BRIEF REPORT

Fluid Therapy in Pediatric Victims of the 2003 Bam, Iran Earthquake

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Abbreviations:
ARF = acute renal failure
CI = crush injury
CPK = creatine phospholeinese
DL/EX = delivered to expected ratio
GFR = gloerular filtration rate
IV = intravenous
LDH = lactate dehydrogenase
SGOT = asparate aminotransferase

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Abstract

Introduction: On 26 December 2003, at 05:26 hours, an earthquake of magnitude 6.6 (Richter scale) caused a disaster in the Bam region of Southeastern Iran, which had a population of approximately 102,000. In this study, the clinical and laboratory features and therapeutic interventions in pediatric (three months to 14 years) crush victims were analyzed. Determination of the type and amount of fluid therapy for prevention of acute renal failure (ARF) was the main aim of this study.

Methods: The clinical and laboratory data and therapeutic interventions provided to 31 pediatric crush victims were collected. Early and vigorous fluid resuscitation was immediately performed. Resuscitation of the children from hypovolemic shock was initiated by interavenous (IV) administration of normal saline until the signs and symptoms of shock disappeared. For victims with crush injuries, an alkaline intravenous solution, up to 3 to 5 times more than maintenance doses was provided. In this study, there were two groups with decreasing severity of injury: (1) crush injury (CI), with or without ARF; and (2) non-crush injury (Non-CI). According to the above mentioned classification, there were 15 and 16 patients in group I and II, respectively.

Results: The mean time spent under the rubble was 2.2 ±2.5 hours and 0.5 ±0.5 hours in Groups I and II, respectively. Seventy-five percent of ARF patients (n = 8), were admitted to the hospital the day of the earthquake (Day 0) and the day after earthquake (Day 1). In non-ARF patients (n = 7), 85.7% of the victims were admitted on Day 0 and Day 1. In Group II (ARF and non-ARF), all patients were admitted within three days after the earthquake. Although ARF did not develop in any of the children without CI, it was observed in eight of 15 patients with CI. There was no significant difference between CI with ARF (n = 8) and CI without ARF (n = 7) patients, in terms of the admission date, time of admission, hospitalization duration, and time under the rubble (TUR). Admission SGOTs were significantly different between these two groups. The ratio of the amount of delivered IV fluid (DL) to expected (EX) was based on weight of children was the only fluid therapy parameter in which there was a statistically significant difference between ARF and non-ARF groups. It was 3.6 ±0.99 in ARF and 4.8 ±0.74 in Nnon-ARF group (p = 0.01).

Conclusions: Early intravenous volume replacement may prevent both ARF and dialysis need that may develop on the basis of rhabdomyolysis. In adults, six liters or 12–14 liters of fluids for prophylaxis of ARF in crush syndrome, were suggested. In children, it seems that DL/EX ratio (delivered to expected ratio) is the best marker for evolution of IV fluid therapy in pediatric patients. In children with crush injuries, DL/EX ratio of >4.8 was sufficient for the prevention of ARF.

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Introduction

At 05:26 hours on 26 December 2003, a devastating earthquake measuring 6.6 on the Richter scale caused a major disaster in Bam city in the Kerman Province in Southeastern Iran.[1] Bam had a population of 102,000. Victims were hospitalized in centers with dialysis facilities.[2] As a back-up center located 300 km east of the disaster area, Khatam-Al-Anbia University Hospital of Zahedan city, accepted some trauma victims.

In this study, the clinical and laboratory features and therapeutic intervention in pediatric (3 months to 14 years of age) crush victims were analyzed. Determination of the type and amount of fluid therapy for prevention of acute renal failure (ARF) was the main aim of this study.

Acute renal failure related to the crush syndrome is the second most frequent cause of death following injury. Majority of the rescued victims die because of preventable or treatable medical causes, most commonly due to ARF due to rhabdomyolysis.[3] Crush victims with ARF who requires hemodialysis have a mortality rate up to 40%.[4]

Methods

Of the total 195 injured patients who transferred to Zahedan University Hospital, 31 patients were ≤14 years of age. Data for all 30 patients were collected prospectively using questionnaires designed by the Iranian Society of Nephrology. The data consisted of patient demographic data, time under the rubble, time between rescue and first intravenous infusion, type of injury, medical and surgical treatments, laboratory data, complications, presence of ARF, initial investigation for signs and symptoms of shock, and seriousness of injuries. Because of the total destruction of all medical facilities in the region, none of the patients had received intravenous (IV) fluid therapy before admission to Zahedan Hospital.

After admission, six patients showed signs and symptoms of shock (excluding hemorrhagic shock), thus, early and vigorous fluid resuscitation with interavenous (IV) normal saline were initiated until the signs and symptoms of shock disappeared. Laboratory data, measuring the levels of blood urea nitrogen (BUN), creatine (Cr), sodium (Na), potassium (K), creatine phosphokinase (CPK), aspartate aminotransferase (SGOT), lactate dehydrogenase (LDH), and urinalysis (U/A) were collected immediately after admission. In those with at least one of the three following criteria including: (1) CPK level >3–5 times the upper limits of normal; (2) serum potassium >5.5 meq/l; and/or (3) myoglobinuria, an alkaline solution (up to 3 to 5 times more than maintenance doses), was infused. The solution was prepared by adding 15 mEq of bicarbonate to each liter of half normal saline. This vigorous IV therapy with a rate of 3 to 5 times more than maintenance dose was continued until the urine output exceeded 30–200 ml per hour. In the cases with oliguria, heart failure, or head injury, the amount of IV fluid administered was reduced to maintenance dose.

Body weight, blood pressure, and urine output were monitored daily. After normalization of the above criteria, the fluid therapy was returned to maintenance levels.

In this study, Group I was defined as: crush injury (CI) with or without ARF, and Group II consisted of those without crush injury (non-CI). *Crush injury* was defined as injury from collapsing material and debris, muscle swelling (rhabdomyolysis), and/or neurological disturbances in the affected limb.[5] For laboratory confirmation of rhabdomyolysis, serum levels of CPK >1,000 units was needed.[6]

Acute renal failure was defined as a glomerular filtration rate (GFR) of <75% of estimated GFR and/or the persistence of oligoanuria (<400 ml/day). In each individual, the amount of intravenous fluid that was delivered in first three days of admission was registered (delivered-V), for better judgment on the amount of the fluid therapy, the ratio of delivered fluid (Delivered-V) to the basal fluid requirement (Basal-V) was calculated. Basal-V was calculated based on the children's fluid replacement formula (Holliday-Segar Forumula).

Descriptive statistics were calculated for all numeric variables. Two independent group values of the means were compared using the Mann-Whitney *U*-test. A p-value <0.05 was considered statistically significant. STATA 8 software was used for statistical analysis.

Results

Age, sex, and weight distributions of the patients are listed in Table 1. There were 15 patients in Group 1 (CI), and 16 patients in Group II (non-CI). Acute renal failure did not develop in any of the children with non-CI, but it occurred in 8 of the 15 patients (53%) who had sustained CI. In those with CI, the mean times spent under the rubble were 2.2 ±2.5 hours; in those with non-CI it was: 0.5 ±0.5 hours. The mean value for the GFR in the Non-CI group and CI group was 64.9 ±2.1 ml/min and 97.9 ±22.1 ml/min, respectively (Table 2). In the CI group, all patients were admitted within the first three days of earthquake; five admissions were on the day of the earthquake (day zero), or Day 1 (Table 3). In non-ARF patients, six out of seven of the victims were admitted on Day 0 or Day 1 after the earthquake.

The types of injuries encountered are summarized in Table 4. Injuries to the lower and upper extremities were the most common injuries in the CI group. Fasciotomy was performed in one patient and one patient required laparotomy. There was no significant difference between CI patients with (n = 8) and without ARF (n = 7) in terms of the admission data, the time of admission after earthquake, the hospitalization duration, and time under the rubble. The mean value of GFR in ARF and non-ARF groups were 50.3 ±19.0 ml/min and 81.5 ±10.4 ml/min in succeeding (p = 0.001). Asparate aminotransferase level on admission was significantly higher for those with CI and ARF, (520.3 ±741.23 *U*/lit vs. 146.6 ± 234.3 *U*/lit), (p = 0.03). There were not statistically significant differences between CPK and LDH levels on admission between two groups. In another words, the two groups of children had similar severity of injures. There were statistically significant differences between CI patients and non-CI patients in time under the rubble (TUR), hospitalization duration, time of admission, and LDH, CPK, SGOT levels on admission (Table 5). The ratio of delivered intravenous (Delivered-V) fluid to the basal need of fluid (Delivered-V/Basal-V) was significantly different between ARF and non-ARF Groups (Table 6). It was 3.6 ±1.0 in ARF and 4.8 ±0.7 in the non-ARF group (p = 0.01). Other indices of fluid therapy, such as mean values for amounts of IV fluids administered during the first five days of admission (mean IV/day), mean of ml/kg/day

	Age Groups (years)	0 to 10 Kg	>10 to 20 Kg	> 20 Kg	Total
Male	<1	0	0	0	0
	1–5	0	1	0	1
	6–10	0	1	3	4
	>10	0	0	6	6
Female	<1	2	0	0	2
	1–5	0	5	0	5
	6–10	0	0	5	5
	>10	0	0	8	8

Table 1—Age (in years), sex, and weight distribution of the cases

Parameters	Crush (n = 15)	Non-Crush (n = 16)	*p*-value
Admission date	0.7 ±0.8	2.2 ±2.0	0.01
Time of admission after earthquake	25.6 ±13.2	33.1 ±16.1	0.2
Hospitalization duration	6.5 ±2.7	3.0 ±2.2	0.002
Time under rubble	2.2 ±2.5	0.5 ±0.5	0.06
Glomerular Filtration Rate	64.9 ±2.1	97.9 ±22.0	0.001
Mean Creatine Phosphokinase (CPK)	4,683.3 ±4,821.6	206.4 ±175.3	0.001
Maximum CPK	7,563.2 ±7,635.8	314.2 ±195.5	0.001
Admission CPK	6,215.5 ±7,127.5	253.9 ±152.1	0.001
Mean Lactate Dehydrogenase (LDH)	1,316.8 ±932.0	765.2 ±240.8	0.04
Maximum LDH	1,717.3 ±1,672.0	769.0 ±187.7	NS
Admission LDH	1,510.8 ±1,575.7	280.2 ±266.0	NS
Mean SGOT	199.5 ±293.3	33.4 ±11.1	0.0009
Maximum SGOT	316.7 ±546.0	33.1 ±12.4	0.0006
Admission SGOT	333.4 ±562.6	33.1 ±12.3	0.0002

Table 2—Comparison of different parameters in crush and non-crush patients (SGOT = Serum Glutamic-Oxaloacetic Transaminase)

Time (hours)	CI* with ARF (n = 8)	CI without ARF (n = 7)	Non-CI (n = 16)
1st 24	5	3	3
24 to 48	1	3	4
48 to 72	2	1	4
≥72	0	0	5

Table 3—Time of admission after earthquake
*Crush injury (ARF = acute renal failure)

Type of injuries	Crush injury (n = 15)	Non-Crush (n = 16)
Soft tissue without fracture	4	7
Head and neck	3	1
Vertebral column	3	0
Peripheral nerve palsy	1	0
Thoracic compression	3	0
Extremity trauma	9	4
Abdominal trauma	2	0
Pelvic fracture	4	5

Table 4—Type and location of injuries

	CI with ARF (n = 8)	CI without ARF (n = 7)	*p*-value
Admission date	0.6 ±0.9	0.7 ±0.8	NS
Time of admission after earthquake	25.3 ±14.2	26 ±13	NS
Hospitalization duration	7 ±3	5.6 ±2.3	NS
Time under rubble	3.4 ±2.9	0.9 ±0.7	NS
Glomerular Filtration Rate	50.3 ±19.0	81.5 ±10.4	0.001
Mean Creatine Phosphokinase (CPK)	5,700 ±4,47	3,520 ±5,286	NS
Maximum CPK	8,396 ±6,007	6,610 ±9,589	NS
Admission CPK	6,046 ±4,575	6,408 ±9,696	NS
Mean Lactate Dehydrogenase (LDH)	1,665.6 ±1,171.4	918.4 ±284.4	NS
Maximum LDH	2,286.9 ±2,173.6	1,066.4 ±290.3	NS
Admission LDH	2,024.4 ±2,046.5	923.9 ±392.6	NS
Mean SGOT	251 ±343.5	140.7 ±236.6	NS
Maximum SGOT	459.8 ±707.3	153.1 ±321.3	NS
Admission SGOT	520.3 ±741.2	146.6 ±234.3	0.034

Table 5—Comparison of crush injury (CI) with acute renal failure (ARF) and CI without ARF (SGOT = Serum Glutamic-Oxaloacetic Transaminase)

Mean IV/day(Lit)	5.1 ±2.6	6.4 ±1.1	NS
Mean ml/kg/day (ml)	225.6 ±30.7	207.0 ±80.	NS
Delivered/Basal ratio	3.6 ±1.0	4.8 ±0.7	0.01
Day 1	173.4 ±91.3	222.3 ±102.4	NS
Day 2	253.4 ±47.4	202 ±99.15	NS
Day 3	240.0 ±47.7	225.8 ±65.2	NS

Table 6—Comparison of intraveneous fluid therapy between crush injury (CI) with acute renal failure (ARF) and CI without-ARF

of IV fluid in first five days of admission (mean ml/kg/day), and amount of IV fluid (ml/kg) received in days one to three, all were not statistically different between these two groups. None of the ARF patients needed dialysis. The mean mL/kg/day of IV fluid therapy in the crush injury (n = 15) and the non-crush syndrome (n = 16) was 217 ±58 and 112 ±45, respectively ($p = 0.0001$). Furthermore, the Delivered-V/Basal-V ratio was 4.14 ±1.08 and 1.69 ±0.59 in the crush injury and the non-crush injury, respectively ($p = 0.0001$). The amount of fluids delivered to the patients in Day 1, 2, and 3 (ml/kg), were calculated for each group and are in Table 6.

Discussion

In this series, ARF developed only in patients with CI; thus, it seems that CI was the main cause of ARF in these pediatric patients. The Delivered-V/Basal-V ratio was the best marker for evaluation of IV fluid therapy any pediatric patients; any children with crush injuries, a Delivered-V/Basal-V ratio of >4.8 and >3.6 was sufficient to prevent ARF in CI group and the need for dialysis in the ARF group, respectively. In each group, the mean IV fluid therapy was not statistically different and it seems that it is a non-reliable marker of assessment of IV therapy in children. Acute kidney injury (AKI)/failure has been identified in traumatic crush injuries.[6] Volume depletion and renal hypoperfusion, combined with myoglobinuria are the main causes of renal failure. Serum CPK and potassium levels and myoglubulinuria can be used to determine the severity of injury. After stabilization of intravascular volume and the presence of urine flow, a forced alkaline diuresis should be instituted.[7]

Most of the reports about the earthquake casualties are focuse on the adult population.[8–10] However, this study addresses the pediatric population. In this study, the majority of patients were admitted on the day of earthquake. Therefore, the most critical period for effective rescue management was preserved. Hence, the efficacies of manage-

ment to prevent ARF were dependent on other factors such as amount of fluid therapy and severity of injuries.

As shown in Table 5, most of muscle injury indices such as CPK, LDH, and SGOT are not significantly different between ARF and Non-ARF patients. This means that the amount of fluid administered is the most important determinant for prevention of ARF in children with crush injury. Therefore early energetic intravenous volume replacement may prevent both ARF and dialysis.[11,12]

Conclusions

In adults, there are different opinions about the quantity of fluid to be administered for prophylaxis of ARF in patients with crush syndrome, and the amounts ranging from 6 liters[13] to 12–14 liters of fluids per day.[14,15] Based on results of this study, it seems that in children with crush injuries, DL/EX ratio of >4.8 is sufficient for the prevention of ARF, and DL/EX of >3.6 can reduce the need for dialysis. Further study in this regard is recommended.

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