Application of the RIFLE criteria in patients with crush-related acute kidney injury after mass disasters

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Abstract

Background. The term acute kidney injury (AKI) and its classification in strata defined as Risk, Injury, Failure, Loss and End-stage renal failure (RIFLE) need to be validated in different patient groups. RIFLE may be useful to foresee medical and logistic problems in crush-related AKI in disaster victims.

Methods. Taken from the Marmara earthquake crush database, the subjects included 416 patients who were categorized according to the modified RIFLE criteria and 18 victims with crush injury but with normal serum creatinine who served as controls. Associations between each RIFLE category and various parameters were investigated.

Results. There were 27, 79 and 310 patients in the risk, injury and failure groups, respectively. Urine volume and serum albumin were lower; blood pressure, blood urea nitrogen, serum uric acid, potassium and phosphorus were higher; oliguric and polyuric periods were longer; medical complications were more frequent; and number of transfusions, dialysis sessions and days of dialysis support were higher in more severe AKI categories. Glomerular filtration rate at discharge was progressively lower in proportion to the severity of RIFLE classification. However, survival outcome did not differ among controls and patients who suffered from AKI nor in between RIFLE categories.

Conclusions. In disaster crush victims, RIFLE classification can be useful to foresee the medical complications, need for therapeutic interventions and logistic support and also renal function at discharge though, perhaps, not survival.

Keywords: acute kidney injury; crush syndrome; rhabdomyolysis; RIFLE

Introduction

Traditionally, acute renal failure (ARF) has been defined as an ‘abrupt and sustained decrease in renal function resulting in retention of nitrogenous and non-nitrogenous waste products’ [1]. However, this vague terminology does
not provide any insight into onset, extent, duration, severity and outcome of a pathology of which >35 different quantitative definitions exist in the literature [2]. This chaotic situation interferes with: (i) the comparison of various studies [3–5], (ii) developing consistent diagnostic and therapeutic recommendations [6–8], (iii) identifying factors which affect prognosis [9] and (iv) defining the economical burden of the disease.

Therefore, the Acute Dialysis Quality Initiative introduced the concept of acute kidney injury (AKI) which encompasses the entire spectrum of increasing severity of the disease by classifying it into Risk (R), Injury (I), Failure (F), Loss (L) and End-stage kidney failure (E) (RIFLE) stages [10] with the principal aim to overcome the drawbacks mentioned above. RIFLE staging was subsequently updated by the development of the AKIN criteria [4,11]. However, although increasing the sensitivity of the AKI diagnosis, the latter approach did not materially improve the ability of the RIFLE criteria in predicting hospital mortality in intensive care unit (ICU) patients [12,13]; thus, at least for the time being, it seems as if RIFLE and AKIN classifications will not generate significant differences in the prediction of the final outcome of AKI patients [14].

The AKI concept and the RIFLE stratification have gained wide attention, and the primary publication has become the most frequently viewed [14] article of all times [15]; RIFLE also became the most widely used definition of ARF in both critical care and nephrology literature [14]. However, gaining wide acceptance and enjoying common application can be supported only by validating the new system in different patient groups. This concern has yielded a number of studies, which validated the RIFLE classification in various AKI populations, such as the hospitalized [16–18], the critically ill [19–22], the septic [23], severely burned [24] and traumatized traffic accident patients [25] and those having undergone cardiac surgery [26] or hematopoietic cell transplantation [27]. The total number of patients included in studies validating RIFLE classification exceeded 200,000 in 2008 [14]. To our knowledge, however, there is no data on validation of the RIFLE system in crush patients after mass disasters.

AKI due to crush-induced rhabdomyolysis is the second most frequent cause of mortality after traumatic impact in catastrophic earthquakes [28]. This risky patient population may benefit from being assessed by the RIFLE system not only for medical purposes but also for logistic reasons.

We, therefore, retrospectively analysed crush syndrome database of the Marmara earthquake to validate the RIFLE classification.

**Materials and methods**

The Marmara database included 639 patients, who suffered from crush injury-related nephrological problems, of whom 477 (74.6%) were dialysed [29].

In that particular database, crush injury was described as ‘trauma by collapsing material and debris and manifested muscle swelling and/or neurological disturbances in the affected part of the body’ [30]. Nephrological problems were described as follows: oliguria (urinary output <400 mL/day), elevated levels of blood urea nitrogen (BUN) (>40 mg/dL), serum creatinine (>2 mg/dL), uric acid (>8 mg/dL), potassium (K+ (>6 mEq/L), phosphorus (P) (>8 mg/dL) and/or decreased serum calcium (Ca2+) (<8 mg/dL) [29]. On the other hand, no definitions were provided for overall medical complications, infections and
disseminated intravascular coagulation (DIC) in the methodology of the original questionnaire, and diagnoses were made by the local doctors according to standard diagnostic criteria, which included clinical and laboratory findings and also imaging tools.

This particular database was used for the present study as well, which excluded patients in whom serum creatinine upon admission was not available in the questionnaires and/or who were younger than 20 years of age.

Patients who upon admission did not show any signs related to renal disease and/or provided no information regarding previously disturbed renal function in the pre-disaster period were assumed to have had normal renal function prior to the earthquake. Since the baseline serum creatinine before the disaster was not known for any of these patients, this value was estimated based on the MDRD formula, which is:

\[
\text{Estimated serum creatinine} (\text{SCr}) = 75 + 1.154 \times (\text{age}) + 0.203 \times (0.742 \text{ if female})
\]

\[
\times (1.210 \text{ if black}) - 0.299 \text{ if female} + 0.192 \text{ if black})
\]

where estimated glomerular filtration rate is expressed as mL/min per 1.73 m² [10, 11].

Estimated serum creatinine (SCr)

\[
= [75 + 1.154 \times (\text{age}) + 0.203 \times (0.742 \text{ if female})] / 186
\]

Since no black patients were present in this patient population, the last part \([+ 0.192 \text{ if black}]\) of the formula was omitted.

Then the patients were categorized according to the RIFLE criteria indicating severity of AKI [10]; this was based on the first serum creatinine value obtained after admission to the hospital and the estimated serum creatinine before the disaster.

For the purpose of the present analysis, patients whose serum creatinine level was between 0.8 and 1.4 mg/dL at admission were assumed to have no AKI and hence served as a control group.

Associations between each of the RIFLE strata and blood pressure (BP) and blood biochemistry upon admission [BUN, serum uric acid, K, Ca, P, creatine phosphokinase (CK), alanine aminotransferase (ALT), aspartate aminotransferase (AST), lactate dehydrogenase (LDH), albumin] and haematological parameters as well as length (days) of oliguria, length (days) of polyuria, number of blood product transfusions, need of dialysis support, number of dialysis sessions, days on dialysis support and final outcome (death or survival) were evaluated.

In 225 of the 434 patients, the last serum creatinine at discharge from the nephrology wards was available as well; this value was used for further analyses.

Since only 20 patients were dialysed >4 weeks and we were not aware of any end-stage renal disease after discharge, L or E categories of RIFLE classification were not considered. Hospitalization period varied significantly among the patients, so that mortality was not truncated at a certain time point; all reported outcomes were based on hospital mortality.

**Statistics**

The association between RIFLE strata and numerical variables (e.g. BP, laboratory test values) was analysed primarily by univariate methods, i.e. comparison of mean values of RIFLE strata by one-way analysis of variance (ANOVA) or Kruskal–Wallis nonparametric ANOVA, corresponding to variables with normal and non-normal distributions, respectively. When any difference among RIFLE strata was evidenced by ANOVA technique, then appropriate post-hoc tests (i.e. Tukey honestly significant difference testing one-way ANOVA and Mann–Whitney U-test) were performed.
following Kruskal–Wallis nonparametric ANOVA) were applied in order to detect the source of the significance.

The associations between RIFLE strata and categorical variables were also analysed primarily by univariate methods. The choice between these two methods was made by taking into account the expected values in the cells. When one of the variables was on ordinal scale, then Mantel–Haenszel chi-square test for linear association was also reported along with chi-square test.

Statistical significance was assigned to P values <0.05.

**Results**

**Demographic features**

In total, 434 patients, in whom crush-related nephrological problems had been diagnosed, were submitted to analysis. There were 27, 79 and 310 patients in the R, I and F groups; 18 patients served as controls.

Overall, mean age of the victims was 36.8 ± 12.7 years (Figure 1A). In the entire group, there were only 10 patients >70 years old (seven in the F and three in the I category), and no cases older than 60 were present in the control and R groups.

There were more males [n = 248 (57.1%)] in the whole group (Figure 1B); however, gender differences were insignificant.

Mean time under the rubble (TPR) was 11.4 ± 13.8 (range: 0.5–135) h. This duration was longer in the controls compared with R, I and F (Figure 1C).

Time from disaster to admission was 3.6 ± 3.9 days; there was a significant difference among the control, R, I and F groups (P = 0.004) (Figure 1D). This duration was shorter in the I group as compared to the F category (P = 0.009).

**Clinical findings at admission**

Overall, mean systolic BP was 130 ± 27 mmHg; it was 119 ± 14, 114 ± 23, 125 ± 22 and 133 ± 28 mmHg in the control, R, I and F groups, respectively (P < 0.001). Systolic BP was lower in R vs F (P = 0.004); other intermutual comparisons were not significant.

Mean overall diastolic BP was 78 ± 15 mmHg; it was 75 ± 9 mmHg in the controls, 71 ± 13 mmHg in the R, 75 ± 15 mmHg in the I and 79 ± 15 mmHg in the F groups (P = 0.027). There were no significant differences among R, I and F categories. Considering the whole series, 45.9% (192 of 418) of the patients had a BP above 140/90 mmHg; this figure was 17.6% (3 of 17), 27.3% (6 of 22), 37.2% (29 of 78) and 51.2% (154 of 301) in the control, R, I and F groups, (P = 0.003). Stratified systolic and diastolic blood pressure values at admission to hospitals have been provided in Table 1.

Overall, urine volume was 2108 ± 1970 mL/day at the first day of hospital admission; this volume was 3517 ± 2591 mL/day in the control group; 2286 ± 2204 mL/day in R, 2144 ± 1751 mL/day in I and 2099 ± 1948 mL/day in F groups (P = 0.034). Urinary volume was higher in controls when compared with F (P = 0.020); other intermutual analyses were not significant.

**Laboratory findings at admission**

**Serum creatinine.** In the whole group, calculated serum creatinine before trauma was 1.06 ± 0.15 mg/dL; serum creatinine at admission to the hospitals was measured as 4.88 ± 2.83 mg/dL. Calculated and measured serum creatinine levels before trauma and at admission to the hospitals in various categories of RIFLE are provided in Table 2A and B.

**GFR.** Before trauma, GFR was calculated at 75 ± 0 mL/min/1.73 m²; in the whole group, it was 19.8 ± 17.2 mL/min/1.73 m² at admission (Table 2C), corresponding to a 73% decrease (P < 0.001) (Table 2D).

**Other laboratory parameters.** BUN, serum uric acid, K, P and albumin levels showed significant differences among the control, R, I and F groups at admission; haematocrit was at the borderline of significance (Table 3). The frequency of elevated levels of BUN (>40 mg/dL), serum creatinine (>2 mg/dL), uric acid (>8 mg/dL), potassium (K+) (>6 mEq/L), phosphorus (P) (>8 mg/dL) and de-

| Table 2. GFR and serum creatinine values before trauma and at admission to hospitals |
|---------------------------------|-----------|--------|
| **Parameter** | **Category** | **Mean ± SD** | **P =** |
| **A** | Calculated serum creatinine | Control | 1.12 ± 0.13 | 0.172 |
| | before trauma (mg/dL) | Risk | 1.10 ± 0.15 | |
| | | Injury | 1.07 ± 0.15 | |
| | | Failure | 1.06 ± 0.15 | |
| **B** | Measured serum creatinine at admission (mg/dL) | Control | 1.08 ± 0.22 | <0.001 |
| | | Risk | 1.70 ± 0.23 | |
| | | Injury | 2.60 ± 0.51 | |
| | | Failure | 5.96 ± 2.64 | |
| **C** | GFR at admission (mL/min/1.73 m²) | Control | 82.4 ± 21.4 | <0.001 |
| | | Risk | 45.5 ± 4.9 | |
| | | Injury | 27.3 ± 4.5 | |
| | | Failure | 11.5 ± 4.4 | |
| **D** | Change in GFR (%) vs calculated value before admission | Control | −9.9 ± 28.6 | <0.001 |

*a vs R; b vs I; c vs F; d vs I; e vs F; f vs F. *P < 0.05, **P < 0.001.
creased serum calcium (Ca2+) (<8 mg/dL) in R, I and F groups have been provided in Figure 2.

Variations in leukocyte and platelet counts as well as in serum Ca, ALT, AST, CK and LDH levels did not reach statistical significance.

Clinical course and complications

Overall, oliguria lasted for 8.5 ± 8.1 days; it was 0.1 ± 0.3 days in the controls, 3.2 ± 5.5 days in R, 7.2 ± 7.7 days in I and 9.8 ± 8.1 days in F groups (P < 0.001). Duration of oliguria was shorter in the controls when compared with I (P = 0.006) and F (P < 0.001); also, this period was shorter in R when compared with F (P < 0.001); other intermutual analyses were not significant. Patients in more severe categories of RIFLE were characterized by longer periods of oliguria, when oliguria was stratified into 1–5, 6–10, 11–20 and >20 days (P < 0.001) (Figure 3A).

Duration of polyuria (defined as daily urinary output of >2000 mL) was 11 ± 8.1 days. Overall, it was 10.7 ± 8.3 days in the controls, 9.5 ± 9.4 days in R, 9.6 ± 9.4 days in I and 11.6 ± 7.5 days in F groups. The duration of polyuria was shorter in I when compared with F (P = 0.015); however, overall variation among other categories of RIFLE did not reach significance. Similar to oliguria, in more severe categories of RIFLE, the proportion of patients with polyuria were higher when the latter was stratified into 1–5, 6–10, 11–20 and >20 days (P = 0.032) (Figure 3B).

Medical complications were noted in 57.8% (251 of 434) of the whole group; they were more common in the R (8 of 27 = 29.6%), I (40 of 79 = 50.6%) and F groups (199 of 310 = 64.2%) when compared with the controls (4 of 18 = 22.2%) (P < 0.001). Among these, a linear association was noted between RIFLE categories vs infections and DIC. Infections were noted in 38% (165 of 434) of the whole group; 16% (3 of 18) of the controls, 11.1% (3 of 27) of R, 35.4% (28 of 79) of I and 42.3% (131 of 310) of F groups suffered from infections (P = 0.002). Overall, DIC incidence was 9% (39 of 434); it was present in 6.3% (5 of 79) and 11% (34 of 310) of the I and F groups, respectively, while none of the patients in the control and R groups suffered from this complication (P = 0.085).

Other medical complications did not show statistical significance among various categories of RIFLE.

Treatment modalities

Blood and blood product transfusions. Of all patients, 68.7% (298 of 434) needed blood product transfusions. This need was significantly higher in the R (12 of 27 = 44%), I (55 of 79 = 69.6%) and F groups (227 of 310 = 73.2%) compared with the controls (4 of 18 = 22.2%) (P < 0.001). When analysed separately, overall need for blood (P = 0.002) and human albumin transfusions (P = 0.007) differed significantly among various RIFLE categories (Figure 4).
Dialysis. On the whole, 351 out of 434 (80.9%) patients needed dialysis support. Dialysis was required in 92.3% (286 of 310) of the patients in the F group; this figure was 55.6% (15 of 27) in the R and 63.3% (50 of 79) in the I groups (P < 0.001).

In general, mean duration of dialysis was 11.3 ± 10.1 (range: 0–48) days. Patients in F needed the longest duration (13.5 ± 9.9 days) of renal replacement therapy; R and I group patients were dialysed for 3.2 ± 4.2 and 7.9 ± 9.4 days, respectively (P < 0.001). Duration of dialysis was significantly shorter in R and I when compared with F (P < 0.001, for both analyses). A significant difference was noted among the AKI categories when duration of dialysis was grouped into the 1–5, 6–10, 11–30 and >30 days strata (P < 0.001) (Figure 5A).

Number of HD sessions was 2.5 ± 3.9 in R, 6.3 ± 7.6 in I and 10.8 ± 8.3 in F groups (P < 0.001); it was lower in R and I when compared with F (P < 0.001 for both analyses). More severe categories of RIFLE were characterized by a higher number of dialysis sessions when grouped into the strata of 1–5, 6–10, 11–30 and >30 (P < 0.001) (Figure 5B).
Outcome

**Serum creatinine and GFR at discharge.** Mean serum creatinine at discharge was 1.39 ± 1.12 mg/dL; the highest values were observed in the patients of the F group (overall \( P = 0.007 \); R vs F: \( P = 0.020 \); I vs F: \( P = 0.017 \)) (Table 4A). The highest serum creatinine at discharge was 9.89 mg/dL, corresponding to a GFR of 6 mL/min/1.73 m².

On the average, GFR at discharge was 79.6 ± 42.1 mL/min/1.73 m²; it was lowest in the F group (Table 4B) and showed significant variations among various RIFLE categories (R vs F: \( P = 0.031 \); I vs F: \( P = 0.022 \)).

More serious RIFLE categories were characterized by a worsening kidney function at discharge, with GFR stratified according to the National Kidney Foundation’s stages of chronic kidney disease, i.e. <15, 15–30, 31–60, 61–90 and >90 mL/min (Table 4C).

**Mortality rates.** Seventy-three of the 434 patients died, corresponding to an overall mortality rate of 16.8%. There were no significant differences in intermutual analyses among the groups; this non-significance was maintained even after RIFLE categories were dichotomized, such as into C vs R+I+F or C+R vs I+F (Table 5).

Discussion

We based the present analysis on the Marmara earthquake crush patient database. The principal results are (i) clinical findings and laboratory values at admission are worse; and therapeutic interventions such as blood/blood product transfusions and dialysis are needed more frequently as RIFLE categories become more severe and (ii) survival outcome does not differ among the controls and patients who suffered from AKI nor in between RIFLE categories.

When compared with AKI of other aetiologies, crush-induced AKI shows highly specific features due to (i) a high incidence of life-threatening electrolyte disturbances, such as hyperkalaemia [32,33]; (ii) the frequent simultaneous presence of medical and surgical problems in the clinical course, resulting in a high number of complications [34]; and (iii) high need for therapeutic interventions such as blood and blood product transfusions and dialysis [30,35]. When crush occurs in conjunction with mass disasters, major logistic problems should be added to these obstacles since many health care facilities are out of order, while the number of patients is overwhelming [36,37].

In the present series, casualties were trapped for a relatively short period, and the TPR of the patients in the control group was longer compared with the AKI patients, confirming previous findings of this database [38]. A likely explanation is selection bias, since only patients with mild trauma could survive under the rubble for longer periods.

**Table 4. GFR and serum creatinine values at discharge from the hospitals in various categories of RIFLE classification**

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Risk</th>
<th>Injury</th>
<th>Failure</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A</strong> Creatinine at discharge (mg/dL)</td>
<td>n: 6</td>
<td>10</td>
<td>46</td>
<td>163</td>
</tr>
<tr>
<td>mean ± S.D.</td>
<td>1.11 ± 0.95</td>
<td>1.31 ± 1.42</td>
<td>1.25 ± 0.95</td>
<td>1.44 ± 1.15</td>
</tr>
<tr>
<td>P</td>
<td>0.007</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>B</strong> GFR at discharge (mL/min/1.73 m²)</td>
<td>n: 6</td>
<td>10</td>
<td>46</td>
<td>163</td>
</tr>
<tr>
<td>mean ± S.D.</td>
<td>113.8 ± 71.4</td>
<td>106.7 ± 55.2</td>
<td>89.5 ± 44.2</td>
<td>73.8 ± 37.8</td>
</tr>
<tr>
<td>P</td>
<td>0.010</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>C</strong> GFR strata at discharge (mL/min/1.73 m²)</td>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>&lt;15</td>
<td>0</td>
<td>0.0%</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>15–30</td>
<td>1</td>
<td>16.7%</td>
<td>2</td>
<td>20.0%</td>
</tr>
<tr>
<td>31–60</td>
<td>0</td>
<td>0.0%</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>61–90</td>
<td>1</td>
<td>16.7%</td>
<td>1</td>
<td>10.0%</td>
</tr>
<tr>
<td>&gt;90</td>
<td>4</td>
<td>66.7%</td>
<td>7</td>
<td>70.0%</td>
</tr>
<tr>
<td>P</td>
<td>0.027</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

GFR, glomerular filtration rate.

**Table 5. Outcome of the patients in the whole group and in various dichotomies of AKI categories (C+R vs I+F; C+R+I vs F) and the controls**

<table>
<thead>
<tr>
<th>Outcome</th>
<th>C</th>
<th>R</th>
<th>I</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survived</td>
<td>38</td>
<td>15.6%</td>
<td>66</td>
<td>17.0%</td>
</tr>
<tr>
<td>P</td>
<td>0.811</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Died</td>
<td>16</td>
<td>88.9%</td>
<td>22</td>
<td>81.5%</td>
</tr>
<tr>
<td>Survived</td>
<td>2</td>
<td>11.1%</td>
<td>5</td>
<td>18.5%</td>
</tr>
<tr>
<td>P</td>
<td>0.520</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Died</td>
<td>2</td>
<td>11.1%</td>
<td>7</td>
<td>17.1%</td>
</tr>
<tr>
<td>Survived</td>
<td>16</td>
<td>88.9%</td>
<td>345</td>
<td>82.9%</td>
</tr>
<tr>
<td>P</td>
<td>0.857</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Died</td>
<td>2</td>
<td>11.1%</td>
<td>71</td>
<td>17.1%</td>
</tr>
<tr>
<td>Survived</td>
<td>102</td>
<td>82.3%</td>
<td>259</td>
<td>83.5%</td>
</tr>
<tr>
<td>P</td>
<td>0.745</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

C, control; R, risk; I, injury; F, failure; there were no significant differences.
Overall, 24-h urine output was satisfactory, and arterial blood pressure was adequate at admission. Of note, some patients were polyuric, which might be related to the polyuric phase of acute tubular necrosis or previous administration of large volumes of fluids in the primary health care centres [34]. Interestingly, systolic and diastolic blood pressures progressively increased in the R, I and F groups, while the opposite might be expected because higher blood pressures might have indicated a better kidney perfusion pressure and a better ultimate outcome. However, this hypothesis is valid only in the early hours of prerenal AKI. In cases with a considerable delay at admission to hospitals, as happened in this case, acute tubular necrosis may develop, and increased blood pressure might be the consequence and indicator of subsequent volume overload. Progressively decreasing urine volumes in R, I and F groups also support this hypothesis. Of note, two patients with normal serum creatinine were registered as oliguric in this database, which is an unexpected finding. We can explain this inconsistent result only by errors in registration of urinary volume in chaotic conditions, as they occur especially during the first days of the disaster.

In this analysis, several laboratory tests (Hct, BUN, serum uric acid, K, P and albumin levels) deteriorated as more severe RIFLE categories were reached [39]. Among these laboratory abnormalities, hyperkalaemia is vital because it is a major cause of mortality in crush victims [40]. Thus, the patients in more severe categories of RIFLE should be given priority for empirical treatment of hyperkalaemia. More severe hyperkalaemia per RIFLE category has been noted in accidental trauma patients as well [25].

During the clinical course, oliguria and medical complications other than AKI, which also are indicators of a bad prognosis [25,41–43], were more frequent in more serious RIFLE categories. All these findings are indicators of a bad prognosis and, together with the need for a progressively higher number of blood and blood product transfusions and a more intense dialysis support in the R, I and F groups, indicate a poor outcome [44,45]. Also, these findings are vital from a logistic point of view, which provides the opportunity to anticipate the amount of required material and personnel help from national and international organizations shortly after admission of crush cases.

On the other hand, one should underline that the mortality rate in crush victims is affected by several demographic, medical and surgical conditions. For example, children and women are relatively spared in earthquakes; type and extent of trauma are associated with mortality and incidence of fasciotomies, and amputations can act as confounding variables; of note, fasciotomy, a very frequent intervention in crush victims, has a negative effect on the prognosis [29,34,45]. Thus, a specific complication profile independent of the renal condition might have a deep impact on the ultimate outcome.

In this analysis, overall mortality was quite low, when one considers overwhelming dimensions of the disaster and chaotic circumstances. Surprisingly, there was no association between AKI severity categories and ultimate survival outcome, a finding in contradiction with many studies that include AKI patients due to various aetiologies [22,46].

There are several explanations for this discrepancy:

(1) Crush-related AKI is characterized by many problems, which are not only medical but also surgical, generating a specific complication profile independent of the renal condition. In the present series, mortality rate of the control patients was 11%, which is higher than mortality of control cases in many other studies [18,21,25]. On the other hand, mortality of AKI patients was proportionally low (16.8%).

(2) The study might not have been powered enough to detect differences because of a low number of patients especially in the control, R and I groups.

(3) A selection bias might have occurred in a way that, among the most severe cases, only those with the highest survival chances were rescued to reach the hospitals.

The design of this study differs from that of most other RIFLE validation studies, which are based on AKI patients who were subjected to well-organized regular follow-up and the evolution of the RIFLE score was taken into account. In the present study, this approach was impossible due to disaster circumstances, i.e.: (i) regular laboratory testing was difficult, (ii) data registration was prone to be incomplete as in several past disasters [25,47,48] and (iii) data had to be obtained from post hoc collection. In order to maintain reliability, we collected only serum creatinine on admission and at discharge. In spite of these limitations inherent to the study topic, RIFLE still correlated well with most outcome parameters.

In the present study, we excluded patients with serum creatinine <1.4 mg/dL, assuming that this value may indicate a normal renal function, a policy which might be criticized for missing some AKI cases, especially in the elderly. However, lower cut-offs might have resulted in classifying younger males as having renal dysfunction if they had a serum creatinine in the range of 1.4 mg/dL. Considering that only 10 patients in this database were >70 years old, we thus defined the upper normal limit of serum creatinine as 1.4 mg/dL.

Our study has certain limitations: (i) It is a retrospective analysis that does not give opportunity to search for the effect of different interventions (i.e. early dialysis) on the outcome of patients. (ii) True pre-disaster baseline serum creatinine levels were not available. (iii) It is possible that the relatively young age of many patients—which is not typical for AKI in other settings—puts the present group into a low-risk category to begin with.

To conclude, this study validates the RIFLE staging system in disaster-related crush cases as a useful tool to predict the risk of complications and need for intensive therapeutic interventions. Also, it has proved to be useful in quantifying the amount of needed medical material and personnel help and to make appropriate support calls. This underscores the high practical value of the RIFLE classification related to vital logistic concerns. On the other hand, our data did not corroborate the usefulness of the RIFLE classification for the estimation of survival in this specific population, which may be due to confounding factors.
Application of RIFLE in crush-related AKI

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References


Acute kidney injury in tropical acute febrile illness in a tertiary care centre—RIFLE criteria validation

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Abstract

Background. Acute febrile illnesses are a common cause of tropical acute kidney injury (AKI). The incidence and severity of AKI in tropical febrile illnesses and validity of RIFLE classification are unclear.

Methods. Consecutive adult inpatients of a tertiary hospital in southern India with tropical acute febrile illness between January 2007 and January 2008 were prospectively studied for the incidence and severity of AKI based on RIFLE classification and its association with mortality and dialysis requirement.

Results. The 367 patients (mean age 39.7 ± 16.9 years; 60% males) with tropical acute febrile illness due to scrub typhus (51.2%), falciparum malaria (10.4%), enteric fever (8.7%), dengue (7.6%), mixed malaria (6.5%), leptospirosis (3.3%), undifferentiated acute febrile illness (8.4%) and others (3.8%) (spotted fever, vivax malaria and Hantavirus infection) had an overall mortality rate of 12.3%. The incidence of AKI was 41.1%; of which, 17.4%, 9.3% and 14.4% were in the Risk, Injury and Failure classes, respectively. Of the patients, 7.9% required dialysis. Among the Risk, Injury and Failure groups, there was an incremental risk of mortality (OR 6.9, 20.2 and 25.6; P < 0.001) and dialysis requirement (OR 3.4, 28.8 and 178.8; P < 0.001).

Conclusions. The incidence of AKI in the common tropical acute febrile illnesses in our study such as scrub typhus, falciparum malaria, enteric fever, dengue and leptospirosis is 41.1%. RIFLE classification is valid and applicable in AKI related to tropical acute febrile illnesses, with an incremental risk of mortality and dialysis requirement.

Keywords: acute kidney injury/acute renal failure; dengue; malaria; RIFLE; scrub typhus

Introduction

Worldwide incidence of acute kidney injury (AKI) is variable [1, 2], and even more among the developed and the developing countries [3]. Tropical acute febrile illnesses such as malaria, typhoid, leptospirosis, dengue and others are a major cause of AKI in the tropics [4, 5]. There is renewal of interest with the emergence of such diseases in the developed nations and non-tropical regions [6, 7] due to global warming [8, 9] and travel to tropics [10, 11]. Incidence of AKI with these infections has been unclear due to varying definitions of AKI [12, 13], and overestimation due to referral bias in tertiary care centre reports. The Risk, Injury, Failure, Loss of function and End stage (RIFLE) criteria unified the definition and classification of AKI [14], and were originally validated for ischaemic AKI [15]. There are limited data on validity of RIFLE classification for AKI in tropical acute febrile illnesses. We evaluate the incidence of AKI and validity of the RIFLE classification in tropical acute febrile illnesses.

Materials and methods

The study was permitted by the institutional review board and ethics committee. From January 2007 to January 2008, consecutive medical ward...