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Special Feature

Renal disaster relief in Europe: the experience at L'Aquila, Italy, in April 2009

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Abstract

On 6 April 2009, an earthquake struck the city of L'Aquila and the surrounding Abruzzo mountains. The disaster left 66 000 people homeless, while 1500 were wounded and 298 died. Although Europe as a whole is not so often affected by massive earthquakes, Italy is an exception with 12 earthquakes with an intensity >6.0 on the Richter scale during the last 100 years. This article offers preliminary information on the L'Aquila earthquake. For the time being, nine AKI patients who needed dialysis treatment are known. In all of them, kidney function recovered. This positive result can be attributed to the efficient and intensive rescue efforts coupled to the availability of disaster plans that had been developed in advance. This article stresses the importance of (i) advance planning of disaster rescue; (ii) the inclusion in these plans of approaches for kidney problems and their complications; (iii) the formulation of recommendations supporting (para-)medical professionals in their preventive, therapeutic and logistic approach to massive incidences of crush.

Keywords: disaster; acute kidney injury; earthquake; crush syndrome; L'Aquila

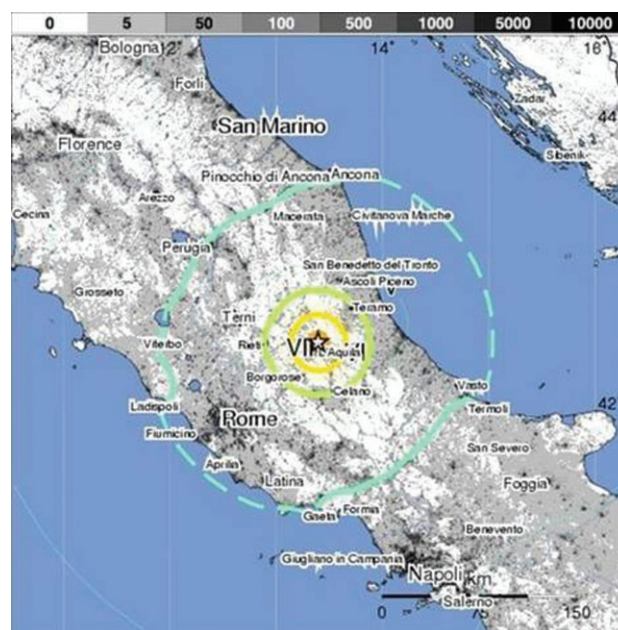


Fig. 1. Map of the Abruzzo area surrounding L'Aquila.

Introduction

On Monday, 6 April 2009, at 3.32 a.m. local time (1.32 GMT), an earthquake with maximum intensity of 6.3 on the Richter scale struck the Italian city of L'Aquila (80 000 inhabitants) and the surrounding district of the Abruzzo mountains (Figure 1). The disaster left 66 000 people homeless, while 1500 were wounded and 298 died (Figure 2). The primary seism was followed by several aftershocks, the most severe of which, on Thursday evening 9 April, caused definitive damage to the local hospital, which fortunately had been evacuated already the first day after the disaster.

Earthquakes and renal disasters

Earthquakes threaten large sections of the globe, and sometimes densely inhabited areas, such as the Mediterranean, Middle and South-East Asia and California. Major cities, like Istanbul, Tehran and San Francisco, are located in high risk zones [1,2].

Such catastrophes are a major concern to the nephrological community as they are frequently associated with rhabdomyolysis leading to crush syndrome; this is a conglomerate of life-threatening functional disturbances, of which acute kidney injury (AKI) and need for dialysis are among the most common and most fatal features in traumatized disaster victims [3–8].

Real epidemiologic occurrences of AKI in earthquakes were observed for the first time only in the aftermath of



Fig. 2. Pictures of the L'Aquila disaster (courtesy of S Stuard); above a venous line is positioned in a victim during extrication.

Table 1. Major earthquakes in the last two decades and their ratio of dialysed victims to deaths ($\times 1000$)

Location	Country	Year	Ratio
Spitak	Armenia	1988	9.0–15.4
Northern Iran	Iran	1990	3.9
Kobe	Japan	1995	24.6
Marmara	Turkey	1999	28.1
Chi-Chi	Taiwan	1999	13.3
Gujarat	India	2001	1.7
Boumerdes	Algeria	2003	6.6
Bam	Iran	2003	3.7
Kashmir	Pakistan	2005	2.4
Yogyakarta	Indonesia	2006	0.7
Chengdu	China	2008	1.9
L'Aquila	Italy	2009	30.2

the Armenian Spitak earthquake in 1989, which resulted in the term 'renal disaster' [9]. Since then, at least 13 major earthquakes have occurred necessitating dialysis treatment of victims with AKI (Table 1). The experience gained with these disasters was one of the elements at the origin of initiatives aiming at better prevention and treatment of AKI in crush victims [10,11].

The dramatic rise in the number of victims with crush to be treated by dialysis during recent disasters is in part related to the migration of people with limited resources from relatively safe rural areas to endangered urban sectors where the quality of buildings is mediocre. On the other hand, the worldwide availability of intensive care and dialysis infrastructure allows for massive treatment of severely affected victims. If adequate dialysis can be provided, survival rates of 80% or more have been reported for the most recent events (1999 and beyond) [5,8,12–16], a figure markedly higher than in previous earthquake experience [17,18]. Although definite data are not yet known, the L'Aquila experience should be even more positive, as up to now no fatal AKI cases are known, probably related to the limited number of AKI patients together with appropriate and timely therapeutic measures.

The registration of an increasing number of disasters with a substantial number of renal victims has also led to the installation of bodies offering material and personnel support for nephrologic treatment, such as the Renal Disaster Relief Task Force (RDRTF) of the International Society of Nephrology (ISN), which operates with logistic support of Médecins Sans Frontières (MSF) [2,19,20].

Of note, although AKI remains the most striking renal feature in the aftermath of disasters, major problems might occur with the treatment of chronic dialysis patients as well, especially if hospital infrastructure is damaged. This has been demonstrated not only in the aftermath of earthquakes [21], but also following hurricane Katrina [22,23], and was an issue at L'Aquila as well.

Earthquakes in Europe and Italy

Compared to other regions or countries such as Turkey, Iran, Pakistan, California, India, or South-East Asia, continental Europe is less frequently struck by major earthquakes. In the list of worldwide earthquakes causing more than 10 000 fatalities per event from 1900 on, only two events

that occurred in Europe are mentioned, but both occurred in Italy (the 1908 Messina/Reggio di Calabria earthquake with 70 000 deaths and the 1915 Avezzano quake with 32 600 fatalities). In total, in the 20th and 21st centuries, 12 earthquakes occurred in Italy with an intensity of 6.0 or more on the Richter scale, causing > 125 000 deaths.

Hence, there is no debate that Italy is among the most earthquake-prone countries in Europe, and that the recent event in L'Aquila was not exceptional. The potential area at risk is spread over the entire country, but there is a marked predilection for the Southern part including Sicily. The disaster at L'Aquila was the most devastating event in Italy of the last two decades.

Interestingly, there is ample literature on another event in Southern Italy, the 1980 Irpinia earthquake. In this disaster, among 19 crush victims, there were 12 with AKI, as reported by Santangelo *et al.* [24]. This publication contains one of the first descriptions of the crush syndrome subsequent to the original observations by Bywaters and Beall in 1941 during the bombing of London [25], the first description of the histopathology of crush-related AKI and for the first time also makes a link between the crush syndrome and earthquakes. From the same Irpinia earthquake also originated the very first monographies considering logistic aspects related to crush [26,27].

Renal problems in relation to the L'Aquila earthquake

At the moment of submission of the present publication, the authors can only offer a preliminary estimate of the number of renal disaster victims of the L'Aquila earthquake. The Italian Society of Nephrology will generate a thorough report in the nearby future. The reason why it takes time for an in depth analysis is attributable to the necessity to trace patients with AKI who were transferred to centres throughout entire Italy. At this moment, there have been reported 9 victims who developed AKI and needed dialysis.

One of the most urgent necessities in renal disaster management is to predict the number of victims who will need dialysis. Such predictions can then be used for logistic planning which includes needs for transport, material, personnel and vacant positions in dialysis units, nearby or further away from the damaged zone [11].

One of the approaches which has been used is an extrapolation of the projected number of dialysed patients out of the number of deaths, because, for most disasters, the ratio of both factors, if multiplied by 1000, lies somewhere between 2 and 20 (Table 1) [14]. Nevertheless, there are marked differences between earthquakes depending on multiple local factors [13].

The ratio of dialysed victims versus number of deaths was high in the L'Aquila disaster (30.2) and exceeds, although preliminary and possibly still an underestimation, the up to now highest reported ratios which were observed in the aftermath of the Marmara disaster in Turkey, 1999 (28.1), and of the Kobe earthquake in Japan, 1995 (24.6) (Table 1). Many factors may have played a role in this dramatic figure among which the most obvious ones are the intensive and highly successful rescue efforts, the possibility of transferring rescued victims quickly to places where optimum medical care could be offered, the quality of the buildings

containing heavy structural material, but being not strong and flexible enough to withstand an earthquake of high intensity, and last but not least, the overnight occurrence surprising victims in supine position, which increases the likelihood for survival with severe muscle trauma and decreases the risk of immediate death caused by head trauma [13].

An important measure to prevent AKI and/or the need for dialysis that might be overlooked in chaotic disaster circumstances is the administration of fluid to neutralize dehydration and deposition of myoglobin casts in the renal tubules, the two most important patho-physiologic features at the origin of AKI in most cases. This fluid administration should ideally be started before extrication from under the rubble [28,29], since fluid shifts with migration of plasma water into the muscular compartment, starting from the moment the pressure on the muscles is relieved (reperfusion injury) [4]. Early massive fluid administration is certainly the most efficient preventive approach for AKI [16]. Nevertheless, in mass disasters, this may not always be implemented due to chaotic circumstances.

It is too early to present definite data on the fluid administration policy in the aftermath of the L'Aquila earthquake. All patients now known to have developed AKI subsequent to the L'Aquila event were interviewed. Reportedly, all had received an infusion either before or immediately after extrication (MB).

Lessons learned

A fast extrication of crush victims from under the rubble is one of the mainstays of renal disaster rescue. The Italian community should be commended for their excellent extrication efforts which involved a host of rescuers and were lifesaving for many a victim. It will be interesting to compare the organization of extrication with this disaster to that of other events, to learn how this crucial phase can further be optimized.

Obtaining information on the relationship between time under the rubble and outcome of renal patients is another aspect worth further analysis. Rather unexpectedly, previous experience of the Marmara earthquake taught us that victims with AKI not needing dialysis stayed longer under the rubble than the ones dialysed [30]. This was attributed to the fact that only those in good condition were able to survive long enough while trapped under the rubble.

Another stronghold of successful intervention is advance planning. Whereas some disasters, such as hurricanes, can more or less be foreseen, so that measures can be taken to organize at least the evacuation of the chronically dialysed population, for earthquakes disaster plans are to be developed a long time in advance, without knowing when they ever will become operative.

Italy, like many other earthquake-prone countries, has well-developed disaster plans which in the case of L'Aquila undeniably have contributed to the successful rescue of many victims. More importantly, those Italian plans also include instructions on the approach to crush victims. In contrast, in many other countries, disaster plans do not contain clear instructions regarding issues related to nephrologic problems, such as fluid administration, prevention

of hyperkalaemia, definition of dialysis needs and renal replacement therapy. One of the reasons is obviously that crush patients with AKI represent only a minority of people affected by a disaster, so that the problem and the measures that possibly could be corrective are often neglected. On the other hand, such measures are essential, as crush patients with or without AKI usually cost a lot of effort to be extricated, so that it would be counterproductive not to offer optimal therapeutic possibilities after extrication. If such therapeutic measures are applied appropriately, they most often result in survival, whereas death is almost inevitable if nothing is done.

Hence, the International Society of Nephrology, in conjunction with national nephrological societies and kidney foundations of earthquake-prone countries, should collaborate intensively with authorities to develop advance planning, including preventive measures against the deadly complications of the crush syndrome.

Although the RDRTF was in contact with a nephrologist operating in the immediate vicinity of L'Aquila (MB) and, via him, with a local nephrologist at L'Aquila itself (SS), no specific advice was given by the RDRTF regarding pre-emptive fluid administration until a few days after the disaster. Usually, this kind of information is distributed by the assessment teams that are sent out by Médecins Sans Frontières and the RDRTF, but in this case such a scouting initiative was considered redundant because rescue activities were well under control. A lesson learned for the future is that the need for appropriate fluid administration should be stressed by the RDRTF proactively from the moment of the very first contacts made with the disaster area.

The RDRTF is currently developing recommendations for the approach to crush. Most doctors, even nephrologists and intensivists, too rarely see crush syndrome patients to have developed automatism allowing an appropriate preventive and therapeutic approach. This lack of experience is even more important among non-nephrologists, i.e. generalists, anaesthesiologists, emergency ward physicians and surgeons, who may all be the first medical experts to be confronted with crush victims, sometimes hours or even days before a nephrologist becomes involved. Hopefully, the publication and implementation of those recommendations in the nearby future will help further reducing the number of AKI in the aftermath of disasters and improving survival.

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Conflict of interest statement. None declared.

References

- Parsons T, Toda S, Stein RS *et al.* Heightened odds of large earthquakes near Istanbul: an interaction-based probability calculation. *Science* 2000; 288: 661–665
- Vanholder R, Van Biesen W, Lameire N *et al.* The role of the International Society of Nephrology/Renal Disaster Relief Task Force in the rescue of renal disaster victims. *Contrib Nephrol* 2007; 156: 325–332
- Vanholder R, Sever MS, Ereğ E *et al.* Acute renal failure related to the crush syndrome: towards an era of seismo-nephrology? *Nephrol Dial Transplant* 2000; 15: 1517–1521
- Vanholder R, Sever MS, Ereğ E *et al.* Rhabdomyolysis. *J Am Soc Nephrol* 2000; 11: 1553–1561
- Sever MS, Ereğ E, Vanholder R *et al.* Renal replacement therapies in the aftermath of the catastrophic Marmara earthquake. *Kidney Int* 2002; 62: 2264–2271
- Sever MS, Ereğ E, Vanholder R *et al.* The Marmara earthquake: epidemiological analysis of the victims with nephrological problems. *Kidney Int* 2001; 60: 1114–1123
- Sever MS, Ereğ E, Vanholder R *et al.* Clinical findings in the renal victims of a catastrophic disaster: the Marmara earthquake. *Nephrol Dial Transplant* 2002; 17: 1942–1949
- Ereğ E, Sever MS, Serdengeçti K *et al.* An overview of morbidity and mortality in patients with acute renal failure due to crush syndrome: the Marmara earthquake experience. *Nephrol Dial Transplant* 2002; 17: 33–40
- Solez K, Bihari D, Collins AJ *et al.* International dialysis aid in earthquakes and other disasters. *Kidney Int* 1993; 44: 479–483
- Sever MS, Vanholder R, Lameire N. Management of crush-related injuries after disasters. *N Engl J Med* 2006; 354: 1052–1063
- Sever MS, Lameire N, Vanholder R. Renal disaster relief: from theory to practice. *Nephrol Dial Transplant* 2009; 24: 1730–1735
- Hatamizadeh P, Najafi I, Vanholder R *et al.* Epidemiologic aspects of the Bam earthquake in Iran: the nephrologic perspective. *Am J Kidney Dis* 2006; 47: 428–438
- van der Tol A, Hussain A, Sever MS *et al.* Impact of local circumstances on outcome of renal casualties in major disasters. *Nephrol Dial Transplant* 2009; 24: 907–912
- Vanholder R, van der Tol A, De Smet M *et al.* Earthquakes and crush syndrome casualties: lessons learned from the Kashmir disaster. *Kidney Int* 2007; 71: 17–23
- Sever MS, Ereğ E, Vanholder R *et al.* Lessons learned from the catastrophic Marmara earthquake: factors influencing the final outcome of renal victims. *Clin Nephrol* 2004; 61: 413–421
- Gunal AI, Celiker H, Dogukan A *et al.* Early and vigorous fluid resuscitation prevents acute renal failure in the crush victims of catastrophic earthquakes. *J Am Soc Nephrol* 2004; 15: 1862–1867
- Atef MR, Nadjatfi I, Boroumand B *et al.* Acute renal failure in earthquake victims in Iran: epidemiology and management. *Q J Med* 1994; 87: 35–40
- Oda J, Tanaka H, Yoshioka T *et al.* Analysis of 372 patients with crush syndrome caused by the Hanshin-Awaji earthquake. *J Trauma* 1997; 42: 470–475
- Vanholder R, Sever MS, De Smet M *et al.* Intervention of the Renal Disaster Relief Task Force in the 1999 Marmara, Turkey earthquake. *Kidney Int* 2001; 59: 783–791
- Lameire N, Mehta R, Vanholder R *et al.* The organization and interventions of the ISN Renal Disaster Relief Task Force. *Adv Ren Replace Ther* 2003; 10: 93–99
- Sever MS, Ereğ E, Vanholder R *et al.* Features of chronic hemodialysis practice after the Marmara earthquake. *J Am Soc Nephrol* 2004; 15: 1071–1076
- Anderson AH, Cohen AJ, Kutner NG *et al.* Missed dialysis sessions and hospitalization in hemodialysis patients after Hurricane Katrina. *Kidney Int* 2009; 75: 1202–1208
- Kopp JB, Ball LK, Cohen A *et al.* Kidney patient care in disasters: lessons from the hurricanes and earthquake of 2005. *Clin J Am Soc Nephrol* 2007; 2: 814–824
- Santangelo ML, Usberti M, Di Salvo E *et al.* A study of the pathology of the crush syndrome. *Surg Gynecol Obstet* 1982; 154: 372–374
- Bywaters EG, Beall D. Crush injuries with impairment of renal function. 1941. *J Am Soc Nephrol* 1998; 9: 322–332
- De Bruycker M, Greco D, Lechat MF *et al.* The 1980 earthquake in Southern Italy—morbidity and mortality. *Int J Epidemiol* 1985; 14: 113–117

27. De Bruycker M, Greco D, Annino I *et al.* The 1980 earthquake in southern Italy: rescue of trapped victims and mortality. *Bull World Health Organ* 1983; 61: 1021–1025
28. Better OS. The crush syndrome revisited (1940–1990). *Nephron* 1990; 55: 97–103
29. Better OS. Rescue and salvage of casualties suffering from the crush syndrome after mass disasters. *Mil Med* 1999; 164: 366–369
30. Sever MS, Ereğ E, Vanholder R *et al.* Lessons learned from the Marmara disaster: time period under the rubble. *Crit Care Med* 2002; 30: 2443–2449

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