thus potentiating the effect of hypokalemia (11).

Acute renal failure (ARF) is a well recognized complication of

| Electrolyte | % of Patients with Normal Value | % of Patients with Low Value | Concentration |
|-------------|---------------------------------|-----------------------------|---------------|
| P+          | 2%                              | 98%                         | 0.55 ± 0.05 mmol/l |
| Na          | 30%                             | 70%                         | 1.28 ± 1 mmol/l |
| Ca+         | 30%                             | 70%                         | 2.01 ± 0.02 mmol/l |
| K+          | 68%                             | 32%                         | 3.3 ± 0.01 mmol/l |
| Mg+         | 70%                             | 30%                         | 0.6 ± 0.01 mmol/l |

**Table 2. Liver function test in 472 patients with established heat stroke.**

| Test         | % of Patients with Normal Results | % of Patients with Elevated Results |
|--------------|----------------------------------|-----------------------------------|
| Bilirubin    | 17%                              | 83%                               |
| SGPT         | 62%                              | 38%                               |
| SGOT         | 37%                              | 63%                               |
| LDH          | 25%                              | 75%                               |

SGPT = serum glutamic-pyruvic transaminase  
SGOT = serum glutamic-oxaloacetic transaminase  
LDH = lactate dehydrogenase
heat stroke\cite{11-14}. However, in this series, it has been shown the magnitude of this problem in terms of incidence, prognosis and mechanism of ARF.

Also noted, that the mortality in patients who required dialysis was 15% which is much lower than mortality rate related to other causes of ATN. This could possibly be as most of these patients are relatively young and do not have other medical problems. In fact, many of the old patients died before they required dialysis.

Therefore, it is felt that the severe renal failure requiring dialysis in heat stroke may not carry or indicate a poor prognosis. Moreover, in a case report by Lumlertgul et al., the patient had recovered from an acute renal failure after more than 6 weeks\cite{15}.

Age older than 50 years was associated with a mortality rate of 35%. Temperature of 42°C was also associated with a mortality of 35%. Most of these patients died before they required dialysis. Other alternative forms of dialysis have been also attempted in heat stroke associated ARF\cite{16}.

This study showed that renal failure requiring dialysis has a significant incidence (8.8%) but has a relatively good prognosis. The cause of the renal failure was mainly due to rhabdomyolysis. It is very interesting that although, all the patients were dehydrated, shock or severe dehydration were not present. Absence of hypotension may have contributed to the lower incidence of ischemic ATN, that could explain that most of the patient with acute renal failure were related to rhabdomyolysis.

Those patients who lack acclimatization to heat fail to achieve maximal sweating capacity, and therefore their susceptible to develop a classical heat stroke \cite{12}. These patients were not severely dehydrated and their central venous pressure was not very low, possibly because sweating was decreased. The use of rectal temperature measurements during the treatment of heat stroke is not rely (really) recommended to avoid overcoothing effect on the brain\cite{17}.

Heat stroke is salvageable and preventable plus an early intervention can change the prognosis, particularly before the patient develops coma and before the temperature reaches 42°C. Moreover, heat stroke can be prevented by avoiding unnecessary exposure to heat, however, this could be difficult during Hajj period. Nevertheless, to avoid the complications of heat stroke, people are usually encouraged to drink large amounts of water and avoid excess exposure to heat, especially for those pilgrims coming from cold climates.

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