

*Editorial Review***Renal disaster relief: from theory to practice**Mehmet Sukru Sever^{1,2,3}, Norbert Lameire⁴ and Raymond Vanholder^{2,5}

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Introduction

The crush syndrome is the second most frequent cause of disaster-related mortality after earthquakes [1]. However, overall burden of the disaster on public support makes emergency teams concentrate on other needs (e.g. housing, primary health care), so that usually not much attention is paid to crush syndrome patients and, by extension, to the renal victims. According to the general perception, they constitute a relatively minor group requiring complex and labour-intensive therapeutic measures and are rarely included in governmental or local disaster plans.

However, the incidence of crush syndrome can rise up to 2–5% overall in disaster victims [2], whereas it takes a lot of effort to extricate them from the rubble. Hence, it would be deplorable and even counter productive if the proper therapeutic possibilities would not be offered, especially in the case of acute kidney injury (AKI) [3], which is one of the most common potentially lethal but also frequently reversible complications. More importantly, recovery of renal function and survival in crush-induced AKI are markedly better than for other causes of AKI [4,5]. Even less attention is paid to the fate of chronic dialysis patients in the disaster area, although they are ‘connected’ to life through dialysis machines.

Developers of general rescue programmes should thus include renal patients into their disaster preparedness scenarios. In many countries, such plans are still lacking, so that in the case of insufficient preparation, considerable chaotic conditions may ensue for the renal community, as was observed in the aftermath of several recent earthquakes [5–7] as well as after the Hurricane Katrina in 2005 [8]. The medical management of crush-related injuries after a disaster has been described previously [9]. However, there is no structured information available on how to organize this rescue in practice.

This paper stresses the importance of advance renal rescue planning and reviews possible options for such planning based on the experience gained during several mass disasters. The aim is to offer assistance and advice on how national and international rescue organizations can incorporate crush and renal problems in their advance planning and relief actions.

‘Renal disaster’ after earthquakes

If earthquake victims survive direct trauma, injuries to the muscles result in rhabdomyolysis and crush syndrome. Although many crush patients can survive within the first hours or even days until rescue, death will be inevitable for most of them after extrication if emergency measures for the prevention of AKI, or dialysis in established AKI, are not available. The calculated/registered number of crush syndrome victims was as high as 3000, 600 and 639 after the Tangshan-China, Armenian and Marmara-Turkey earthquakes, respectively [2,6,10]; hence, this type of catastrophe has been named ‘renal disaster’ [11]. To cope with this problem, material and personnel support [12] is needed, but if no adequate response can be organized by the local authorities, these efforts will largely remain ineffective unless an organized international support structure is available [13]. Moreover, poorly organized relief worsens the chaos, and creates a ‘second disaster’, interfering with other global rescue activities [11].

The disappointing experiences of the Armenian earthquake convinced the International Society of Nephrology (ISN) to install the ‘Renal Disaster Relief Task Force’ (RDRTF) as a logistic organization to avoid similar problems in future disasters [14,15]. The RDRTF intervened in several disasters, the most important ones being the Marmara, Bam and Kashmir earthquakes (Table 1) [5,7,9,16,17].

Logistic support is vital for this type of interventions and may be offered by non-governmental organizations (NGOs), such as Médecins Sans Frontières (MSF), in the case of the RDRTF.

Table 1. Interventions and offered support by the RDRTF of ISN and duration of intervention in recent earthquakes [5,7,9,16,17]

	Marmara (Turkey, 1999)	Gujarat (India, 2001)	Boumerdes (Algeria, 2003)	Bam (Iran, 2003)	Kashmir (Pakistan, 2005)
Time lag to intervention	22 h	84 h	72 h	36 h	69 h
No. of deaths/injured	17 480/43 953	20 000/200 000	2266/10 261	25 514/30 000	73 000/100 000
No. of crush/dialyzed cases	639/477	35/33	27/25	NA/160	88/55
No. of HD sessions	5137	NA	NA	NA	807
Offered help					
Nephrologists	6	1	1	2	5
Dialysis nurses/technicians	33/1	1/0	2/0	2/0	8/2
Dialysis machines	5	0	0	5	8
Dialysis items	7000 sets ^a	112 dialyzers 20 HD cath 30 PD cath 1 kg kayexalate	40 HD cath 10 PD cath	30 dialyzers 80 HD cath (adults) 10 HD cath (paediatric) 1500 L A-concentrate 3000 L B-concentrate 30 bloodlines	335 dialyzers, 30 HD cath

NA: data not available; HD: haemodialysis; PD: peritoneal dialysis; cath.: catheter; A-concentrate: acidic dialysate concentrate; B-concentrate: bicarbonate-containing dialysate concentrate.

^aA complete set of disposables for one dialysis session consists of needles, inlet and outlet bloodlines and a dialyser.

The major steps in renal disaster response can be described under two main headings: preparations before disaster and measures to be taken in the aftermath of disaster (Figure 1).

Preparations before disaster

A. Composing disaster response team

The disaster response will be realized by several medical and non-medical personnel, who should be assigned according to his/her assumed interventions after disaster; thus, correct selection and training of these personnel are vital. Several rescuers with different profiles should cooperate closely in a team, the members of which can originate from outside the disaster area (mostly international) or from the local area. Ideally, such teams include three types of members:

1. *Directors* (e.g. local keymen, disaster relief coordinators and the chairman of the RDRTF or a similar organization), to coordinate operations. Disasters are chaotic conditions that require rapid decisions followed by dynamic interventions. Crowded commissions, which often hold long and ambivalent discussions, are not suitable for such missions. Therefore, coordination should be run by few, and if possible, trained and experienced leaders.
2. *Assessment team members* are (para-)medical professionals experienced in disasters and have the competence to define the need for help in the affected area.
3. *Rescuers and medical personnel* directly and actively intervene in the disaster field, field hospitals, reference hospitals or, in the case of renal problems, also in dialysis units. Disaster crush victims suffer from multiple complications that require rapid and straightforward medical interventions in problematic circumstances. There is a need for well-trained, devoted and flexible team members, who will support crush victims at various locations.

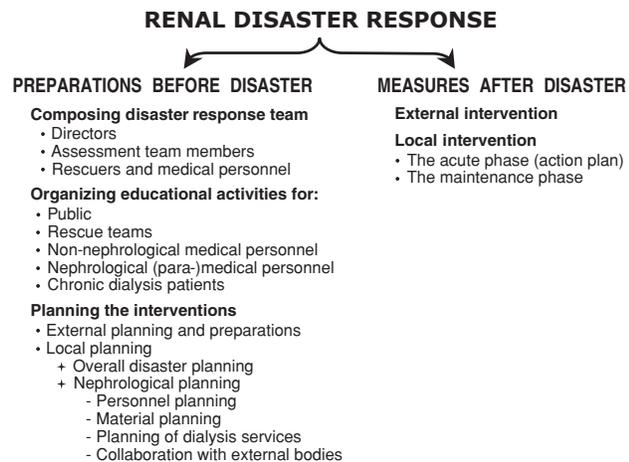


Fig. 1. Major steps in renal disaster response.

Since most disasters occur inadvertently, and persons with whatever qualification living in the disaster area may be unavailable for a variety of reasons, back-ups are needed for every function, especially for the coordinators.

B. Organizing educational activities

Education for disaster circumstances is vital for medical, psychological and logistic reasons (Figure 1). Educational programmes target the public, rescue teams, non-nephrological medical personnel, nephrological (para-) medical personnel and chronic dialysis patients.

The public should be trained on how to secure themselves during and after a disaster. Early fatal injuries are usually caused by collapse of structural elements, but even in undamaged buildings many survivors are injured by non-structural elements, such as furniture or cupboards. Therefore, in earthquake areas, the public should be urged to fix their furniture to the walls, which is a simple and effective method to prevent crush injuries [18]. The public should also be educated on how to behave during quakes to

avoid injuries (i.e. taking fetal position in a proper place; not using stairs or elevators and avoiding entering a damaged building early after a disaster to prevent injuries in the case of an aftershock).

Preparative public education should also focus on the contributions of uninjured people to the rescue activities. The majority of survivors after the Armenian earthquake was rescued by untrained neighbours who had survived the earthquake without major trauma, while only 3.5% of the casualties were extricated by Soviet or foreign experts [19]. However, in the Southern Italian earthquake in 1985, only 18% of the uninjured participated in rescue, which might be attributed at least in part to a lack of education and training [20].

Rescue teams. Optimally, rescue teams should include health care personnel; however, in mass disasters this is often impossible. Thus, non-medical rescue team members should be trained to recognize and treat the problems and complications associated with crushed limbs when extricating a victim [21]. Some casualties who do well while entrapped under the rubble may deteriorate and even die immediately after extrication (rescue death). In these cases, plasma fluid diffuses into the injured muscles from the moment reperfusion starts, resulting in compartment syndrome and subsequent hypotension, while breakdown products from the muscles leak into the systemic circulation resulting in acidosis and fatal hyperkalaemia [22]. A crushed victim receiving medical treatment, and especially fluid resuscitation while still entrapped medical treatment, has a better chance to remain haemodynamically stable after extrication [23].

Non-nephrological medical personnel. The crush syndrome is rarely encountered in daily practice; it is known that unapplied medical knowledge is easily forgotten. In the Marmara earthquake, 10% of the casualties were still receiving potassium-containing solutions at hospital admission [24]; this practice very likely caused the death of several other victims even before they reached a hospital [25]. Therapeutic mistakes, as the one exemplified above, might be avoided if pre-disaster educational programmes discourage such procedures.

Nephrological (para-)medical personnel. The follow-up protocol of AKI in disasters differs from the one applied routinely. Due to a high risk of fatal hyperkalaemia, twice and even thrice daily dialysis may be needed [26], or might even be performed prophylactically, in the case of quickly rising serum potassium [17]. Regarding chronic dialysis patients, decreasing the dialysis dose by reducing the frequency of the dialysis sessions for limited periods does not cause significant risks, if compensated by dietary measures [27]. This allows us to make space for acute and chronic kidney patients if the infrastructure is destroyed.

Dialysis nurses should be trained in dialysing crush victims and treating their intradialytic complications, since some of these complications such as bleeding, intradialytic hypotension and cardiac arrhythmias may be more frequent in this type of patient. The nurses should be further trained

to take the necessary actions when a disaster occurs while haemodialysis sessions are going on.

Chronic dialysis patients. Haemodialysis patients should be trained on how to react during a disaster, especially if the event happens during dialysis. If (para-)medical personnel is not directly available, the patients should be able to disconnect themselves from the haemodialysis machines. They should learn not to panic if their unit is out of function; missing one or two sessions is a valid option, if strict fluid restriction and diet are applied [27]. For chronic peritoneal dialysis patients, nonhygienic conditions should be taken into account and delivery of dialysis solutions should be organized [28,29].

C. Planning of personnel, material and of dialysis services

1. External planning and preparations.

External advance planning allows rapid interventions and should cover the following: (a) enlisting candidates for international response teams that include assessors, coordinators, adult and paediatric nephrologists, intensivists, dialysis nurses and technicians; (b) collaboration with other bodies (such as international and local nephrology societies) and assigning local contact persons even before disasters; (c) cooperation with non-governmental organizations with logistic experience in disaster conditions.

Cooperation with the military may be useful because of their training to act in chaotic conditions. In the aftermath of the Hurricane Katrina, the inability of the North American nephrological community to develop a dialysis response team analogous to the RDRTF was explained by the fact that 'no military organization was prepared to support the logistic needs that are required for such an international response team in the Americas' [30,31]. On the other hand, armies deploying activities in foreign countries in the context of international help may not always be welcomed or trusted by the local population for political or other reasons, hampering the effectiveness of their rescue.

2. Local planning.

Overall disaster planning.

Because this issue directly affects the death toll after major disasters [32,33], governmental health care authorities should encourage local health care providers to develop rescue teams that are capable of extricating victims and delivering medical care immediately after a disaster. These teams should facilitate transport of casualties to predefined evacuation sites and/or unaffected local hospitals [33]. In addition, as not every health care provider is competent enough and psychologically prepared to work in the disaster field [32], macroplanning and training of healthcare personnel who will work in the disaster field, field hospitals, emergency care centres and hospitals should be developed.

Hospitals in disaster-prone regions should prepare their own disaster response plans, designating a responsible person for both the preparation of local disaster response scenarios and the coordination for that particular hospital during disaster. When making plans, medical personnel assignment should be described in detail, e.g. by scheduling more experienced medical personnel on duty within the first

days, when more severely affected patients are expected [6]. Appropriate areas in the hospital gardens should be designated to build field hospitals, if buildings have collapsed or are affected.

Experience is a key element for success; however, since many countries have not endured a disaster, the best solution is to plan a disaster drill, which allows medical officials to evaluate their rescue plans and to make corrections where needed [6,32].

Nephrological planning.

A chief disaster relief coordinator should be responsible for overall nephrological planning before disaster. He/she should divide the country into sectors and assign sector coordinators, who will act as primary coordinator in their own region or as a substitute or supportive primary coordinator, if a disaster occurs elsewhere. The nephrological planning includes developing strategies for the most effective disaster response, which includes personnel and material planning as well as the planning of dialysis services and collaboration with external bodies.

Personnel planning can be complex, because of unexpected early shortages of staff. During the first day of the Kobe earthquake, only 58.4% of the doctors, 35% of the dentists, 44.2% of the nurses and 31% of the administrative staff were present, because of transportation difficulties and injuries to themselves or family members [1]. Even those who reach the hospitals may not work efficiently because of shock and grief [32,34]. The medical services of the area usually cannot cope with acute personnel requirements whereby support from other regions or from abroad may become essential [5,7,16].

Material planning is essential as well because there is almost always a shortage of dialysis material and medication due to increased demand, damage to the stocks and transportation difficulties. Anticipating the evolving medical needs of crushed patients is critical in determining the amount of national and international support. The most frequently used medical materials are various infusion fluids, kayexalate, blood, blood products and dialysis hardware. The quantities of these materials needed in disaster conditions per crush or renal patient have been calculated based on the Marmara earthquake experience and can be extrapolated from there [9].

Planning of dialysis services. Both acute and chronic patients should be considered taking into account three possible scenarios:

1. Dialysis units and city infrastructure are undamaged and the stocks of dialysis material and personnel are adequate. In this case, chronic patients who undergo regular dialysis in fully equipped hospitals should be referred to nearby satellite outpatient units to leave positions vacant for crush cases coming from the disaster area, because these patients with complications can be treated efficiently only in tertiary care units with sufficient therapeutic possibilities [9].
2. Dialysis material, units and city infrastructure are intact, but the number of dialysis personnel is inadequate; in that case, personnel support should be asked for, either from other units in the same country or from abroad.

3. There is extensive damage to city infrastructure and dialysis units. For example, in the aftermath of Hurricane Katrina, 94 dialysis facilities were closed for at least 1 week [31]. In such scenarios, the only option is to transfer patients to other cities of the country or even abroad. Therefore, renal disaster relief planners should prepare in advance a list of dialysis units in the country that also includes their machine and personnel capacities and number of extra patients that can be taken on. After the Marmara earthquake, almost all crush patients were treated in backup hospitals that were relatively distant to the epicentre [35]. In addition, of the 356 chronic dialysis patients who had been treated in the affected region before the disaster, 301 left their dialysis centres temporarily and 31 permanently [27]. Transportation methods may be defined in advance depending on local circumstances and should be anticipated in function of road damage; one might have to recur to boats, helicopters or air bridges.

In the case of major transportation problems, the ultimate option might be the installation of temporary dialysis units nearby the disaster area. However, this option should be used only when there are no valid alternatives.

Collaboration with external bodies. External collaboration is essential for many reasons:

1. following mass disasters, the shortage of dialysis hardware can be supplemented from abroad;
2. contributions of experienced coordinators/nephrologists are crucial to organize support, especially since these external rescuers are not affected by injury to their own family or property;
3. experienced personnel also decrease the workload of local health care services; and, finally,
4. they may provide psychological support to the local medics and paramedics, who are at risk of exhaustion and burn-out [34].

Measures to be taken in the aftermath of disaster

External intervention

Any earthquake above a certain level of severity (either 5.0 or 5.5 on the Richter scale depending on the threshold selected by the recipient) is reported by the US Geological Services [36] to whoever is enrolled on the contact list. Within this frame, also the chairperson of the RDRTF is informed (Figure 2). This chairman assesses the need for relief and estimates the number of crush syndrome victims, based on international press resources (e.g. BBC online) [37] and telephone or e-mail contacts with local keymen. If deemed necessary, the chair dispatches a nephrological assessment team. Continuing collaboration with the local contact persons is vital for both medical and logistic reasons. International intervention may last up to 1 month.

Local intervention

This is the application of the 'action plan' that was prepared in advance (Figure 1). This plan comprises a series

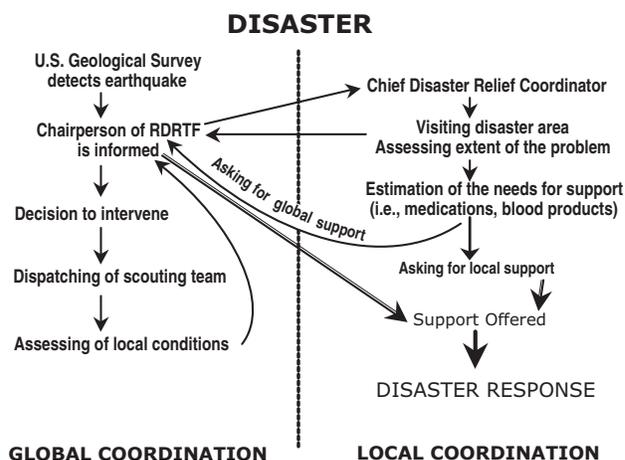


Fig. 2. Major steps in global and local coordination of renal-disaster relief efforts.

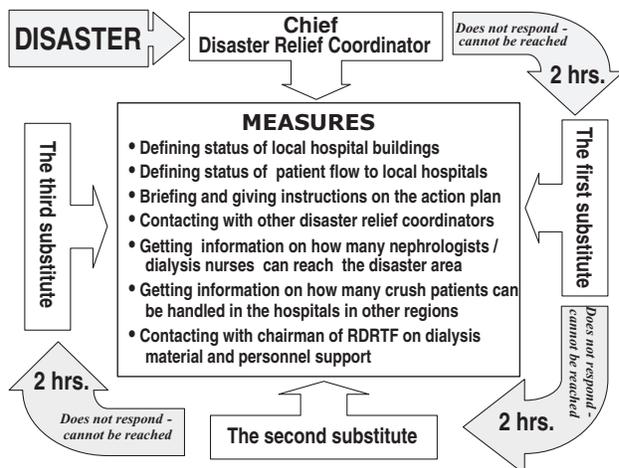


Fig. 3. Major steps of renal rescue during the acute phase of a major disaster at the local level. Measures taken by the chief disaster relief coordinator are summarized. If the chief coordinator does not function within the first 2 h, the first local substitute will take responsibility; if he/she does not respond or cannot be reached, the second local substitute will act as the chief coordinator. If none of them can function within the first 6 h, then the distant coordinator (the third substitute) will be in charge of coordination. RDRTF: Renal Disaster Relief Task Force.

of actions aiming at the provision of an effective disaster response.

The acute phase covers the first 3 days. The chief relief coordinator (usually one of the keymen mentioned above) determines the extent of damage, and preferably visits the most affected zones (Figures 2 and 3). Infrastructure and especially the status of the medical buildings and/or hospitals are evaluated. The local coordinators are subsequently contacted, and following a briefing, initial instructions are given on how to optimize the supportive response (Figure 3). The results of this first assessment are sent to national (governmental and non-governmental) and international organizations (in the case of renal rescue, mainly the RDRTF) allowing a decision/consensus on shipment of

medical material and personnel support and their dimensions.

In the case of severe damage, transportation possibilities to evacuate crush patients from the disaster area should be assessed carefully. Beginning immediately after the disaster, the coordinator is to follow the patient flow to various hospitals and to distribute the casualties to appropriate destinations, with the critically ill being sent to the more experienced centres.

During the acute phase, communication may be problematic and contacts are often difficult. The chief coordinator, who is supposed to start the relief operations, can be disabled due to harm to himself/herself or to his/her family, or not reachable if the wired or wireless telecommunication systems are not operational. Therefore, a step-by-step order of assignment should be developed involving the substitutes next in-line when needed (Figure 3). In the case of Turkey, which has ample experience with renal disaster rescue and preparedness, one chief coordinator and three back-ups are available, the third one living at a distance from disaster-prone areas, with little risk of ever being affected. If any of the unreachable higher-ranked coordinators makes contact at last, he/she overrides the lower level coordinators and resumes his/her activities at the pre-defined level.

The maintenance phase includes the first month. At this stage, the disaster area, hospitals and dialysis units are visited periodically to determine the needs on the spot. Material and personnel support from national and international sources are distributed. Regular follow-up of all crush patients, their need for dialysis and number of recoveries and deaths are registered and the medical community is informed periodically about the short-term outcome. Questionnaires to be used for collecting medical data are distributed to reference hospitals treating crush victims, in order to compose a database allowing a *post hoc* analysis of the results and factors responsible for outcome measures. In the absence of an experimental disaster model, repetition of mistakes can only be avoided by learning from past interventions.

Conclusions

Disasters cause significant morbidity and mortality; the postdisaster period is characterized by confusion and chaos, which further contribute to the death toll. The crush syndrome is the second most frequent cause of mortality after direct impact of trauma. Renal disaster crush victims have complex pathologies and need extensive and expert health care. Also chronic dialysis patients need continued support and care; if maintenance dialysis cannot be offered for a critical period, death becomes inevitable. Therefore, in disaster-prone countries, preparations for the management of renal patients should begin before disaster, and include three stages:

1. composing of the disaster response team;
2. organizing educational activities that target public, rescue teams, non-nephrological and nephrological (para-) medical personnel as well as chronic dialysis patients;

3. advance planning of personnel, material and dialysis services.

In the aftermath of the disaster, both external and local interventions should act synergistically to apply an 'action plan', which comprises a series of actions aiming at the provision of an effective disaster response. These steps may provide an effective health care and the highest chance of survival to the unfortunate renal disaster victims.

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