



Original article

A comparative study of serial serum electrolytes and ECG changes in patients of heat stroke and hyperpyrexia

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ABSTRACT

Background: Heat hyperpyrexia and heat stroke are distinct medical emergencies and common in a tropical country like India. The study compared the serial electrocardiographic (ECG) and electrolyte changes between the patients of heat stroke (HS) and heat hyperpyrexia (HP). **Methods:** Fourteen patients were included in each of the HS and HP groups. Patients of HS were included if they had documented rectal temperatures of (a) 106°F or more, (b) 105°F or more with neurological symptoms or anhidrosis, or along with a history of heat exposure for patients. Patients with hyperpyrexia 106°F or more due to causes other than heat stroke were included in HP group. The biochemical investigations and ECGs were recorded at before, during and after lowering of temperature of patients. **Results:** In HS group, serum sodium and potassium levels were lower on admission, but significantly improved ($p < 0.01$) at 24 hours of hospitalization. Such changes were not observed in the HP group wherein, the serum sodium and potassium levels were comparable and within normal ranges on serial assessment. Hyponatremia was present in 10 (71.4%) patients on admission in HS group compared to only 1 (7.1%) patient in HP group. In both groups, all patients presented with tachycardia on ECG which returned to normal in all patients in HS group but only in 8 (57.1%) in HP group. QTc increase was noted in few patients in both groups. **Conclusion:** Patients of heat stroke present with hyponatremia and hypokalemia on presentation. Changes in ECG are transient in patients of heat stroke and heat hyperpyrexia.

KEYWORDS: Heat stroke, hyperpyrexia, hyponatremia, hypokalemia.

INTRODUCTION

Heat hyperpyrexia or heat stroke is a medical emergency characterised by rectal temperature of 106°F or more, usually associated with anhidrosis and with a history of exposure to high ambient temperature [1]. Death due to heat stroke is not uncommon with mortality rates ranging 17 to 70 percent, and is related to the magnitude of thermal stress, the age of the subject and predisposing factors [2]. Acute circulatory failure has been observed to precede death in more than 8% of cases, but the mechanisms of cardiovascular collapse have not yet been well established [3]. The limited evidence of myocardial damage in heat stroke, is based on the electrocardiographic abnormalities in a small number of patients and the pathologic changes observed on autopsy in fatal cases [4].

Most of the information regarding cardiovascular consequences of heat stroke are made on initial observations or after vigorous treatment. Thus, the hemodynamic and

metabolic status in patients of heat stroke prior to, and during or after treatment is not clearly known. Therefore this prospective study was conducted to evaluate serial electrocardiographic and electrolyte changes prior to initiation of therapy; after reduction of temperature and after 24 hours of therapy in heat stroke patients (HS). These changes in patients of heat stroke were compared to changes in another group of patients of hyperpyrexia (HP) to observe changes specific to heat stroke.

MATERIALS AND METHODS

This prospective observational study was conducted at IGMCG Nagpur during the summer season. Patients of heat stroke (HS) admitted in the hyperpyrexia ward of the hospital were identified and were included if they had documented rectal temperatures of (a) 106°F or more, (b) 105°F or more with neurological symptoms or anhidrosis, or along with a history of heat exposure for patients. In the heat

hyperpyrexia (HP) group, patients with hyperpyrexia 106°F or more, due to causes other than heat stroke were included.

Approval from the Institutional ethics committee was obtained prior to initiation of the study. Informed consent was obtained from legally acceptable representatives during enrolment in the study, and from the patients at discharge. After including the patient, detailed history and general and systemic examination was done. In HS group, outer clothing was removed and patient was laid down on a specially prepared 'Body Cooling Unit' for bringing down the temperature down as soon as possible. Vigorous sponging with lukewarm water under rapidly rotating fans was also done. Patient was shifted from the cooling unit room to the cold ward when temperature (rectal) was brought down to 100°F or 101°F.

Routine haematological and urine examinations were done. Patients were monitored for temperature, pulse rate and respiratory rate every half hour. Blood urea, blood sugar and liver function tests were done in all patients. Serial ECG and

serum electrolytes were done on admission, when the rectal temperature lowered down to 99°F, and after 24 hours of hospitalization. Patients were kept for at least 24 hours after their temperature come down to normal, and were then transferred to respective units of medical wards. In the HP group, similar examinations were done; however in addition, the respective causes of hyperpyrexia in these patients were treated by administration of antibiotics, antimalarials, etc.

Data was entered in a Microsoft Excel sheet and analysed using SPSS version 20 software. Descriptive statistics were described as Mean±SD, frequencies and percentages. Data within a group at multiple intervals was analysed using repeated measures ANOVA. The level of significance in the study was considered at 0.05.

RESULTS

Fourteen patients were enrolled in each of the two groups – HS and HP. Demographics and baseline characteristics of the patients have been described in **Table 1**.

Table 1: Demographic and clinical features of patients

Demographics & Clinical Features	HS (n=14)	HP (n=14)
Age group (years)		
11-20	3 (21.4%)	3 (21.4%)
21-30	4 (28.6%)	6 (42.9%)
31-40	3 (21.4%)	1 (7.1%)
41-50	1 (7.1%)	2 (14.3%)
51-60	2 (14.3%)	2 (14.3%)
61-70	1 (7.1%)	-
Gender		
Male	7 (50%)	9 (64.3%)
Female	7 (50%)	5 (35.7%)
Residence		
Urban	12 (85.7%)	12 (85.7%)
Rural	2 (14.3%)	4 (28.6%)
Occupation		
Labour	4(28.57%)	2(14.29%)
Students	2(14.29%)	4(28.57%)
Housewife	4(28.57%)	6(42.86%)
Rickshaw Puller	1(7.14%)	-
Hath Thela Puller (Cart Vendors)	1(7.14%)	-
Begger	1(7.14%)	2(14.29%)
Unemployed	1(7.14%)	-
History of heat exposure	14 (100%)	2 (14.3%)
Duration of fever		
< 24 hrs	9 (64.3%)	2 (14.3%)
24-48 hrs	4 (28.6%)	3 (21.4%)
2-3 days	1 (7.1%)	3 (21.4%)
3-6 days	-	3 (21.4%)
6-9 days	-	2 (14.3%)
9-12 days	-	-
12-15 days	-	1 (7.1%)
Major presenting complaints		
Fever	14 (100%)	14(100%)
Fever with rigors	2(14.29%)	9(64.29%)
Vomitting	3(21.43%)	2(14.29%)
Headache	8(57.14%)	3(21.23%)
Loose Motions	1(7.14%)	-
Cough	-	4(28.57%)
Irritability	8(57.14%)	3(21.43%)
Abnormal behaviour	2(14.29%)	1(7.14%)
Unconsciousness	1(7.14%)	-

Convulsions	1(7.14%)	-
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In the HP group, there were 9 (64.3%) patients of malarial fever, 3 (23.4%) patients of pneumonitis, and 1 (7.1%) patient each of pulmonary tuberculosis and pyogenic

meningitis. The general and CNS system examination findings have been described in **Table 2**.

Table 2: Examination findings of the patients

Examination findings	HS (n=14)	HP (n=14)
Rectal Temperature		
105°F to 106°F	6(42.9%)	9(64.3%)
106.1°F to 107°F	3(21.4%)	4(28.6%)
107.1°F to 108°F	4(28.6%)	1(7.1%)
108.1°F to 109°F	-	-
109.1°F to 110°F	1 (7.14%)	-
General examination		
Tachycardia	14 (100%)	14 (100%)
Hypotension	1 (7.1%)	-
Tachypnea	4 (28.6%)	5 (35.7%)
Dry Skin	12 (85.7%)	-
Neck rigidity/stiffness	1 (7.1%)	1 (7.1%)
CNS examination		
Drowsy	3 (21.4%)	2 (14.3%)
Stupor	2 (14.3%)	1 (7.1%)
Semi-coma	1 (7.1%)	-
Disorientation	1 (7.1%)	-
Irritability	8 (57.1%)	1 (7.1%)
Papilledema	-	1 (7.1%)
Plantar reflex (Absent/extensor)	1 (7.1%)	1 (7.1%)

The mean temperature of patients was 106.92°F in HS group and 106°F in HP group. Laboratory investigations demonstrated that 10 (71.4%) patients of HS had leucocytosis compared to 4 (28.6%) patients in the HP group. SGOT and SGPT were slightly raised (40-80 U/l) in 10 (71.4%) patients in HS group. As observed in **Table 3**, in HS group, serum sodium and potassium levels were lower

on admission, but significantly improved ($p<0.01$) at 24 hours of hospitalization. Such changes were not observed in the HP group wherein, the serum sodium and potassium levels were comparable and within normal ranges on serial assessment. Hyponatremia was present in 10 (71.4%) patients on admission in HS group compared to only 1 (7.1%) patient in HP group.

Table 3: Mean Serum sodium and potassium levels among study subjects

Groups	Mean Serum sodium			Mean Serum potassium		
	On admission	2 nd sample	24 hrs of hospitalization	On admission	2 nd sample	24 hrs of hospitalization
HS group	132.07	135.9	140.1	3.8	4.1	4.2
HP group	137.6	137.6	138	3.97	4	4.02

In HS group, on ECG (**Table 4**), all patients presented with tachycardia, with an average heart rate of 128/ min on admission. The heart rate had returned to normal rate of an average of 88/min after 24 hours of hospitalization. Normal sinus rhythm and QRS complex was noted in all patients. One patient each presented with Biphasic P in aVL, and in V1. On serial ECG, axis change was observed from positive to negative in 7 (50%) patients, and from negative to positive in 4 (28.6%) while no change of axis was observed in 3 (21.4%) patients. There was a gradual increase in the PR interval from an average of 0.12 seconds on admission to 0.15 seconds at 24 hours. Three patients showed a gradual decrease in PR interval on serial ECG, 3 others had constant PR intervals with tachycardia in 1st ECG indicating evidence of 1st degree heart block in these patients, during hyperpyrexial state.

ST depression was noted in lead II, III, avF in three patients, in V3 to V6 in three patients, and 1 patient in only lead I. This ST depression disappeared in 2nd ECG in 4 patients and disappeared in 3rd ECG in 2 patients while in one patient this change remained persistent in V3 to V6 but disappeared in II, III avF. T wave changes were noted in 12 (85.7%) patients. One patient showed tall T waves in V2 to V4 on admission which normalized on 3rd ECG. T wave inversion / flattening gradually reverted back to normal in all 12 patients. In one patient T wave flattening appeared in V2 to V4 only in 3rd ECG. In another patient T waves which was inverted in III, avF and V2, V3 became upright in 2nd ECG in V3 and in lead III avF, T inversion decreased from 2.5 mm to 1.5 mm in 3rd ECG. QTc interval was gradually increased in 2nd ECG in 3 patients which normalized on 3rd ECG. In 9 patients (64.3%) there is gradual increase in

QTc from 1st to 3rd ECG. and in 2 patients (14.3%) there is gradual increase in QTc from 1st to 3rd ECG. Prolong corrected QT interval was seen in 1st ECG in 2 patients, in

2nd ECG in 2 patients in 3rd ECG. 5 patients. Q waves were seen in 2 patients (14.28%), in one it was in II, III, avF and in other it was in avL.

Table 4: Comparison of ECG variables in heat stroke (HS) and heat hyperpyrexia (HP groups)

Variable	HS group (n=14)			HP group (n=14)		
	1 st ECG	2 nd ECG	3 rd ECG	1 st ECG	2 nd ECG	3 rd ECG
Average heart rate (per min)	128	96	88	120	101	91
Rhythm	Normal sinus Rhythm	Normal Sinus Rhythm	Normal Sinus Rhythm	Normal sinus Rhythm	Normal Sinus Rhythm	Normal Sinus Rhythm
P wave	Biphasic P in avL (n=1) V1 (n=1)	Normal	Normal	Normal	Normal	Normal
QRS complex	Normal	Normal	Normal	Normal	Normal	Normal
Average PR interval length (seconds)	0.12	0.14	0.15	0.13	0.14	0.15
Axis change + to - - to + No change	- - -	- - -	7 (50%) 4 (28.6%) 3 (21.4%)	- - -	- - -	- - 14 (100%)
ST depression	7 (50%)	4 (28.6%)	2 (14.3%)	None	None	None
T wave changes	12 (85.7%)	-	0 (0%)	4 (28.6%)	2 (14.3%)	2 (14.3%)
U wave changes	7 (50%)	9 (64.3%)	6 (42.9%)	None	None	None
Average QTc interval (seconds)	0.41	0.41	0.42	0.4	0.42	0.42
Prolonged QTc interval	2 (14.3%)	2 (14.3%)	5 (35.7%)	3 (21.4%)	1 (7.1%)	1 (7.1%)

In HP group (**Table 4**), tachycardia was seen in all 14 patients on admission and it gradually came back to normal in 8 patients (57.1%) while it remained persistent in 6 patients (42.9%) after 24 hours of hospitalization. The mean heart rate was 120/mm on 1st ECG which improved to 91/mm on 3rd ECG. The axis, rhythm and PR interval were normal in all patients. The PR interval changed from 0.13 seconds on 1st ECG to 0.15 seconds on 3rd ECG, which might be due to decrease in the mean heart rate. None of patients showed prolongation of PR interval. T-wave inversion and flattening was seen in only 4 patients (28.6%). It remained persistent in 2 patients and became upright in 2

patients, in 3rd ECG. There were no ST segment changes in any of the patients. The mean QTc interval was 0.4 seconds on 1st ECG which slightly increased to 0.42 seconds on 3rd ECG.

There was progressive increase of QTc in 5 patients, while progressive decrease in 4 patients till 3rd ECG, while QTc remained relatively constant in 5 patients. In 3 patients QTc was prolonged in 1st ECG which reverted to normal in 2 patients and remained prolonged in 1 patient. These QTc changes from 1st to 2nd or 3rd were not statistically significant. U wave and significant Q waves were not seen.

Figure 1: ECG of a patient showing ST changes: sinus tachycardia with flat T waves in chest leads and ST depression in II, III, avF, V3 to V5.

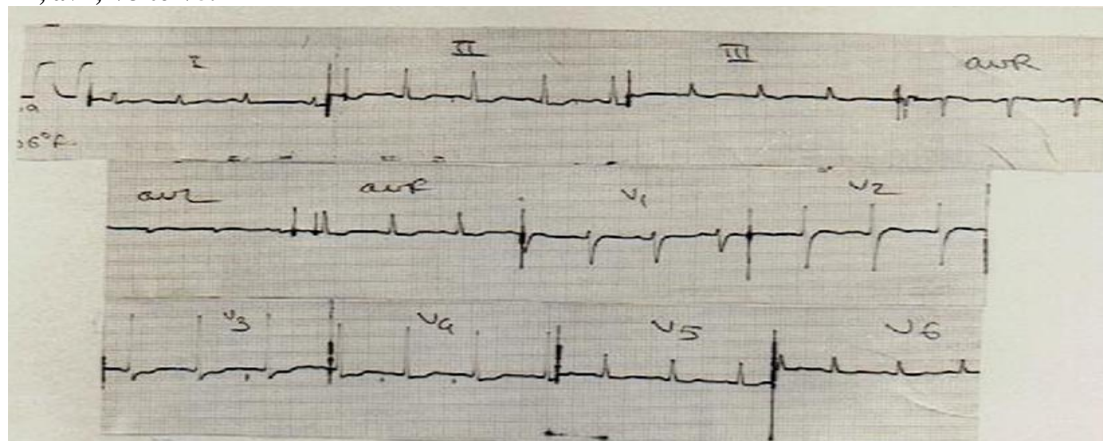
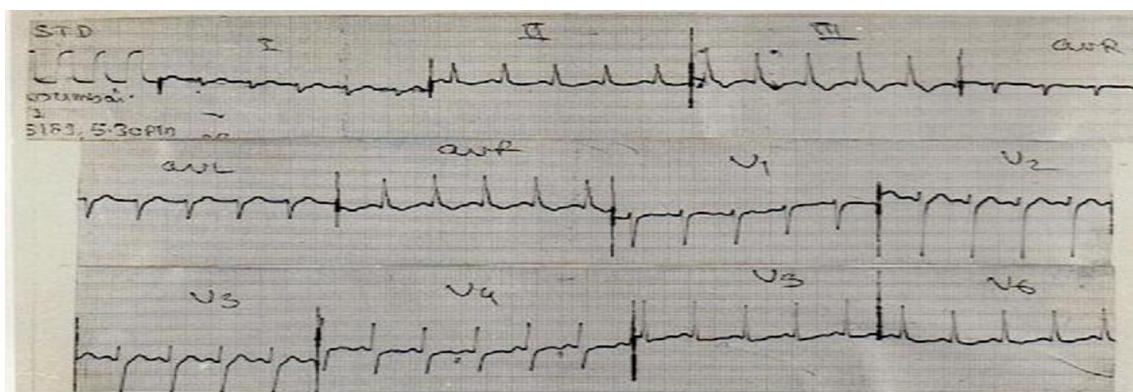


Figure 2: ECG of a patient with changes in QRS axis and T wave: Gross sinus tachycardia, axis +102°, T wave inversion in lead II, III avF in V4 and flattening of T in V5, V6.



DISCUSSION

In the study, male to female ratio was 1 which was in contrast to findings reporting a high male to female ratio of 6:1 [5-7]. Most patients belonged to 21-30 years age which is similar to earlier reporting by Ramanathan and Premkumar et al [7,8]. Heat stroke is of concern in elderly people as they have impaired physiological response to heat stress, are less likely to have the capacity to increase cardiac output adequately and decrease systemic vascular resistance, during hot weather. Similarly the efficiency of sweating also declines with increasing age. Acclimatization to hot weather may also be impaired among elderly persons, particularly those who do not live in hot climate all through the year.

Finally, the elderly are more likely to have underlying diseases or to be receiving medications, (Anticholinergics, Diuretics etc.) that have reported to increase the risk of heat stroke [6,8,9]. Patients doing vigorous physical activity in high ambient temperature such as labourers, cart vendors, etc. commonly present with heat stroke [7,8]. Percentage of patients from urban areas was higher owing to greater awareness and ease of public in the city - to reach the hospital [7]. The other factors are, higher environmental temperature in the city due to greater retention of heat by buildings, overcrowding, automobiles, industries and less wind velocity and as the rural persons are more acclimatized [10]. Major presenting symptoms of fever, abnormal behaviour, irritability, unconsciousness, and convulsions were also reported by previous studies [6,8,9].

Mean rectal temperature of the patients of heat stroke in our study was 106.92°F, similar to that reported earlier [10,11]. Anhydrosis was seen in 85.7 1% of patients of heat stroke. Similar observation have also been reported by Gold, who suggested that high output type of cardiac failure is the primary event and increased venous pressure is ultimately responsible for cessation of sweating, leading to heat stroke [12]. Anhydrosis is secondary to failure of central neurogenic mechanism, due to direct effect of heat stroke [6,13]. CNS changes like irritability, disorientation, drowsiness, stupor and semicoma were also reported earlier [7,8]. These changes are probably due to a widespread cellular damage of neurones of CNS, as a result of an acute rise in temperature - in heat stroke. Neck rigidity in the patients of heat stroke might be due to either petechial haemorrhages in the meninges (meningism) or in the muscles of neck [7]. Elevation of liver transaminases in heat strokes can be attributed to the thermal injury to the liver

parenchyma and has been reported in similar studies [4,8,9,14].

In the patients of heat stroke, hyponatremia was common on admission which normalized with treatment following to 24 hours. Austin et al found hypernatremia in 12 patients, in his study of 100 patients of heat stroke [6]. Serum Na was reported normal in heat stroke patients in some studies [14,15]. The present study findings differ from earlier studies as none of the authors have performed serial estimation of serum sodium, at the time of admission, following, reduction of temperature to 99°F (rectal) and 24 hours after admission to the hospital. Moreover most of the author have observed serum Na values hours to days after the heat stroke. As hyponatremia was corrected without the administration of normal saline, the correction can be attributed to restoration of the normal homeostatic mechanisms. Also hypokalemia noted in present study was similar to earlier reportings [6,9], and is due to increase in potassium excretion, intracellular loss due to hemoconcentration from, increased bicarbonate excretion which accompanies potassium excretion [16].

The ECG changes in patients of heat stroke have been reported earlier [4,8,17,18]. However, these studies have been single ECG recordings and not serial ECGs. The cardiac ECG abnormalities have been attributed to the direct thermal injury and myocardial anoxia from the circulatory collapse, adding to the increased tissue demand during hyperpyrexia. Also, changes in serum electrolytes may play a role in the observed ECG changes in patients of heat stroke. Metz found QT prolongation in patients of heat stroke, which persisted for 2 - 10 days [17]. Costrini also found the similar changes in 50% of his study of heat stroke and attributed this prolongation to hypocalcemia, which occur due to increased excretion or due to rhabdomyolysis [19].

CONCLUSION

Patients of heat stroke present with hyponatremia and hypokalemia on presentation. ECG abnormalities are observed in substantial amount of patients. These changes revert back to normal with, only rapid reduction of body temperature to normal, and do not require any treatment. The cardiovascular abnormalities produced by heat stroke are transient and reversible with treatment of heat stroke, and can be, in part, due to changes in serum electrolytes.

Competing interest: The authors declare that they have no competing interests.

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