ACUTE RENAL FAILURE IN HEAT EXHAUSTION

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SUMMARY: Acute renal failure (A.R.F.) is a well recognised but rare complication of heat exhaustion due to muscular exertion. It has been estimated to occur in 2 to 9 per cent of cases (Malamud, Haymaker and Custer 1946, Leithead and Lind 1964, Austin and Berry 1956, Shibolet et al 1967, Barry and King 1962). We report a recent case, discuss the outcome of five other cases treated in the Renal Unit, Princess Mary's R.A.F. Hospital, Halton, and consider the aetiology and prevention of this condition.

Case report

A 23 year old T.A.V.R. officer, who regarded himself as reasonably fit, attempted an 11 mile forced march in full kit on a hot summer's day, during a pre-parachute training course. He had not taken any appreciable quantity of fluid that morning, and did not have any water during the march. He began to feel unwell at the half-way stage, but managed to carry on in a dazed condition until he collapsed 400 yards from the end. He was taken to the Cambridge Military Hospital, where he was found to be confused, sweating, peripherally cyanosed and clinically fluid depleted. The oral temperature was 39°C (rectal temperature is more accurate in these cases, and is usually recorded), pulse rate 140/minute, and blood pressure 90/35 mm Hg.

A diagnosis of heat exhaustion was made and he was cooled and given 6 litres of intravenous fluid rapidly, with some improvement in his general condition. The urine contained numerous red cells, free haemoglobin, and some protein, but no myoglobin was detected. The initial haemoglobin was 18.1 g/dl, packed-cell volume 57.6 per cent, falling rapidly with rehydration. Urine output remained at about 1 1/24 hr, but blood urea rose from 9.9 mmol/l to 16.8 mmol/l in 2 days. He had developed non-oliguric acute renal failure. Conservative management, with a 20 g protein diet and salt and water restriction, was initiated, but as the blood urea rose to 27.3 mmol/l on the 8th day, he was transferred to the R.A.F. Renal Unit. On admission clinical examination revealed a blood pressure of 150/85, some tenderness over the muscles of the back, and diminished reflexes, but was otherwise normal. Conservative treatment was continued, and blood urea rose to 36.75 mmol/l by the 12th day. He was not dialysed as serum potassium remained normal, and he had only slight clinical evidence of uraemia. Urine output remained at 1 1/24 hr until the 10th day, when a diuresis commenced. The blood urea started to fall spontaneously from day 13 as the urine output exceeded 2 1/24 hr (Fig. 1).

The initially elevated aspartate aminotransferase (A.A.T.) of 213 IU/l, and creatinine phosphokinase (C.P.K.) of 228 IU/l, returned to normal. Urinary fibrin degradation products (F.D.P's) were raised at 20 to 40 µg/ml and serum F.D.P's at 10 µg/ml, but the

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Fig. 1. Course of acute renal failure showing a spontaneous fall in blood urea as the urine output exceeds 2 litres in 24 hours. Unbroken line denotes blood urea and broken line urine output.

platelet count remained normal. Serum uric acid was elevated at 0.81 mmol/l. All other investigations were normal.

The blood urea fell as the diuresis continued, and he was discharged with a normal blood urea on the 24th day of the illness.

Clinical features of A.R.F. in heat exhaustion

The other five patients treated at Halton, all of whom were young men, have similar histories. The clinical details are summarised in Table I. It is noteworthy that they had all indulged in exercise more strenuous than that to which they were accustomed, four in unusually hot weather, and four with a documented lack of adequate fluid intake. They all had clinical evidence of muscle damage.

Four cases required haemodialysis, and there was one death, which occurred during the diuretic phase, and was due to septicaemia. Two patients had renal biopsies, and both showed acute tubular necrosis, with pigment casts in the tubules. Three patients had histologically confirmed skeletal muscle necrosis. In four cases where it was measured there was marked elevation of A.A.T., but other liver function tests were normal, making it probable that the enzyme was of muscle origin. Myoglobinuria was not detected in any of the patients, but none were admitted in the first 48 hours of their illness. All five patients after recovery had blood urea levels in the normal range, but in three cases where it was recorded creatinine clearance was slightly depressed.

Our experience is similar to that described in other recent papers (Jackson 1970, Vertel and Knochel 1967, Schrier et al 1967, Raju, Robinson and Bower 1973). The clinical features of A.R.F. in heat exhaustion are collapse, muscle pain, tenderness and weakness, confusion, dehydration, hypotension, often hyperpyrexia, and oliguria with

Table I
Summary of the case histories of A.R.F. in heat exhaustion
treated at the R.A.F. Renal Unit

Case	Age (years)	Climate	Exercise	Muscles involved	Duration oliguria (days)	Number H.D's.	Blood urea on recovery (mmol/l)
1	22	Bahrain	Sprinting	Rectus Abdominis	4	NIL	4.3
2	30	Spring (U.K.)	Forced March	Erector Spinae	20	4	Died
3	19	Summer (U.K.)	Forced March	Quadriceps	10	2	7.3
4	28	Borneo	Road Race	Quadriceps Gastrocnemius	12	2	4.4
5	13	Summer (U.K.)	Football Training	Quadriceps	9	6	5.0
6	23	Summer (U.K.)	Forced March	Erector Spinae	10*	NIL	6.9

* Case 6. Although not oliguric as internationally defined, had a low urine output with fixed inappropriate osmolality.

dark urine. Laboratory findings include proteinuria, haemomyoglobinuria, and raised levels of serum transaminases, C.P.K., uric acid, haemoglobin, and blood urea. The majority of the early cases reported were fatal (Schrier et al 1967, Baxter and Teschan 1958, Knochel et al 1961, Romero 1966). More recent series show a high recovery rate (Jackson 1970, Vertel and Knochel 1967). This is probably due to advances in the management of A.R.F. as renal biopsy in most patients has revealed the reversible changes, of acute tubular necrosis (Malamud, Haymaker and Custer 1946, Vertel and Knochel 1967, Schrier et al 1967, Kew et al 1966).

Aetiology of A.R.F. in heat exhaustion

The majority of cases of exercise induced A.R.F. reported so far have been in American military recruits, and American football players in training (Vertel and Knochel 1967, Schrier et al 1967). The commonest types of exertion involved have been squat jumps and press-ups. In this country, marching and athletics have been found to be major causes (Climatic Physiology Committee 1958). The exertion has been severe and unaccustomed, and has occurred in the early stages of training, in hot weather, in the majority of cases.

The pathogenesis has been reviewed recently (Vertel and Knochel 1967, Schrier et al 1967, Raju, Robinson and Bower 1973, Schrier et al 1970) and will only be summarised here. The postulated aetiological factors include hypotension, dehydration, myoglobinuria, thermal damage, hypokalaemia and hyperuricaemia.

Hyperpyrexia was not present on admission in all of our cases, but was shown in one series to occur transiently in all subjects after strenuous exercise (Schrier et al 1970). It does not therefore seem likely that direct thermal injury is a major factor.

Hyperuricaemia can be induced by exertion (Schrier et al 1970) but the initial levels are unrelated to the onset of A.R.F. As hyperuricaemia occurs in A.R.F., high uric acid levels in those cases of heat exhaustion progressing to A.R.F. are to be expected.

Hypokalaemia has frequently been noted in heat stroke (Malamud, Haymaker and Custer 1946, Sobel et al 1963) although it was not a feature in our series. It has been postulated that hypokalaemia may predispose to rhabdomyolysis in exertion, and hence to A.R.F. (Vertel and Knochel 1967). However, the serum potassium does not appear to be significantly depressed consistently enough for it to be considered an important factor.

The role of myoglobinuria in A.R.F. has been well documented in a variety of clinical situations including exertion, trauma (especially crush injuries), burns, carbon monoxide, barbiturate and alcohol poisoning, sea-snake bites, Haff disease, and idiopathic paroxysmal myoglobinuria. Myoglobinuria has not been detected consistently in exercise induced A.R.F., but this may be because it is rapidly excreted and must be sought in the first 24 to 48 hours. Myoglobinuria alone however, does not usually lead to renal failure, and has been detected by sensitive methods in a high proportion of athletes after severe exertion (Ono 1953, Elliot, Shafer and Gibas 1967). The degree of muscle damage, and hence myoglobinuria, is more severe in cases of exercise-induced A.R.F., and appears likely to be one of the factors involved (Jackson 1970, Raju, Robinson and Bower 1973).

There is no evidence that patients suffering from exercise-induced A.R.F. have an unusual susceptibility to this syndrome. No deficiency of muscle enzymes, as in McArdle's syndrome, has been reported, and similar degrees of exertion can be repeated without a recurrence of A.R.F.

Dehydration and hypotension are well established causes of A.R.F. The relative renal cortical ischaemia observed in acute renal failure due to shock may be caused by activation of the renin-angiotensin mechanism (Brown et al 1970). The majority of cases of exercise-induced A.R.F. are found to be hypotensive and dehydrated. However, a comparable degree of shock in heat exhaustion, without muscle damage, seems less likely to lead to A.R.F. (Austin and Berry 1956). It may be that the nephrotoxicity of myoglobin is enhanced by the coexisting hypotension and fluid depletion in those cases of heat exhaustion progressing to A.R.F.

There is some experimental support for this hypothesis, as rats can be protected from the nephrotoxicity of myoglobin by prior renin depletion (Thiel, McDonald and Oken 1970) and rats and dogs can be shown to develop haemoglobin-induced A.R.F. more readily when dehydrated or hypovolaemic (Maluf 1949, Braun et al 1970, Theil et al 1967).

Conclusion

Certain practical lessons can be learnt from consideration of the fairly typical case histories of the patients reported here. Those responsible for the training and exercise programmes of military recruits and sportsmen should bear in mind the possible serious ill-effects of exertion. The programme should allow a gradual increase in excretion. Adequate fluid intake must be insisted upon, even in "cool" climatic conditions, and provided during long exercises.

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All instructors must be aware of the importance of symptoms such as the passage of dark urine, unusual muscular pain, vomiting or collapse. They must be prepared to stop an individual with these symptoms at any point during an exercise, and arrange for him to receive medical attention.

All service doctors making a diagnosis of heat exhaustion should consider the possibility of non-oliguric renal failure, and monitor renal function *ab initio*.

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