Dialysis practice and patient outcome in the aftermath of the earthquake at L’Aquila, Italy, April 2009

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Abstract

Background. In the aftermath of large natural and man-made disasters, the need for continuing maintenance haemodialysis (HD) in end-stage renal disease patients of the disaster area and care including dialysis for patients suffering from acute kidney injury (AKI) due to crush syndrome are the two most important nephrological problems.

Methods. We report on how renal patients and renal care personnel faced emergency in the aftermath of the earthquake that struck the Italian town of L’Aquila and a surrounding district, on Monday 6 April 2009, causing 308 deaths, some 1500 injured and 66 000 people to be displaced.

Results. The Dialysis Centre in the town did not collapse but was seriously damaged and out of action, making it necessary to move 88 patients on regular dialysis treatment to the closest available facilities to continue treatment. This was all the more urgent in that 45 patients of the Monday–Wednesday–Friday batch were coming off the long interdialytic interval, with possible medical problems (i.e. high increase in weight gain, blood pressure, etc.). In spite of manifold difficulties (including road interruption and shortage of means of transportation, problems in establishing contact between patients and care personnel due to failure of phone and electronic communication and the limited number of available dialysis posts), no patient missed any scheduled HD session. This was obtained thanks to the transfer of patients to neighbouring functioning units, often with extra dialysis shifts. In 3 days, a provisional Dialysis Centre was set up in an inflatable military-style tent, enabling 780 dialysis sessions to be performed safely on patients who had opted to return to L’Aquila. The tent facility was replaced by a rigid modular structure, insulated as living accommodation, containing 13 dialysis machines (20 from 17 November) functioning in HD or on-line haemodiafiltration. Ten cases of crush-related AKI needing dialysis treatment were recorded, the ratio of dialysed victims to number of deaths (32.4: 10 cases/308 deaths, 1000×) being the highest value yet reported. Fasciotomy was performed in six patients but none of the patients had to be amputated. Intermittent HD was used in most cases as the single modality of renal replacement therapy. All patients survived and recovered renal function on discontinuing dialysis treatment. Serum creatinine returned to normal values upon discharge from hospital or during the follow-up period.

Conclusions. Each earthquake is different and may pose issues that will require unanticipated response efforts. Advance planning and rescue coordination, flexibility and creativity in the emergency situation, as well as the hard work and dedication of the entire dialysis care community, contributed to the remarkably positive outcome of dialysis-needing patients in the aftermath of the Aquila earthquake.

Keywords: acute kidney injury; crush syndrome; dialysis; earthquake; temporary dialysis unit

Introduction

Earthquakes affect the renal community in its entirety: on the one hand, there is the need for continuing maintenance haemodialysis (HD) in end-stage renal disease (ESRD) patients of the damaged area; on the other hand, crush victims have complex pathologies and need extensive and expert health care usually including fluid, electrolytes and dialysis therapy due to acute kidney injury (AKI). Disasters may obviously increase the number of subjects requiring renal replacement therapy while simultaneously disabling dialysis units [1, 2].

Treatment of ESRD on life-sustaining dialysis in the aftermath of a renal disaster may be problematic due to several reasons, including damage to the dialysis facilities [1–4], damage to urban facilities such as electricity and water causing loss of efficiency by HD machines [4] and a considerable drop in HD personnel [2, 5]. This may result in missed HD sessions, which has a harmful impact on patient outcome [6–8], unless compensated by dietary measures [2]. After Hurricane Katrina in 2005, out of 386 patients contacted by 9 New Orleans HD units,
An early and general picture of renal disaster relief as experienced after the Aquila earthquake has been previously provided [16]. The aim of the present article is to analyse HD practice as well as the fate of chronic HD patients and of dialysis-needing AKI patients in the aftermath of the Aquila event.

Materials and methods

Data on ESRD patients were collected by one of the authors (S.S.), who was a local nephrological coordinator.

On the eve of the disaster, 88 ESRD patients were on regular dialysis treatment at the Dialysis Centre of L’Aquila hospital, equipped with 27 dialysis machines. By 4 a.m. that morning, it was agreed that the dialysis centre was out of action due to flooding (the pipes having burst on the osmosis plant preparing dialysis water). At 4:30 a.m., the call went out to the Health Managements of hospitals relatively near to L’Aquila to put dialysis facilities on stand-by. This was all the more urgent in that 45 patients were coming off the long interdialytic interval. The distribution of dialysis facilities in the Abruzzo region is shown in Figure 1. A mere 3 days after the event, a 104-m² inflatable military-style tent was set up in the field hospital under canvas (Figure 2). Inside this, three flexi-tube dialysis circuits were installed, each connected to a portable osmosis plant to prepare the water needed for treatment (Fresenius AquaWTU, kindly gifted by Fresenius MC). Chemical, physical and bacteriological tests were duly performed on the dialysis liquid, confirming its suitability for extracorporeal dialysis treatment. In all, 10 dialysis monitors were connected up to the plant, including the ones already being used by the hospital.

On 23rd May, the tent was dismantled and a 120-m² rigid modular construction put up in its place, insulated as living accommodation, manufactured by Modular srl (Figure 3). Learning from experience, this was equipped with four polyvinyl chloride (PVC) dialysis circuits, each connected to an osmosis machine (Fresenius AquaWTU) giving a total of 13 (20 from 17 November) dialysis machines functioning in HD or on-line haemodiafiltration (HDF) modality. Unlike its predecessor, this facility was air conditioned; each patient had audio–video facilities and a free satellite connection (Figure 3). There was also a 15-m² waiting room, a small storeroom and a canteen space for staff. The main features of temporary dialysis units at the Aquila field hospital are reported in Table 1.

Extrication of victims from under the rubble was carried out by rescue teams, including trained non-medical rescue team members and health care workers. Attempts were made (oral communication or limited physical examination) to determine the physical status of the victim (position, subjective complaints, presence of vital signs, bleeding and volume status). Fluid intervention was initiated whenever possible before extrication, with infusion of isotonic saline which was kept up for the entire period of extrication, victims receiving 2 L of fluid. After extrication, victims received another 500 mL–1 L of saline (1 L was given to extricated victims who did not receive fluid while entrapped because a vein could not be found). In cases of significant blood loss, type-specific or zero-negative blood was administered. Full spinal precautions were maintained.

After completing triage and a primary survey assessment, crush victims needing hospitalization were referred to experienced and well-equipped hospitals. In the meantime, they had been receiving fluids at a low infusion rate (0.25 L/h of normal saline alternated with 5% dextrose to reduce the potential sodium load).

Data for patients suffering from crush-related AKI needing dialysis treatment were collected according to the Crush Syndrome Patients Questionnaire by the Renal Disaster Relief Task Force (RDRTF) of the International Society of Nephrology (ISN), kindly provided by Drs Mehmet Sever and Raymond Vanholder. The questionnaires were sent to the renal units that treated such patients, located in the hospitals of Chieti, Pescara, Rome, Sulmona and Teramo. In most cases, patients were first admitted to the emergency unit and then referred to the nephrology unit after biochemical and clinical examination. Dialysis support was initiated according to standard indications, such as the presence of oliguria or anuria, volume overload or biochemical abnormalities (severe uraemia, hyperkalaemia and acidaemia). Whether to begin and what type of renal replacement therapy to perform were decisions taken by the local physicians. Dialysis support was discontinued when

44% were reported to have missed at least one session and as many as 17% to have missed three or more dialysis sessions [3]. Importantly, an association was identified between missing more than two HD sessions and being hospitalized [3]. Another example of less frequent dialysis between missing more than two HD sessions and being hospitalized [3]. Another example of less frequent dialysis between missing more than two HD sessions and being hospitalized [3]. Another example of less frequent dialysis between missing more than two HD sessions and being hospitalized [3]. Another example of less frequent dialysis between missing more than two HD sessions and being hospitalized [3]. Another example of less frequent dialysis between missing more than two HD sessions and being hospitalized [3]. Another example of less frequent dialysis between missing more than two HD sessions and being hospitalized [3]. Another example of less frequent dialysis between missing more than two HD sessions and being hospitalized [3]. Another example of less frequent dialysis between missing more than two HD sessions and being hospitalized [3]. Another example of less frequent dialysis between missing more than two HD sessions and being hospitalized [3]. Another example of less frequent dialysis between missing more than two HD sessions and being hospitalized [3]. Another example of less frequent dialysis between missing more than two HD sessions and being hospitalized [3]. Another example of less frequent dialysis between missing more than two HD sessions and being hospitalized [3]. Another example of less frequent dialysis between missing more than two HD sessions and being hospitalized [3]. Another example of less frequent dialysis between missing more than two HD sessions and being hospitalized [3]. Another example of less frequent dialysis between missing more than two HD sessions and being hospitalized [3]. Another example of less frequent dialysis between missing more than two HD sessions and being hospitalized [3]. Another example of less frequent dialysis between missing more than two HD sessions and being hospitalized [3]. Another example of less frequent dialysis between missing more than two HD sessions and being hospitalized [3]. Another example of less frequent dialysis between missing more than two HD sessions and being hospitalized [3]. Another example of less frequent dialysis between missing more than two HD sessions and being hospitalized [3]. Another example of less frequent dialysis between missing more than two HD sessions and being hospitalized [3]. Another example of less frequent dialysis between missing more than two HD sessions and being hospitalized [3]. Another example of less frequent dialysis between missing more than two HD sessions and being hospitalized [3]. Another example of less frequent dialysis between missing more than two HD sessions and being hospitalized [3]. Another example of less frequent dialysis between missing more than two HD sessions and being hospitalized [3]. Another example of less frequent dialysis between missing more than two HD sessions and being hospitalized [3]. Another example of less frequent dialysis between missing more than two HD sessions and being hospitalized [3]. Another example of less frequent dialysis between missing more than two HD sessions and being hospitalized [3]. Another example of less frequent dialysis between missing more than two HD sessions and being hospitalized [3]. Another example of less frequent dialysis between missing more than two HD sessions and being hospitalized [3]. Another example of less frequent dialysis between missing more than two HD sessions and being hospitalized [3]. Another example of less frequent dialysis between missing more than two HD sessions and being hospitalized [3]. Another example of less frequent dialysis between missing more than two HD sessions and being hospitalized [3]. Another example of less frequent dialysis between missing more than two HD sessions and being hospitalized [3]. Another example of less frequent dialysis between missing more than two HD sessions and being hospitalized [3]. Another example of less frequent dialysis between missing more than two HD sessions and being hospitalized [3]. Another example of less frequent dialysis between missing more than two HD sessio
urine volume normalized in a patient as serum biochemistry values improved in the absence of fluid overload. Likewise, the execution and timing of fasciotomy was decided by the local surgeons.

Results

ESRD patients on maintenance HD

As well as the search for working dialysis units with sufficient capacity to take on extra patients, there were other difficulties in arranging dialysis for chronic ESRD patients:

(i) Mobile phone system temporarily down (for >1 h); 
(ii) Inability to set up telephone communications outside the hospital, the central switchboard service having been put out of action by the earthquake (this difficulty was solved when the mobile phone system resumed); 
(iii) Difficulty of tracing patients who had abandoned their homes: this problem was solved when many patients spontaneously converged on the city hospital seeking information on dialysis and when the mobile phone system was restored;
(iv) Need to go on working inside the hospital despite the violent cascade of tremors since all the patient dialysis files were exclusively uploaded on the hospital’s own data processing centre;
(v) Difficulty in arranging transportation for dialysis patients since most vehicles were busy ferrying the 450 (approximately) already occupying the Aquila hospital

Fig. 1. Map showing the distribution of dialysis units in the Abruzzo region.

Fig. 2. (Top) L’Aquila field hospital under canvas completed by 2 a.m. on 7 April. Circle shows the inflatable military-style tent housing the Dialysis Centre, operative from 9 April to 23 May. (Bottom) Inside view of the field dialysis unit.
or being used for the casualties converging on the Aquila Hospital First Aid point. Transportation possibilities proved indeed to be a major obstacle in renal-relief coordination. The problem was solved thanks to the collaboration of communities and voluntary relief association groups, contacted by the coordinator of Italian Civil Protection and the head of the local emergency service, which offered their transportation (mostly mini-coaches) to convey ESRD patients to nearby facilities.

In the event, L’Aquila HD patients were transported to four dialysis centres in Abruzzo (Popoli, 50 km away from L’Aquila; Avezzano, 55 km; Tagliacozzo, 54 km; Teramo 59 km) and one centre in Lazio Region (Rieti, 60 km). The nursing staff of the city hospital dialysis centre accompanied L’Aquila patients to other dialysis centres and actively collaborated with staff there. By midday on 6 April, L’Aquila dialysis patients on the morning shift had been (free positions in operational units) or were being (extra workshift) dialysed, followed at about 4 p.m. by the beginning of an extra workshift for afternoon shift patients. Regular patients on the afternoon shift of operational units, duly informed, were then dialysed in the evening.

Likewise on the day after, dialysis was administered, morning and afternoon, to the Tuesday–Thursday–Saturday patient batch. However, since patients had been transferred to centres throughout Abruzzo, there was hardly any need for extra workshifts (which ended on 8 April). In all, 83 of the 88 dialysis patients previously being treated at the Aquila Hospital managed to get their dialysis in Abruzzo health units, while 5 were sent to the Rieti Dialysis Centre.

Another 11 patients afterwards moved from Abruzzo to other dialysis centres in Italy.

On 9 April, dialysis activity started in the temporary dialysis unit located in a tent (Figure 2) for those patients who had opted to return to L’Aquila rather than be moved to other centres. From 9 April to 23rd May, these facilities enabled 780 dialysis sessions to be performed. No significant intradialytic complications occurred, though there were various logistic difficulties: primarily controlling the indoor temperature in view of the daily temperature range that L’Aquila is normally exposed to. It was also hard to keep up the supply of warehouse materials. Since the general dialysis warehouse had been put out of action, material had to be kept in hospital corridors inside air-conditioned tents and containers.

These problems were mostly solved by replacement of the tent facility with the rigid modular structure (Figure 3). Extracorporeal procedures in the temporary dialysis unit were nonetheless carried out safely, without the occurrence of any clinically relevant side effects and with no major changes to either dialysis prescription or medical therapy.

Over time, the ESRD patients have gradually returned to dialyse regularly at the Aquila Centre (Figure 4). As of May 2010, 78 chronic dialysis patients are being treated at the temporary Aquila dialysis unit, 41 by conventional HD and 37 by on-line HDF. They divide into three dialysis shifts from Monday to Saturday. Acute patients are now being dialysed at the emergency room created inside the former G8 hospital overlooking San Salvatore, prepared for action in the month of June. The same room also caters for various plasmapheresis techniques and procedures for catheterizing central veins.

Table 1. Main features of temporary dialysis units at Aquila field hospital; UPS, uninterruptible power supply

<table>
<thead>
<tr>
<th></th>
<th>Tent</th>
<th>Rigid modular structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Osmosis plants</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Dialysis circuits</td>
<td>3 (flexi-tube)</td>
<td>4 (PVC)</td>
</tr>
<tr>
<td>Dialysis machines</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Monitor for HCV patients</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Infective complications</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Logistic difficulties</td>
<td>Yes (UPS−)</td>
<td>No (UPS+)</td>
</tr>
<tr>
<td>Electricity supply</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Air conditioning system</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Hail and rain</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Dialysis material stocking</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>
AKI needing dialysis therapy

It has been estimated that 159 subjects were extricated from under the rubble following the 6 April earthquake at L’Aquila. To the best of our knowledge, based on direct contact with each hospital involved in the care of patients from the Aquila earthquake, there were 10 cases (three females and seven males, aged 35–69 years, range 16–69 years) of crush-related AKI needing dialysis treatment. We are unable to provide the overall incidence of renal failure related to crush syndrome (or other causes) since data on victims with renal injury not necessitating renal replacement therapy were not collected as part of the present survey.

The main admission findings on crush-related AKI casualties receiving dialysis in the Aquila disaster are reported in Table 2. All patients had suffered from trauma to the extremities, causing fractures in six cases. Abdominal trauma and thorax trauma had occurred in six and five patients, respectively. Fasciotomy was performed in six patients but none of the patients had to be amputated. Antibiotic therapy was administered to each patient at admission or shortly after.

Most patients presented with diuresis reduction and all with dirty-brownish urine discolouration due to myoglobinuria (Table 2). By way of renal replacement therapy, most patients were treated by a single type of therapy, intermittent HD being the most common (Table 3). Upon discharge from hospital, 6 of 10 patients (Table 3) had a normal serum creatinine value, a finding confirmed in following checks. Of the remaining four patients, one (Case no. 5) was lost to follow-up due to change of residence, while in the other three patients (Case nos. 3, 8 and 10), serum creatinine returned to normal values (1.01, 1.10 and 0.9, mg/dL, respectively) during the follow-up period.

All crush-related AKI patients required blood transfusions, in some cases a large number of units; many of them also received fresh frozen plasma and human albumin transfusions (Table 3).

Discussion

Treatment of chronic dialysis patients in the aftermath of mass disasters is problematic for both logistic and medical reasons [2]. Detailed information on the fate of HD patients and facilities are, however, scanty, with the exception of the Kobe [5, 9], Marmara [2] and Katrina [3, 17] experiences. In those events, characterized by heavy damage to many dialysis facilities and a large number of HD patients displaced from their home centres, less frequent dialysis care was provided in many cases, although this did not result in excess mortality [17].

The fact that the Abruzzo region dialysis network encompasses so many centres (Figure 1) undoubtedly helped to get all the ESRD Aquila patients treated promptly in the emergency. It also made for adequate storage of dialysis material. In order to cope with dialyzing the Aquila patients, extra workshifts had to be run at operational dialysis units. The treatment time for local patients was in some cases slightly shortened to accommodate the additional patients. The important fact is that no patient missed any regularly scheduled HD session.

Managing to start up a temporary dialysis unit in the field hospital on 9 April certainly facilitated dialysis care with the Aquila chronic dialysis patients, as it allowed them to return to their hometown. The installation of temporary dialysis units near a disaster area calls for adequate water supplies, and such field units can usually only handle a few patients [18]. In terms of time, length and numbers of chronic dialysis patients being treated, the experience of the temporary Aquila dialysis unit in the tent must count as unique. The aim was to meet a legitimate demand on the part of such patients who are not only machine dependent but would otherwise have had to travel over 350 km a week in order to stay in their earthquake-shattered town. The results obtained so far (the experience is still on-going) demonstrate the feasibility of dialyzing many patients in a temporary dialysis unit for a prolonged time period.
Return of the dialysis unit inside the Aquila hospital is scheduled for the end of 2010.

Major earthquakes over the past few decades have mostly occurred in remote parts of various countries [11, 15, 19, 20]. The earthquake that affected L’Aquila, occurring in a modern context, is an exception, like the ones that hit Mexico City in 1985 [21], and Kobe, Japan, in 1995 [4, 5, 9]. The catastrophic earthquake that struck Kobe and its vicinity on 17 January 1995 caused 6308 deaths and injured ~35 000 people [5]. Because HD facilities drastically failed as did the water and dialysate supply, patients on maintenance HD had to move to unaffected institutions outside the city of Kobe in order to get dialysis treatment. Unlike the Aquila event, this situation lasted for a few weeks but often resulted in less frequent dialysis [9]. Another difference was the attendance of HD personnel during the day of the disaster. In Kobe, only 44.2% of the nurses and 58% of the doctors were present because of injuries to themselves or family members or transportation difficulties [5]. In contrast, at L’Aquila, 88% (15 of 17) of the nurses and 75% (3 of 4) of the doctors were present, despite being shocked and in some cases injured.

Since the first epidemiologic occurrence of AKI in the aftermath of the Armenian Spitak earthquake in 1989 [22], there have been a number of major earthquakes, including the recent Haiti and Chile [23, 24] events, calling for dialysis treatment of victims with AKI [16]. The ratio of dialysed victims to number of deaths (32.4:10 cases/308 deaths, 1000×) was higher in the Aquila event than ratios reported in previous major earthquakes of the last two decades [16]. Factors playing a role in this dramatic figure include the intensive and highly successful rescue efforts, the transfer of rescued victims to adequately equipped hospitals, the timing of the quake at night, surprising people in a supine position [25] and last but not least, an efficient fluid administration policy. Victims extricated from under the rubble subsequent to the Aquila earthquake received fluid infusion either before or immediately after extrication. Fluid administration to neutralize dehydration and deposition of myoglobin casts in the renal tubules is an efficient preventive approach for crush-related AKI, which should be started early, ideally before extraction from the rubble [26]. Isotonic saline is the preferred solution since it is readily available and highly efficient for volume replacement. The usefulness of early fluid administration was clearly demonstrated in the Bingöl earthquake in Turkey in 2003 [27]. Of 17 crush victims, only 4 needed dialytic support: in these patients, the duration between rescue and fluid resuscitation was significantly longer (9.3 ± 1.7 h) than in non-dialysed victims (3.7 ± 3.3 h) [27].

Another reason for the low number of crush-induced AKI needing dialysis after the Aquila earthquake might be related to the time period under the rubble. The time spent under rubble before extrication is regarded as an important indicator for crush-induced AKI and a critical factor influencing the final outcome [28]. Crush-related AKI after the BAM earthquake developed in casualties who had been entrapped longer (6.2 ± 4.1 h) as compared to victims extricated earlier (2.1 ± 3.9 h, P < 0.001) who developed no AKI [15]. The shorter time spent under the rubble by crush-related AKI patients in the aftermath of the Kashmir earthquake, as compared to the Marmara group of AKI (7.2 ± 6.1 versus 11.3 ± 13.3 h, P < 0.001), was considered one of various reasons for the fewer crush-induced complications in the Kashmir group [25]. The time spent under the rubble by the Aquila victims needing dialysis for crush-induced AKI was 8 ± 5.1 h (mean ± SD). Although we cannot make a comparison with extricated victims not developing AKI, such a time period is shorter than that reported after the Marmara disaster and could be another reason for the relatively favourable outcome in the Aquila experience.

The course of crush-related acute renal failure may be complicated and need dialysis, a lifesaving procedure in such patients. Intermittent HD, continuous renal replacement therapy and peritoneal dialysis are all valid therapeutic options, each one posing specific logistic challenges [18]. In AKI patients after the Aquila event, intermittent HD was used in most cases as a single modality (Table 3). The mean number of HD sessions was 14.4 and the mean duration of HD support was 21.8 days, indicating that daily HD was required in some patients. Importantly, all patients recovered renal function on discontinuing dialysis treatment.

Patients with crush syndrome need numerous blood-product transfusions to treat medical and surgical

### Table 2. Laboratory and clinical findings at admission in AKI crush syndrome patients needing renal replacement therapy after L’Aquila earthquake

<table>
<thead>
<tr>
<th>Case no.</th>
<th>Time under rubble, h</th>
<th>Blood pressure, mmHg</th>
<th>First 24 h urine volume, mL</th>
<th>Serum creatinine, mg/dL</th>
<th>BUN, mg/dL</th>
<th>Creatine phosphokinase, IU/L</th>
<th>Blood ph</th>
<th>K⁺, mEq/L</th>
<th>Hb, g/dL</th>
<th>WBC count, 10³/µL</th>
<th>Platelet count, 10³/µL</th>
<th>Calcium, mg/dL</th>
<th>Uric acid, mg/dL</th>
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<tbody>
<tr>
<td>1</td>
<td>3</td>
<td>150/90</td>
<td>500</td>
<td>2.3</td>
<td>28</td>
<td>178 430</td>
<td>7.15</td>
<td>4.3</td>
<td>18.3</td>
<td>21.2</td>
<td>267</td>
<td>8.4</td>
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<td>140/80</td>
<td>100</td>
<td>2.2</td>
<td>26</td>
<td>86 124</td>
<td>7.20</td>
<td>4.3</td>
<td>16.5</td>
<td>21.5</td>
<td>194</td>
<td>8.8</td>
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<tr>
<td>3</td>
<td>7</td>
<td>160/100</td>
<td>50</td>
<td>2.0</td>
<td>21</td>
<td>87 986</td>
<td>7.22</td>
<td>4.9</td>
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<td>4</td>
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<td>110/70</td>
<td>400</td>
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<td>6</td>
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</table>

[a] BUN, blood urea nitrogen; Hb, haemoglobin; K⁺, potassium; WBC, white blood cell.
### Table 3. Main clinical course findings in AKI crush syndrome patients needing renal replacement therapy after L’Aquila earthquake; CVVH, continuous venovenous haemofiltration; CVVHD, continuous venovenous haemodialysis; CVVHDF, continuous venovenous haemodiafiltration; FFP, fresh frozen plasma; IHD, intermittent haemodialysis

<table>
<thead>
<tr>
<th>Case no.</th>
<th>Surgical interventions</th>
<th>Dialysis Type</th>
<th>No. of dialysis sessions</th>
<th>No. of days on dialysis</th>
<th>No. of blood transfusions</th>
<th>Number FFP transfusions</th>
<th>Number human albumin transfusions</th>
<th>Complications</th>
<th>Outcome</th>
<th>Serum creatinine at discharge$^a$ (mg/dL)</th>
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<td>1</td>
<td>None</td>
<td>CVVH IHD</td>
<td>5$^b$</td>
<td>13</td>
<td>4</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>Discharged</td>
<td>1.21</td>
</tr>
<tr>
<td>2</td>
<td>Pleural drainage</td>
<td>IHD</td>
<td>17</td>
<td>25</td>
<td>4</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>Discharged</td>
<td>1.25</td>
</tr>
<tr>
<td>3</td>
<td>Fasciotomy; left shoulder osteosynthesis</td>
<td>IHD</td>
<td>16</td>
<td>25</td>
<td>9</td>
<td>None</td>
<td>None</td>
<td>Left sciatic nerve deficit</td>
<td>Discharged</td>
<td>2.45</td>
</tr>
<tr>
<td>4</td>
<td>Fasciotomy; bilateral peroneal nerve deficit</td>
<td>IHD</td>
<td>11$^c$</td>
<td>32</td>
<td>4</td>
<td>None</td>
<td>6</td>
<td>Bilateral peroneal nerve deficit</td>
<td>Transferred to Como Hospital; discharged</td>
<td>0.9</td>
</tr>
<tr>
<td>5</td>
<td>Fasciotomy; right hemi-colectomy</td>
<td>CVVHD/CVVHDF</td>
<td>Continuous renal replacement therapy $^d$</td>
<td>11</td>
<td>40</td>
<td>55</td>
<td>17</td>
<td>None</td>
<td>Discharged</td>
<td>2.0</td>
</tr>
<tr>
<td>6</td>
<td>Fasciotomy; right pleural drainage</td>
<td>IHD</td>
<td>16</td>
<td>22</td>
<td>None</td>
<td>None</td>
<td>Left peroneal nerve deficit</td>
<td>Discharged</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Fasciotomy; head injury suture</td>
<td>IHD</td>
<td>8</td>
<td>10</td>
<td>29</td>
<td>15</td>
<td>Compartment syndrome</td>
<td>Discharged</td>
<td>0.9</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Fasciotomy; pleural drainage</td>
<td>IHD</td>
<td>26</td>
<td>32</td>
<td>16</td>
<td>45</td>
<td>10</td>
<td>Pneumonia, pleural effusion</td>
<td>Transferred to Modena Hospital; discharged</td>
<td>1.94</td>
</tr>
<tr>
<td>9</td>
<td>Fasciotomy; pleural drainage</td>
<td>IHD</td>
<td>22</td>
<td>36</td>
<td>21</td>
<td>25</td>
<td>21</td>
<td>Pneumonia, pleural effusion</td>
<td>Discharged</td>
<td>1.01</td>
</tr>
<tr>
<td>10</td>
<td>Pleural drainage</td>
<td>IHD</td>
<td>13</td>
<td>18</td>
<td>10</td>
<td>6</td>
<td>11</td>
<td>Transferred to Rome (Gemelli Hospital); discharged</td>
<td>1.5</td>
<td></td>
</tr>
</tbody>
</table>

$^a$Creatinine method with calibration traceable to isotope dilution mass spectrometry; normal values are 0.52–1.04 mg/dL (female) and 0.66–1.25 mg/dL (male).

$^b$Preceded by three CVVH days.

$^c$Eight IHD sessions at Chieti and three IHD sessions at Como.

$^d$Preceded by four CVVHDF days.
Complications [29]. This was also observed in the Aquila experience (Table 3). It should be noted that the present analysis was restricted to victims with AKI requiring dialysis; if all the victims of the disaster had been taken into account, larger amounts would have been needed. Thus, when a disaster occurs, calls for blood donation should be carefully timed and gauged to cover the anticipated period of need [18].

Considering prognosis, the calculated survival rate in the dialysed crush victims of the Iran (Year 1990) and Japan Kobe earthquake was ~60% [19, 30]. This figure has markedly improved in disasters from 1999 onward, registering survival rates of ≥80% [11, 12, 25, 27, 31]. The Aquila experience was even more positive, as no AKI fatalities occurred. This may be related to the limited number of AKI patients, together with the appropriate and timely therapeutic measures [16]. Although a survival rate comparison between various disasters is simply impossible since many non-medical factors can play a role in the final outcome of crush victims, prognosis in crush-related AKI in relation to earthquakes is apparently improving. This might be due not only to better awareness by the renal community but also to the experience gained during various mass disasters and reported in seminal publications on medical management and strategies for tackling renal problems related to disasters [18, 32].

In the aftermath of the Aquila earthquake, although many issues were well dealt with, there were others that warrant improvement. The speed, efficiency and coordination of the relief operation amid the chaos have already been acknowledged [16]. Disaster plans including instructions on the approach to crush victims contributed to the successful rescue of many victims. Again, the active and dynamic cooperation between disaster relief coordinators, emergency organizations and the local nephrological coordinator (S.S.) enabled many problems relative to renal patient treatment to be solved, as described above.

Though detailed nephrology planning processes in the Abruzzo region did not occur before the Aquila event, it had been assumed that in the unfortunate case of a regional disaster like an earthquake, dialysis units would be non-operational and dialysis patients would have to be treated away from their customary dialysis facility. Standing collaborative agreements among regional dialysis centres to transfer patients as needed, together with wide distribution of such centres throughout the area, would mean that the service can cope with a sudden influx of patients, as was experienced after the 6 April Aquila earthquake.

Advance registration of all dialysis facilities and their capacity (machines and personnel) in a given region or country is considered as a prerequisite for any structured procedure once a disaster takes place [33]. The Abruzzo region has a web-based dialysis patient registry that includes all regional dialysis units and collects the main characteristics of chronic dialysis patients for epidemiologic purposes. One lesson learned from the Aquila experience is the need to upgrade the database with additional data on each dialysis centre and patient, an operation that is currently going ahead. A region-wide system for retrieving patient medical records, medication list, dialysis prescription and infection status may make for safer treatment and better informed staff in the event of a disaster [33]. Being a web-based tool, and hence, allowing access to patient information from any location, the implemented Abruzzo dialysis database would also solve one problem encountered in arranging dialysis for Aquila patients (see Point 4 in Result section).

Other lessons have been learned from the Aquila experience and need to be taken into account for the future. Firstly, the failure of communication technologies, particularly right after the earthquake, as a result of limitations in the regular phone service, calls for alternative communication modes. The institution of an emergency hotline, use of solar powered technology or use of satellite systems providing telephone and Internet access may be valid options. In addition, the website of the Abruzzo dialysis registry could be used as an emergency resource for communication, both enabling the current situation to be addressed and acting as a clearing-house to identify needs and solutions. Secondly, the transportation shortage experienced suggests transportation methods should be defined in advance. A prearranged transportation plan for transferring renal patients should include school buses, rental buses and vans and designated drivers; with if local circumstances permit, this could extend to helicopter or air bridges. Thirdly, the Aquila earthquake revealed that chronic dialysis patients are not trained how to react during a disaster, especially if the event happens during dialysis.

Corrective action to improve the above critical issues is now being worked on, including disaster-related education for patients. In this regard, recommendations currently being prepared by the RDRTF of the ISN, covering all disaster-related aspects of kidney disease and crush, and recommendations on specific dialysis-related aspects developed in the USA after Hurricane Katrina [33] will certainly be helpful and improve response to future disasters.

In the aftermath of disasters, renal problems are frequent and severe while delivery of care by the renal community is problematic. For an effective disaster response, the importance of logistic planning, coordination of medical interventions and educational campaigns targeting the public, rescue teams, non-nephrological and nephrological (para-) medical personnel has been stressed [18, 32]. However, every disaster is different [25] and may pose different challenges requiring unanticipated response efforts. Advance planning, rescue coordination, flexibility and creativity in the emergency situation, as well as the hard work and dedication of the entire dialysis care community, contributed to the continuity of chronic dialysis care and to the successful rescue of many victims in the aftermath of the Aquila earthquake.

Acknowledgements. Special commendation should go to the nursing staff of L'Aquila hospital dialysis centre who accompanied Aquila patients to other dialysis centres and actively collaborated with staff there, despite being shocked and in some cases injured as they and their families had been directly involved in the drama.

We express admiration for the staff of dialysis centres receiving the Aquila patients who displayed professionalism, self-sacrifice and solidarity in dealing with the sudden influx of needy cases. The same appreciation goes to the personnel (medical and paramedical) involved in the care of patients suffering from AKI needing dialysis support.
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