Disaster nephrology: crush injury and beyond

R.T. Noel Gibney[1], Mehmet S. Sever[2] and Raymond C. Vanholder[3,4]

[1]*Faculty of Medicine and Dentistry, Division of Critical Care Medicine, University of Alberta, Edmonton, Alberta, Canada;* [2]*Renal Disaster Relief Task Force (RDRTF) for Turkey, Department of Internal Medicine/Nephrology, Istanbul School of Medicine, Istanbul, Turkey;* [3]*Renal Disaster Relief Task Force (RDRTF) of the International Society of Nephrology (ISN), Department of Internal Medicine/Nephrology, University Hospital, Ghent, Belgium and* [4]*Renal Division, Department of Internal Medicine, University Hospital, Ghent, Belgium*

Disasters result in a substantial number of renal challenges, either by the creation of crush injury in victims trapped in collapsed buildings or by the destruction of existing dialysis facilities, leaving chronic dialysis patients without access to their dialysis units, medications, or medical care. Over the past two decades, lessons have been learned from the response to a number of major natural disasters that have impacted significantly on crush-related acute kidney injury and chronic dialysis patients. In this paper we review the pathophysiology and treatment of the crush syndrome, as summarized in recent clinical recommendations for the management of crush syndrome. The importance of early fluid resuscitation in preventing acute kidney injury is stressed, logistic difficulties in disaster conditions are described, and the need for an implementation of a renal disaster relief preparedness program is underlined. The role of the Renal Disaster Relief Task Force in providing emergency disaster relief and the logistical support required is outlined. In addition, the importance of detailed education of chronic dialysis patients and renal unit staff in the advance planning for such disasters and the impact of displacement by disasters of chronic dialysis patients are discussed.

Kidney International (2014) **85,** 1049–1057; doi:10.1038/ki.2013.392; published online 9 October 2013

KEYWORDS: acute kidney injury; acute renal failure; chronic hemodialysis; chronic kidney disease; hemodialysis; rhabdomyolysis

Correspondence: *R.T. Noel Gibney, Division of Critical Care Medicine, Faculty of Medicine and Dentistry, University of Alberta, Room 3C1.12 WMC, 8440-112 Street, Edmonton, Alberta, Canada T6G 2B7. E-mail: ngibney@ualberta.ca*

Received 11 April 2013; revised 20 July 2013; accepted 25 July 2013; published online 9 October 2013

Worldwide, mass disasters affect thousands of people yearly, creating large needs for food, shelter, and primary health care. Today, nearly 400 million people live in cities in earthquake-prone areas and almost as many inhabit areas with a high probability of tropical cyclones. By 2050, these numbers will likely have doubled. With the rapid growth of mega cities such as the Mexico City, Istanbul, Tokyo, and Tehran, in areas of high seismic risk, a single quake may claim the lives of up to three-million people and injure several millions more.[1–3]

Each year, millions of people must contend with earthquakes, cyclones, hurricanes, and other natural disasters (tornados, landslides, and flooding) or man-made disasters (wars, terrorist attacks, air and railway crashes, and collapsed poorly constructed buildings). Secondary hazards, including tsunamis, dam failures, landslides, fires, and diseases are often even more damaging than the primary hazards. The damage depends on the depth, magnitude, time of day and duration of the earthquake, next to the proximity of the epicenter to major urban areas, population density around the epicenter, local building standards, geology (soft or hard soil), and the degree of preparedness of the inhabitants.[3] Buildings, not earthquakes, kill people.[4] Casualty rates are much higher in the emerging world, due to poor building materials and lack of appropriate construction standards so that massive destruction can occur with earthquakes of relatively low magnitude.[4] Although not earthquake related, the recent garment building disaster in Bangladesh clearly shows the risk associated with poor building construction.[5] In this respect, the fatality rate of earthquakes is also significantly related to socioeconomic conditions, public infrastructure, and emergency response.[6,7]

NEPHROLOGICAL IMPACT OF DISASTERS

On a smaller but highly intensive scale, disasters result in a substantial number of renal problems, either by the creation of crush injury in victims trapped in collapsed buildings or by the destruction of existing dialysis facilities leaving dialysis-dependent patients without access to their dialysis units or medical care. Table 1 demonstrates the outline of this paper.

Efforts to extricate trapped victims may be futile if the means to resuscitate and treat rescued victims are not available, as occurred following the 1988 earthquake in Armenia.[8] Many rescued victims subsequently died of crush-related acute kidney injury (AKI) and hyperkalemia because of poorly organized relief and inability to provide dialysis to all patients with AKI.[9,10] It was also evident that a poorly organized relief effort resulted in a chaotic influx of untrained, unsupported volunteers and materials that overloaded available distribution systems and interfered with transport of supplies, creating a 'second disaster'.[8–11] Consequently, it was clear that there was a need to organize an international response system to prevent and manage crush-induced AKI. The International Society of Nephrology founded the Renal Disaster Relief Task Force (RDRTF) in 1989, as a response to the chaotic relief efforts of the Armenian earthquake.[12,13]

The RDRTF has intervened in several disasters, the most important ones being the Marmara, Bam, Kashmir, and Haiti earthquakes. The program is embedded within the broader rescue support program deployed by Médecins sans Frontières.[14–22]

Crush injury

Major earthquakes can result in massive injury and death (Table 2.) The vast majority of deaths following earthquakes occur immediately from massive trauma or asphyxia.[3]

However, many victims who are extricated after entrapment develop crush syndrome and die later from myoglobinuric AKI.[9,10,23–26] Other complications, including non-AKI-associated hyperkalemia, acute respiratory distress syndrome, and sepsis, may also be fatal.[27–32] However, because of chaos and lack of knowledge, crush injury is not always recognized by rescuers and health-care professionals, so that the narrow time window is missed when intensive fluid resuscitation may limit the degree of AKI and prevent oliguria.[33–36]

Pathogenesis of crush injury

Crush syndrome is the systemic manifestation of traumatic muscle injury.[37] The incidence of crush syndrome in injured victims of catastrophic earthquakes varies widely.[38,39] The muscle damage in the injured limb results in tissue edema and intravascular hypovolemia. Because of the limited space available in muscle compartments in the limbs, intracompartmental pressure increases rapidly and this results in a decrease in muscle arteriolar perfusion. The degree of decrease in perfusion depends on the pressure gradient between the mean arterial pressure and the intracompartment pressure.[40–42] The myocyte wall is damaged by direct trauma and ischemia, leading to the release into the circulation of contents including myoglobin, potassium, and uric acid following reperfusion.[42–44] Once the circulating myoglobin levels exceed the protein-binding capacity of the plasma, it is filtered into the glomerular filtrate and precipitates within the tubules potentially causing heme pigment–associated AKI. Myoglobin may injure the kidney by causing tubular obstruction, possibly in association with uric acid, by proximal cell injury and by myoglobin scavenging of nitric oxide causing vasoconstriction of renal medullary arterioles.[44–52]

Features of crush syndrome include hypovolemic shock, hyperkalemia, hyperphosphatemia, hypocalcemia, metabolic acidosis, arrhythmias, cardiac arrest, acute respiratory distress syndrome, disseminated intravascular coagulation, and heme pigment – induced AKI.[14,16,44,53] Delayed thromboembolic disease, hemorrhage, and sepsis are common, as in other patients following trauma.[31,54,55] Many survivors develop psychiatric disorders such as post-traumatic stress disorder, anxiety, and depression.[56,57]

Table 1 | Outline

Nephrological impact of disasters
- Crush injury and acute kidney injury: pathogenesis, prevention by resuscitation, monitoring, and dialysis
- Acute compartment syndrome

Management of chronic dialysis patients
- Advance planning
- Post-disaster response: logistics, communications, and supplies
- Disengagement and debriefing

PREVENTION OF AKI

The diagnosis of rhabdomyolysis may be missed, as muscular pain, swelling, and tenderness may not be prominent, particularly in the early stage of muscle reperfusion, although this is the stage at which fluid prophylaxis is most effective.[34,58] Although a definitive diagnosis of rhabdomyolysis is based on laboratory tests, particularly creatine kinase levels, these are not always available in a timely manner after major disasters. Consequently, all first responders and health-care professionals involved in extrication and emergency treatment should be aware of

Table 2 | Earthquakes associated with mortality >5000 since 1985

Location	Year	Magnitude	Deaths	Crush syndrome	Dialysis
Michoacan, Mexico	1985	8.0	9500	Unknown	Unknown
Spitak, Armenia	1988	6.7	25,000	600	225-385
Western Iran	1990	7.4	50,000	Unknown	156
Latur-Killari, India	1993	6.2	9748	Unknown	Unknown
Kobe, Japan	1995	6.9	5000	372	123
Marmara, Turkey	1999	7.6	17,118	639	477
Gujarat, India	2001	7.6	20,085	35	33
Bam, Iran	2003	6.6	31,000	124	96
Sumatra, Indonesia	2004	9.1	227,898	Unknown	Unknown
Kashmir, Pakistan	2005	7.6	86,000	118	65
Sumatra, Indonesia	2006	6.3	5749	Unknown	Unknown
Sichuan, China	2008	7.9	87,587	229	113
Port au Prince, Haiti	2010	7.0	316,000	Unknown	79
Tohoku, Japan	2011	9.0	20,896	Unknown	Unknown

Adapted from the US Geographic survey, http://earthquake.usgs.gov/earthquakes/world/world_deaths.php; accessed 23 May 2013.

the importance of early fluid resuscitation in crush injury victims.[58,59]

Early intensive fluid resuscitation

Intravenous cannulae should be inserted and fluid resuscitation started soon after the victim is located and extrication efforts are underway. If a suitable vein cannot be located, and a lower limb is accessible, fluid infusion can be accomplished using an intra-osseous needle. In some mass disasters, it appears that crush victims have been triaged away from active treatment because of lack of dialysis availability.[60,61] However, intensive fluid management can restore renal function in some patients with crush injury, avoiding the need for dialysis regardless of whether it is available or not.[15,21,62–64]

An algorithm for fluid resuscitation (Figure 1) provides guidance for the clinician to adequately restore intravascular fluid volume while avoiding hypervolemia, pulmonary edema, and the subsequent need for emergency dialysis.[58] Unless there is evidence of urethral injury, bladder catheterization can help to monitor urine output. It is not possible to develop a uniform early intensive fluid resuscitation strategy to prevent crush syndrome. Fluid administration should be individualized on the basis of the following considerations:[15,58,63-65]

(a) Scale of the disaster: in mass disasters, fluids should be restricted to 3–6 l/day if close monitoring is impossible.

(b) Environmental conditions: less fluid is needed in the case of low ambient temperatures.

(c) Time spent under the rubble: more fluid is needed for victims whose rescue is delayed. If this takes several days, however, a more conservative approach is needed, as many of these patients will be anuric with established AKI. In the Marmara earthquake, more fluid was infused in victims in need of dialysis, mainly because they were admitted several days after the disaster without urinary response to fluids, resulting in hypervolemia and a high need for dialysis.[15]

(d) Length of extrication procedure: the extrication period for entrapped victims varies from several minutes to hours. If fluid resuscitation has been started with the victim still under the rubble, as preferred, the initial fluid infusion rate should be 1000 ml/h, to be tapered by at least 50% after 2 h (Figure 1).

(e) Demographic characteristics of the victims: older victims, children, and patients with a low body mass or with mild trauma are more prone to volume overload and should receive less fluid.

(f) Volume status and urine flow: hypotension, bleeding, and third spacing suggest hypovolemia, requiring more fluid administration; less fluid should be given with signs of fluid overload, especially in anuria.

Fluid resuscitation controversies

Potassium-containing balanced salt fluids such as Lactated Ringer's solution, Hartmann's solution, and Plasmalyte A must be avoided in patients with suspected or proven crush syndrome, as the potassium levels may increase markedly, even with intact renal function, following extrication from the now-reperfused limb.[16,38,58]

Starch-based fluids are associated with an increased rate of AKI and bleeding, and should be avoided.[66–68] Bicarbonate-containing fluids have been advocated in the prophylaxis of heme pigment nephropathy on the theoretical grounds that alkalinization of the urine may prevent precipitation of myoglobin casts in the renal tubules.[52] However, current evidence does not suggest benefit from active alkalinization over active fluid resuscitation.[65,69] In addition, large doses of bicarbonate may decrease free calcium and worsen the hypocalcemia associated with crush injury.[70]

There is controversy regarding the administration of mannitol to disaster crush victims. Mannitol has diuretic, antioxidant, and vasodilatory properties. It has the potential to prevent renal tubular cast deposition, expand extracellular volume, and, theoretically, reduce intracompartmental pressure, muscle edema, and pain.[52,71] However, studies suggest there is little extra benefit to mannitol with regard to kidney function as compared with fluid resuscitation with crystalloids alone.[65,69] In addition, mannitol is potentially nephrotoxic and requires close monitoring, which is often impossible after massive disasters.[71,72]

LABORATORY MONITORING IN CRUSH SYNDROME

If the local hospital laboratory systems are not destroyed or overwhelmed, crush patients should be monitored similar to any critically ill patient with multiple trauma and rhabdomyolysis for electrolytes, acid–base status, lactate, creatine kinase, blood urea nitrogen, and creatinine levels.[16,58] However, if standard core laboratory infrastructure is not available, the use of point-of-care devices such as iStat (Abbott, Princeton, NJ) can be lifesaving, while providing accurate standard laboratory results including creatinine and potassium in the field within minutes.[17,20,21,73] However, it is not widely known that these devices have a narrow operational temperature range (16–30 °C). If used in extreme temperatures, they must be kept in temperature-controlled containers.[20]

DIALYSIS IN CRUSH INJURY

The timing of renal replacement therapy in AKI is controversial.[74,75,131,76] Compared with AKI by other causes, life-threatening complications such as acidosis, hyperkalemia, or fluid overload are more frequent in crush-related AKI, which may necessitate earlier initiation and more frequent dialysis.[16,58,59] Trauma-associated AKI has a high mortality rate, and it has been suggested that earlier renal replacement therapy initiation may be associated with improved survival in trauma-associated AKI.[77-79]

A major challenge facing the clinician following a disaster is the need to ration the available dialysis machines and staff to cope with the numbers of severely injured patients

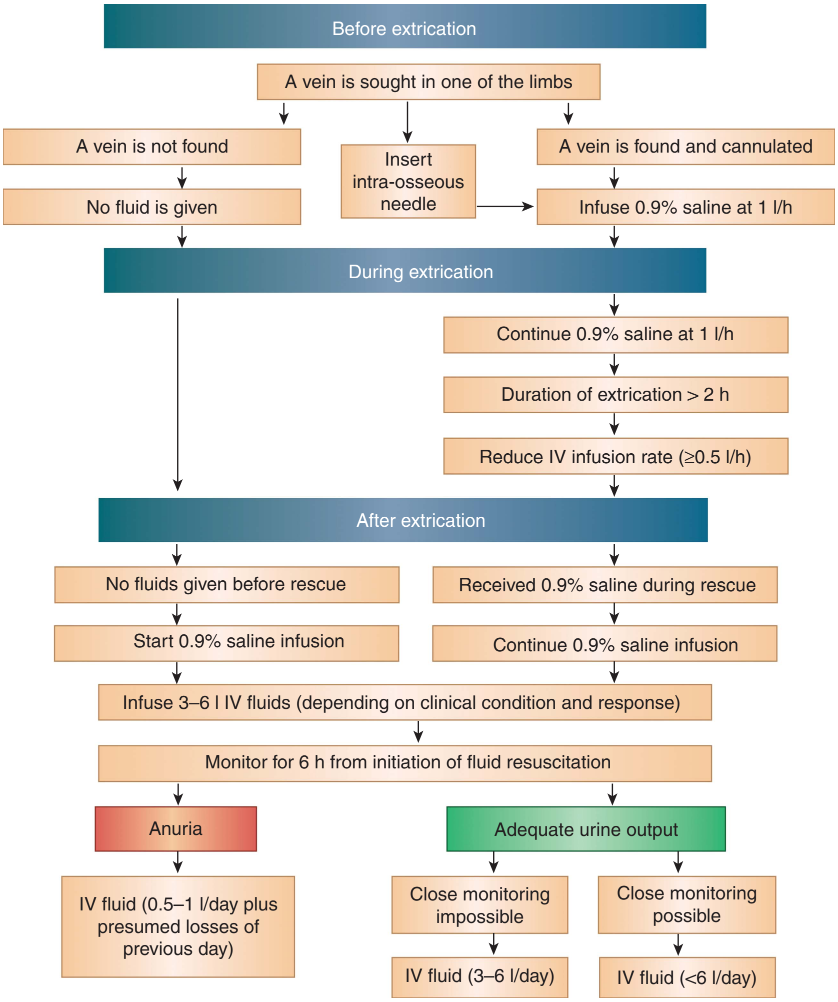

Figure 1 | Algorithm for fluid resuscitation in crush victims of mass disasters before, during, and after extrication. IV, intravenous. Modified from Sever *et al.*[58]

requiring dialysis while continuing to treat the chronic dialysis patients.[28,80,81]

Because of the typical hypercatabolic state of crush patients, one or more dialysis treatments per day are often required to control potassium. However, it may be necessary to limit the duration of dialysis treatments in both AKI and chronic patients in case of high patient numbers or limited available treatment time or equipment, as occurred in Haiti, even though this solution was not ideal.

Mode of renal replacement therapy

Although a small number of patients with crush-induced AKI have been treated with peritoneal dialysis and continuous renal replacement therapy, the majority have received intermittent hemodialysis.[9,80–85]

This modality provides medical and logistic advantages, such as rapid clearance of potassium, ability to treat several patients per day on the same machine, and options for minimal anticoagulation in bleeding-prone patients. The major challenge in providing intermittent hemodialysis is the availability of a suitable water supply in a disaster zone.[86] In this respect, the dialysis technician on the RDRTF team is invaluable and often liaises with other volunteers such as firemen in order to provide suitable water for dialysis. More compact systems for blood purification compared with the standard machines have been developed and would be preferable with regard to transport. One major concern is, however, whether sufficient clearance could be delivered in extreme disaster conditions, e.g., for the treatment of hyperkalemia.

Continuous renal replacement therapy may be performed if the technology is available, but requires a high level of nursing care on a 24/7 basis, which may not be available in a disaster zone.[83,87] Anticoagulation options must be carefully weighed in trauma patients and consideration given to using no anticoagulation or citrate regional anti-coagulation.[88] Peritoneal dialysis may be preferable in small children and is an option if other options are not available. Rapid exchanges may be required to allow more efficient potassium removal, and frequent exchanges with high-glucose solutions may be applied to maximize ultra-filtration.[58]

ACUTE COMPARTMENT SYNDROME OF THE LIMBS, FASCIOTOMY, AND AMPUTATION

Acute compartment syndrome (ACS) of the limbs may be caused by crush injury and refers to a constellation of symptoms, which result from interstitial pressure increases in closed osseofascial compartments.[89] Unrecognized ACS can leave the patient with a nonviable limb requiring amputation and causes rhabdomyolysis by itself. It is essential for the diagnosis of ACS to be made early if a good outcome is to be achieved. The initial suspicion of a diagnosis of ACS is based on clinical findings. The classic symptoms of ACS are pain, paresthesia, paresis, and pain with stretch.[90] More recently, pulse examination and pink skin color were added to complete the '6 Ps ' of ACS.[91] Subsequent development of pulselessness and pallor is an indicator of arterial occlusion and is indicative of a late diagnosis of ACS.

The pressure of a normal limb muscle compartment is less than 10 mm Hg. Initial management of ACS involves removing any tightly fitting dressings or splitting casts on the injured limb and avoiding elevation of the limb as this may reduce the blood flow.[92] If this does not reduce intracompartment pressure significantly, it has been suggested that fasciotomy is indicated in hypotensive patients with intracompartment pressures >20 mm Hg, in uncooperative or unconscious patients with intracompartment pressures >30 mm Hg, or in normotensive patients with positive clinical findings, who have compartment pressures >30 mm Hg, and whose duration of increased pressure is unknown or thought to be longer than 8 h.[92–94] The benefits of fasciotomy decrease, and the disadvantages increase considerably the later fasciotomy is performed.[95–97] Fasciotomy is effective in treating ACS but is often the cause of complications including bleeding and infection.[37,98–103] Amputation should only be performed if lifesaving, e.g., with a clearly unsalvageable limb or rapidly spreading, therapy-resistant sepsis.[31,32,59,102,103] In patients with clear indications, amputation is tolerated better when performed early after trauma.[59,104]

MANAGEMENT OF CHRONIC DIALYSIS PATIENTS FOLLOWING DISASTERS

Major disasters destroy dialysis facilities, leaving patients without lifesaving therapy in their local environment. This was a major challenge following Hurricane Katrina, Cyclone Yasi, the Kobe and Marmara earthquakes, and the recent Tohuku earthquake and tsunami, which was followed by the Fukushima nuclear power plant meltdown.[105–113]

In these situations, if possible, dialysis-dependent end-stage renal disease patients must be transferred to other centers, often in other cities, to continue their dialysis treatment. This may involve a number of days without dialysis while the patients are relocated or the facilities are repaired and brought back into service. During that period, chronic dialysis patients must be contactable and, if possible, have access to potassium-binding resins, and understand the importance of fluid and dietary restriction. To this end, they have to receive precise advance instructions. Depending on local circumstances and the possibility of obtaining further supplies, some patients managed with peritoneal dialysis at home may be able to stay there.[106,108,111]

Relocation of chronic dialysis patients places significant pressures on receiving dialysis units. Following Hurricane Katrina, 700 dialysis patients from New Orleans were added to the usual 1000 in Baton Rouge, LA. Hospitalizations of dialysis-dependent patients were significantly increased, particularly in those patients who missed treatment sessions.[107,114–116] Similar challenges were faced in dialysis units in nearby centers following the Kobe, Marmara, and Tohoku earthquakes.[105,106,108,112] Prior planning for disaster-related evacuation significantly improves patient outcomes and confirms the value of advance planning as advocated by the Kidney Community Emergency Response Coalition.[117,118] In addition, the lessons learned during Hurricane Katrina have further informed subsequent advance planning for chronic dialysis patients following disasters. These have been summarized and were recently implemented following the flooding associated with Hurricane Sandy.[119] Many dialysis clinics in New Jersey and Long Island were unable to function and patients were relocated. These unpredictable events impacting the chronic dialysis population clearly outline that all dialysis units, especially those in disaster-prone areas, must have clear evacuation plans for patients and staff alike.

Predisaster preparation for renal patients should stress identification and location of alternative dialysis facilities, education about the renal emergency diet, and plans for early evacuation similar to those made available by the National Kidney Foundation in the United States.[120] Patients should be provided with appropriate copies or summaries of their medical documents outlining their dialysis treatments and medications and be instructed how to react if a disaster occurs during a session. Dialysis facilities in the United States are required to have an up-to-date disaster plan, which is regularly rehearsed. Preparation for dialysis facilities includes identification of partner renal units and clinics, development of a communication plan, which recognizes that telephone and Internet services will be disrupted, and considers the possibility of staff shortages simultaneous to an influx of new patients and back-up plans for power and water. These disasters also outline the importance of coordination across broad areas and the involvement of local and national agencies for patient evacuation in the event a disaster is massive in scale or scope.

A significant challenge faced by patients following large-scale disasters with massive infrastructure destruction is the loss of medications in destroyed homes and inability to obtain essential medications including insulin, oral hypoglycemic agents, antihypertensives, diuretics, anti-arrhythmic agents, and, for patients with organ transplants, immunosuppressant medications. Consequently, patients are at a high risk for decompensation of previously stable chronic conditions.[121–123] In addition, there has been an association between increased cardiovascular mortality and natural disasters, such as earthquakes.[124–126] This increase in mortality is thought to result from effects on blood pressure, blood viscosity, and hemostatic factors, and is possibly enhanced by acute or chronic psychological stress.[127–129]

LOGISTICS

The main aim of the RDRTF advance response teams is to assess and implement fluid and dialysis treatment and send the necessary manpower and materials in rapid succession, to assist disaster victims not only with AKI but also chronic dialysis patients in disaster-affected areas.[22,38,58] A wide array of support to these RDRTF response teams is provided by the Médecins Sans Frontières. The first major deployment of the RDRTF was in response to the 1999 Marmara, Turkey, earthquake.[14–17]

The benefit of advance planning and coordinated and streamlined response fine tuned by experience in earlier disasters was further shown after subsequent earthquakes in Bam (Iran, 2003), Kashmir (Pakistan, 2005), Wenchuan (China, 2008), and Haiti, 2010.[18–21]

The RDRTF has published widely on the epidemiology, clinical features, and the management of crush injury, and has also developed clinical practice guidelines for the management of crush-injured patients.[58,59] Donated hemodialysis machines are kept in storage for transport to disaster zones and also have a database of international volunteer physicians, nurses, and dialysis technicians. If possible, following initial stabilization, patients with crush injury should be transported to intact facilities with the necessary surgical, renal, and critical-care resources.[58,59] On rare occasions, when the devastation is so massive that no major hospitals are intact, it is necessary to restore or rebuild the water systems and implement auxiliary power systems in destroyed dialysis units in the disaster area.[21,86]

Communications

Following major disasters, communications between the relief agencies and that between the relief agencies and governmental bodies are challenging, particularly if the scale of the disaster is massive. Relief agencies rotate their medical staff frequently to prevent burnout, sometimes as often as weekly. This creates gaps in knowledge of which groups are providing specialty medical services and how to contact them. Following the Haiti earthquake, the RDRTF team members regularly visited other relief groups and field hospitals to make them aware of their presence.[20,21]

The United Nations Office for the Coordination of Humanitarian Affairs offers a platform where relief agencies can meet to harmonize their activities. In the future, depending on the local mobile phone or Internet availability, a web-based inventory of such specialty services with contact numbers could be invaluable in disaster zones.

Volunteers and emergency supplies

Conditions on the ground for volunteers in disaster zones are challenging with long hours of work, sparse accommodation, and considerable psychological stress, particularly in the early phase of a relief effort. For this reason, more experienced volunteers are typically dispatched initially and volunteer deployments do not exceed 10–14 days. Ideally, volunteer teams are a combination of those with prior experience and newcomers, and have included nephrologists, intensivists, dialysis nurses, and dialysis technicians interested in disaster relief.[22,58] Volunteers should be immunized against tetanus, hepatitis A and B, and, ideally, be fluent in speaking French, as the teams are embedded within the Médecins Sans Frontières.

It is critical that health professionals wishing to provide aid following major disasters are embedded within an organization that can provide transportation, accommodation, food, and personal security. For this reason, the RDRTF of the International Society of Nephrology collaborates with the Médecins Sans Frontières. Volunteers arriving independently are at a major risk of injury or death, and may divert resources away from the relief effort when they need to be rescued. It is also important that only the equipment and supplies specifically needed are transported. Unwanted items are often generously offered, only to take up the needed transport and storage space and to need later disposal. Following the Haiti earthquake, large amounts of peritoneal dialysis fluid were transported to Port au Prince but were never used.[21,22,58]

Disengagement and return of responsibility to local nephrology services

Typically, most cases of crush-related AKI arrive within 1 week after an earthquake, whereas patients who present after 10 days have early-stage chronic kidney disease with deterioration in renal function due to dehydration or sepsis. Many of these patients never recover renal function.[21] In all instances, the RDRTF has left the hemodialysis machines brought in for relief in the local renal units rather than fly them back to their headquarters.[21,53]

Debriefing and implementation of lessons learned

Although the RDRTF has now been actively involved on the ground or in giving advice in almost all major earthquakes since its formation in the early 1990s, it is clear that each situation is unique and there are different lessons learned from each one. For this reason, it is important that there is at least a daily report during the period that teams are deployed, followed after the relief effort has been completed, and all teams have returned home, by a formal debriefing involving as many volunteers as possible.[22,38,58,130] Summaries of the activities during each relief mission should be published to allow comparison with previous events and adaptation of practical approaches.

CONCLUSIONS

Unfortunately, major disasters, both natural and man-made, will continue to occur and generate new victims of whom many survivors will develop crush injury, as well as have an impact on chronic dialysis patients. Much has been learned over the past decades from analysis of the emergency response to the many disasters around the world. Comprehensive clinical practice guidelines have been developed for the management of crush injury following major earthquakes. The requirements to support international renal disaster relief are substantial and would not be possible without an elaborate network of volunteering medical professionals supported by experienced rescue organizations, such as the Médecins Sans Frontières, in the case of the RDRTF of the International Society of Nephrology. The role of patient and provider education is a vital component of the advance planning for dialysis unit evacuation in the event of a major disaster, which also needs local and sometimes international collaboration, communication, and coordination.

DISCLOSURE

R.T.N.G. has provided consulting services to Gambro. M.S.M. and R.V.H. declared no competing interests.

ACKNOWLEDGMENTS

Information on the RDRTF and how to volunteer can be obtained from the secretariat of the coordinating center at rdrtf@ugent.be.

REFERENCES

1. Bilham R. Earthquakes and urban growth. *Nature* 1988; **336**: 625–626.
2. Lall SV, Deichman U. *Density and Disasters: Economics of Urban Hazard Risk* 2009; https://gfdrr.org/docs/WPS5161.pdf. Accessed 16 February 2013.
3. Bartels SA, VanRooyen MJ. Medical complications associated with earthquakes. *Lancet* 2012; **379**: 748–757.
4. McKenna P. Earthquake engineer: earthquakes don't kill, but buildings do. *N Scientist* 2011; **210**: 23.
5. en.wikipedia.org/wiki/2013_Savar_building_collapse 2013 Accessed 29 May 2013.
6. Nejat A, Monica Escaleras M, Register C. Earthquake fatalities: the interaction of nature and political economy. *J Public Econ* 2005; **89**: 1907–1933.
7. Chou YJ, Huang N, Lee CH *et al.* Who is at risk of death in an earthquake? *Am J Epidemiol* 2004; **160**: 688–695.
8. Noji E, Armenian HK, Oganessian A. Issues of rescue and medical care following the 1988 Armenian earthquake. *Int J Epidemiol* 1993; **22**: 1070–1076.
9. Collins AJ. Kidney dialysis treatment for victims of the Armenian earthquake. *N Engl J Med* 1989; **320**: 1291–1292.
10. Eknoyan G. Acute renal failure in the Armenian earthquake. *Ren Fail* 1992; **14**: 241–244.
11. Armenian HK, Melkonian AK, Hovanesian AP. Long term mortality and morbidity related to degree of damage following the 1998 earthquake in Armenia. *Am J Epidemiol* 1998; **148**: 1077–1084.
12. Solez K, Bihari D, Collins AJ *et al.* International dialysis aid in earthquakes and other disasters. *Kidney Int* 1993; **44**: 479–483.
13. Lameire N, Vanholder R, Clement J *et al.* The organization of the European Renal Disaster Relief Task Force. *Ren Fail* 1997; **19**: 665–671.
14. Sever MS, Erek 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.
15. Sever MS, Erek E, Vanholder R *et al.* Treatment modalities and outcome of the renal victims of the Marmara earthquake. *Nephron* 2002; **92**: 64–71.
16. Sever MS, Erek E, Vanholder R *et al.* Serum potassium in the crush syndrome victims of the Marmara disaster. *Clin Nephrol* 2003; **59**: 326–333.
17. Sever MS, Erek E, Vanholder R *et al.* The Marmara earthquake: admission laboratory features of patients with nephrological problems. *Nephrol Dial Transplant* 2002; **17**: 1025–1031.
18. Vanholder R. Intervention of the renal disaster relief task force (RDRTF) in the Kashmir earthquake. *Nephrol Dial Transplant* 2006; **21**: 40.
19. 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.
20. Vanholder R, Gibney N, Luyckx VA *et al.* Renal Disaster Relief Task Force in Haiti earthquake. *Lancet* 2010; **375**: 1162–1163.
21. Vanholder R, Borniche D, Claus S *et al.* When the earth trembles in the Americas: the experience of Haiti and Chile 2010. *Nephron Clin Pract* 2011; **117**: c184–c197.
22. Sever MS, Lameire N, Vanholder R. Renal disaster relief: from theory to practice. *Nephrol Dial Transplant* 2009; **24**: 1730–1735.
23. Richards NT, Tattersall J, McCann M. Dialysis for acute renal failure due to crush injuries after the Armenian earthquake. *Br Med J* 1989; **298**: 443–445.
24. Better OS. The crush syndrome revisited (1940—1990). *Nephron* 1990; **55**: 97–103.
25. 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.
26. Noji EK. Acute renal failure in natural disasters. *Ren Fail* 1992; **14**: 245–249.
27. Sheng ZY. Medical support in the Tangshan earthquake: a review of the management of mass casualties and certain major injuries. *J Trauma* 1987; **27**: 1130–1135.
28. Sever MS, Erek E, Vanholder R *et al.* The Marmara earthquake: epidemiological analysis of the victims with nephrological problems. *Kidney Int* 2001; **60**: 1114–1123.
29. Kang P, Zhang L, Liang W *et al.* Medical evacuation management and clinical characteristics of 3,255 inpatients after the 2010 Yushu earthquake in China. *J Trauma Acute Care Surg* 2012; **72**: 1626–1633.
30. Noji EK. Natural disasters. *Crit Care Clin* 1991; **7**: 271–292.
31. Chen X, Zhong H, Fu P *et al.* Infections in crush syndrome: a retrospective observational study after the Wenchuan earthquake. *Emerg Med J* 2011; **28**: 14–17.
32. Kazancioglu R, Cagatay A, Calangu S *et al.* The characteristics of infections in crush syndrome. *Clin Microbiol Infect* 2002; **8**: 202–206.
33. Zhang L, Fu P, Wang L *et al.* The clinical features and outcome of crush patients with acute kidney injury after the Wenchuan earthquake: differences between elderly and younger adults. *Injury* 2012; **43**: 1470–1475.
34. Better OS, Stein JH. Early management of shock and prophylaxis of acute renal failure in traumatic rhabdomyolysis. *N Engl J Med* 1990; **322**: 825–829.
35. Noji EK. Prophylaxis of acute renal failure in traumatic rhabdomyolysis. *N Engl J Med* 1990; **323**: 550–551.
36. Better OS, Abassi ZA. Early fluid resuscitation in patients with rhabdomyolysis. *Nat Rev Nephrol* 2011; **7**: 416–422.
37. Slater MS, Mullins RJ. Rhabdomyolysis and myoglobinuric renal failure in trauma and surgical patients: a review. *J Am Coll Surg* 1998; **186**: 693–716.
38. Sever MS, Vanholder R, Lameire N. Management of crush-related injuries after disasters. *N Engl J Med* 2006; **354**: 1052–1063.
39. He Q, Wang F, Li G *et al.* Crush syndrome and acute kidney injury in the Wenchuan Earthquake. *J Trauma* 2011; **70**: 1213–1217.
40. Matsen FR, Krugmire RB. Compartmental syndromes. *Surg Gynecol Obstet* 1978; **147**: 943–949.
41. Vollmar B, Westermann S, Menger MD. Microvascular reponse to compartment syndrome like external pressure elevation: an *in vivo* fluorescence microscopic study in the hamster striated muscle. *J Trauma* 1999; **46**: 91–96.
42. Better OS, Rubinstein I, Reis DN. Muscle crush compartment syndrome: fulminant local edema with threatening systemic effects. *Kidney Int* 2003; **63**: 1155–1157.
43. Odeh M. The role of reperfusion-induced injury in the pathogenesis of the crush syndrome. *N Engl J Med* 1991; **324**: 1417–1422.
44. Vanholder R, Sever MS, Erek E *et al.* Rhabdomyolysis. *J Am Soc Nephrol* 2000; **11**: 1553–1561.
45. Zager RA. Rhabdomyolysis and myohemoglobinuric acute renal failure. *Kidney Int* 1996; **49**: 314–326.
46. Heyman SN, Rosen S, Fuchs S *et al.* Myoglobinuric acute renal failure in the rat: a role for medullary hypoperfusion, hypoxia, and tubular obstruction. *J Am Soc Nephrol* 1996; **7**: 1066–1074.
47. Holt S, Moore K. Pathogenesis of renal failure in rhabdomyolysis: the role of myoglobin. *Exp Nephrol* 2000; **8**: 72–76.
48. Zager RA, Burkhart KM, Conrad DS *et al.* Iron, heme oxygenase, and glutathione: effects on myohemoglobinuric proximal tubular injury. *Kidney Int* 1995; **48**: 1624–1634.

49. Knochel JP. Serum calcium derangements in rhabdomyolysis. *N Engl J Med* 1981; **305**: 161–163.
50. Paller MS. Hemoglobin and myoglobin-induced acute renal failure in rats: role of iron in nephrotoxicity. *Am J Physiol* 1988; **255**(3 Pt 2): F539–F544.
51. Mannix R, Tan ML, Wright R *et al.* Acute pediatric rhabdomyolysis: causes and rates of renal failure. *Pediatrics* 2006; **118**: 2119–2125.
52. Zager RA. Studies of mechanisms and protective maneuvers in myoglobinuric acute renal injury. *Lab Invest* 1989; **60**: 619–629.
53. Khan FY. Rhabdomyolysis: a review of the literature. *Neth J Med* 2009; **67**: 272–283.
54. Shibata M, Hanzawa K, Ueda S *et al.* Deep venous thrombosis among disaster shelter inhabitants following the March 2011 earthquake and tsunami in Japan: a descriptive study. *Phlebology* 2013 PHL474252.
55. Keven K, Ates K, Sever MS *et al.* Infectious complications after mass disasters: the Marmara earthquake experience. *Scand J Infect Dis* 2003; **35**: 110–113.
56. Dell'osso L, Carmassi C, Massimetti G *et al.* Age, gender and epicenter proximity effects on post-traumatic stress symptoms in L'Aquila 2009 earthquake survivors. *J Affect Disord* 2013; **146**: 174–180.
57. Wang W, Fu W, Wu J *et al.* Prevalence of PTSD and depression among junior middle school students in a rural town far from the epicenter of the Wenchuan earthquake in China. *PLoS One* 2012; **7**: e41665.
58. Sever MS, Vanholder R. RDRTF of ISN Work Group on Recommendations for the Management of Crush Victims in Mass Disasters. Recommendation for the management of crush victims in mass disasters. *Nephrol Dial Transplant* 2012; **27**(Suppl 1): i1–67.
59. Sever MS, Vanholder R. Management of crush victims in mass disasters: highlights from recently published recommendations. *Clin J Am Soc Nephrol* 2013; **8**: 328–335.
60. Merin O, Ash N, Levy G *et al.* The Israeli field hospital in Haiti-ethical dilemmas in early disaster response. *N Engl J Med* 2010; **362**: e38.
61. Merin O, Miskin IN, Lin G *et al.* Triage in mass-casualty events: the Haitian experience. *Prehosp Disaster Med* 2011; **26**: 386–390.
62. 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.
63. Altintepe L, Guney I, Tonbul Z *et al.* Early and intensive fluid replacement prevents acute renal failure in the crush cases associated with spontaneous collapse of an apartment in Konya. *Ren Fail* 2007; **29**: 737–741.
64. Iraj N, Saeed S, Mostafa H *et al.* Prophylactic fluid therapy in crushed victims of Bam earthquake. *Am J Emerg Med* 2011; **29**: 738–742.
65. Scharman EJ, Troutman WG. Prevention of kidney injury following rhabdomyolysis: a systematic review. *Ann Pharmacother* 2013; **47**: 90–105.
66. Zarychanski R, Abou-Setta AM, Turgeon AF *et al.* Association of hydroxyethyl starch administration with mortality and acute kidney injury in critically ill patients requiring volume resuscitation: a systematic review and meta-analysis. *JAMA* 2013; **309**: 678–688.
67. Myburgh JA, Finfer S, Bellomo R *et al.* Hydroxyethyl starch or saline for fluid resuscitation in intensive care. *N Engl J Med* 2012; **367**: 1901–1911.
68. Perner A, Haase N, Guttormsen AB *et al.* Hydroxyethyl starch 130/0.42 vs. Ringer's acetate in severe sepsis. *N Engl J Med* 2012; **367**: 124–134.
69. Brown CV, Rhee P, Chan L *et al.* Preventing renal failure in patients with rhabdomyolysis: do bicarbonate and mannitol make a difference? *J Trauma* 2004; **56**: 1191–1196.
70. Eneas JF, Schoenfeld PY, Humphreys MH. The effect of infusion of mannitol-sodium bicarbonate on the clinical course of myoglobinuria. *Arch Intern Med* 1979; **139**: 801–805.
71. Better OS, Rubinstein I, Winaver JM *et al.* Mannitol therapy revisited (1940–1997). *Kidney Int* 1997; **52**: 886–894.
72. Gadallah MF, Lynn M, Work J. Case report: mannitol nephrotoxicity syndrome: role of hemodialysis and postulate of mechanisms. *Am J Med Sci* 1995; **309**: 219–222.
73. Kost GJ, Tran NK, Tuntideelert M *et al.* Katrina, the tsunami, and point-of-care testing: optimizing rapid response diagnosis in disasters. Am. *J Clin Pathol* 2006; **126**: 513–520.
74. Bagshaw SM, Uchino S, Bellomo R *et al.* Beginning and Ending Supportive Therapy for the Kidney (BEST Kidney) Investigators. Timing of renal replacement therapy and clinical outcomes in critically ill patients with severe acute kidney injury. *J Crit Care* 2009; **24**: 129–140.
75. Cruz DN, Ricci Z, Bagshaw SM *et al.* Renal replacement therapy in adult critically ill patients: when to begin and when to stop. *Contrib Nephrol* 2010; **165**: 263–273.
76. Seabra VF, Balk EM, Liangos O *et al.* Timing of renal replacement therapy initiation in acute renal failure: a meta-analysis. *Am J Kidney Dis* 2008; **52**: 272–284.
77. Karvellas CJ, Farhat MR, Sajjad I *et al.* A comparison of early vs. late initiation of renal replacement therapy in critically ill patients with acute kidney injury: a systematic review and meta-analysis. *Crit Care* 2011; **15**: R72.
78. Vivino G, Antonelli M, Moro ML *et al.* Risk factors for acute renal failure in trauma patients. *Intens Care Med* 1998; **24**: 808–814.
79. Gettings LG, Reynolds HN, Scalea T. Outcome in post-traumatic acute renal failure when continuous renal replacement therapy is applied early vs. late. *Intens Care Med* 1999; **25**: 805–813.
80. Bagshaw SM, George C, Gibney RT *et al.* A multi-center evaluation of early acute kidney injury in critically ill trauma patients. *Ren Fail* 2008; **30**: 581–589.
81. Sever MS, Erek E, Vanholder R *et al.* Renal replacement therapies in the aftermath of the catastrophic Marmara earthquake. *Kidney Int* 2002; **62**: 2264–2271.
82. Bonomini M, Stuard S, Dal Canton A. Dialysis practice and patient outcome in the aftermath of the earthquake at L'Aquila, Italy, April 2009. *Nephrol Dial Transplant* 2011; **26**: 2595–2603.
83. Ozturk S, Kazancioglu R, Sahin GM *et al.* The effect of the type of membrane on intradialytic complications and mortality in crush syndrome. *Ren Fail* 2009; **31**: 655–661.
84. Li CY, Gu JW, Li YM *et al.* Continuous renal replacement therapy and blood transfusions in treating patients with crush syndrome: 8 case studies from the Wenchuan earthquake. *Transfus Apher Sci* 2011; **45**: 257–260.
85. 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.
86. Sever MS, Erek 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.
87. Yuan CM, Perkins RM. Renal replacement therapy in austere environments. *Int J Nephrol* 2011; **2011**: 748053.
88. Cheng Y, Wang T, Zhang F *et al.* Management of 7 earthquake crush syndrome victims with long-term continuous renal replacement therapy. *Am J Emerg Med* 2013; **31**: 432–435.
89. Oudemans-van Straaten HM, Ostermann M. Bench-to-bedside review: citrate for continuous renal replacement therapy, from science to practice. *Crit Care* 2012; **16**: 249.
90. http://bestpractice.bmj.com/best-practice/monograph/502.html. 2013 Accessed: 14 March 2013.
91. Ulmer T. The clinical diagnosis of compartment syndrome of the lower leg: are clinical findings predictive of the disorder? *J Orthop Trauma* 2002; **16**: 572–577.
92. Cascio BM, Wilckens JH, Ain MC *et al.* Documentation of acute compartment syndrome at an academic health-care center. *J Bone Joint Surg Am* 2005; **87**: 346–350.
93. Mubarak SJ, Hargens AR, Owen CA *et al.* The wick catheter technique for measurement of intramuscular pressure. A new research and clinical tool. *J Bone Joint Surg Am* 1976; **58**: 1016–1020.
94. Whitesides TE, Haney TC, Morimoto K *et al.* Tissue pressure measurements as a determinant for the need of fasciotomy. *Clin Orthop Relat Res* 1975; **113**: 43–51.
95. Mubarak SJ, Hargens AR. Acute compartment syndromes. *Surg Clin North Am* 1983; **63**: 539–565.
96. Malinoski DJ, Slater MS, Mullins RJ. Crush injury and rhabdomyolysis. *Crit Care Clin* 2004; **20**: 171–192.
97. Sheridan GW, Matsen FA 3rd. Fasciotomy in the treatment of the acute compartment syndrome. *J Bone Joint Surg Am* 1976; **58**: 112–115.
98. Safari S, Najafi I, Hosseini M *et al.* Outcomes of fasciotomy in patients with crush-induced acute kidney injury after Bam earthquake. *Iran J Kidney Dis* 2011; **5**: 25–28.
99. Reis ND, Better OS. Mechanical muscle-crush injury and acute muscle-crush compartment syndrome: with special reference to earthquake casualties. *J Bone Joint Surg Br* 2005; **87**: 450–453.
100. Guner S, Guner SI, Isik Y *et al.* Review of Van earthquakes form an orthopaedic perspective: a multicentre retrospective study. *Int Orthop* 2013; **37**: 119–124.
101. Zhang H, Zeng JW, Wang GL *et al.* Infectious complications in patients with crush syndrome following the Wenchuan earthquake. *Chin J Traumatol* 2013; **16**: 10–15.

102. Wall CJ, Lynch J, Harris IA *et al.* Clinical practice guidelines for the management of acute limb compartment syndrome following trauma. *ANZ J Surg* 2010; **80**: 151–156.
103. Mabvuure NT, Malahias M, Hindocha S *et al.* Acute compartment syndrome of the limbs: current concepts and management. *Open Orthop J* 2012; **6**: 535–543.
104. Smith J, Greaves I. Crush injury and crush syndrome: a review. *J Trauma* 2003; **54**: S226–S230.
105. de Mestral C, Sharma S, Haas B *et al.* A contemporary analysis of the management of the mangled lower extremity. *J Trauma Acute Care Surg* 2013; **74**: 597–603.
106. Sever MS, Erek E, Vanholder R *et al.* Features of chronic hemodialysis practice after the Marmara earthquake. *J Am Soc Nephrol* 2004; **15**: 1071–1076.
107. Ozener C, Ozdemir D, Bihorac A. The impact of the earthquake in northwestern Turkey on the continuous ambulatory peritoneal dialysis patients who were living in the earthquake zone. *Adv Perit Dial* 2000; **16**: 182–185.
108. Kopp JB, Ball LK, Cohen A *et al.* Kidney patient care in disasters: learning lessons from the hurricanes and earthquake of 2005. *Clin J Am Soc Nephrol* 2007; **2**: 814–824.
109. Sakai R. The Japanese experience during the Kobe Earthquake: management of continuous ambulatory peritoneal dialysis patients in a disaster. *Ren Fail* 1997; **19**: 693–699.
110. Hayes B 2011; Renal dialysis service and patient evacuation during the Queensland Cyclone Yasi disaster. *Ren Soc Aust J* 2011; **7**: 72–75.
111. Johnson DW, Hayes B, Gray NA *et al.* Renal services disaster planning: lessons learnt from the 2011 Queensland floods and North Queensland cyclone experiences. *Nephrol (Carl)* 2013; **18**: 41–46.
112. China S. Management of continuous ambulatory peritoneal dialysis patients in a disaster: the Japanese experience during the Kobe Earthquake. *Ren Fail* 1997; **19**: 687–692.
113. Akabayashi A, Kodama S. Lessons from Japan's March 2011 earthquake regarding dialysis patients. *Ther Apher Dial* 2011; **15**: 334.
114. Kamei D, Kuno T, Sato S *et al.* Impact of the Fukushima Daiichi Nuclear Power Plant accident on hemodialysis facilities: an evaluation of radioactive contaminants in water used for hemodialysis. *Ther Apher Dial* 2012; **16**: 87–90.
115. Kutner NG, Muntner P, Huang Y *et al.* Effect of Hurricane Katrina on the mortality of dialysis patients. *Kidney Int* 2009; **76**: 760–766.
116. Howard D, Zhang R, Huang Y *et al.* Hospitalization rates among dialysis patients during Hurricane Katrina. *Prehosp Disaster Med* 2012; **27**: 325–329.
117. 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.
118. www.kcercoalition.com. 2013. Accessed 7 March 2013.
119. Vanholder RC, Van Biesen WA, Sever MS. Hurricane Katrina and chronic dialysis patients: better tidings than originally feared? *Kidney Int* 2009; **76**: 687–689.
120. Kleinpeter MA, Norman LD, Krane NK. Dialysis services in the hurricane-affected areas in 2005: lessons learned. *Am J Med Sci* 2006; **332**: 259–263.
121. http://www.kidney.org/atoz/pdf/disaster_prepardness.pdf. 2013. Accessed 17 March 2013.
122. Sengul A, Ozer E, Salman S *et al.* Lessons learnt from influences of the Marmara earthquake on glycemic control and quality of life in people with type 1 diabetes. *Endocr J* 2004; **51**: 407–414.
123. Lloyd CE, Dyer PH, Lancashire RJ *et al.* Association between stress and glycemic control in adults with type 1 (insulin-dependent) diabetes. *Diabetes Care* 1999; **22**: 1278–1283.
124. Inui A, Kitaoka H, Majima M *et al.* Effect of the Kobe earthquake on stress and glycemic control in patients with diabetes mellitus. *Arch Intern Med* 1998; **158**: 274–278.
125. Trichopoulos D, Katsouyanni K, Zavitsanos X *et al.* Psychological stress and fatal heart attack: the Athens (1981) earthquake natural experiment. *Lancet* 1983; **1**: 441–444.
126. Leor J, Poole WK, Kloner RA. Sudden cardiac death triggered by an earthquake. *N Engl J Med* 1996; **334**: 413–419.
127. Kario K, Ohashi T. Increased coronary heart disease mortality after the Hanshin-Awaji earthquake among the older community on Awaji Island. Tsuna Medical Association. *J Am Geriatr Soc* 1997; **45**: 610–613.
128. Minami J, Kawano Y, Ishimitsu T *et al.* Effect of the Hanshin-Awaji earthquake on home blood pressure in patients with essential hypertension. *Am J Hypertens* 1997; **10**: 222–225.
129. Saito K, Kim JI, Maekawa K *et al.* The great Hanshin-Awaji earthquake aggravates blood pressure control in treated hypertensive patients. *Am J Hypertens* 1997; **10**: 217–221.
130. Tanaka K, Nakayama M, Tani Y *et al.* The great East Japan earthquake: blood pressure control in patients with chronic kidney disease. *Am J Hypertens* 2012; **25**: 951–954.
131. Fukagawa M. Nephrology in earthquakes: sharing experiences and information. *Clin J Am Soc Nephrol* 2007; **2**: 803–808.