Earthquakes and crush syndrome casualties: Lessons learned from the Kashmir disaster

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Major earthquakes may provoke a substantial number of crush casualties complicated by acute kidney injury (AKI). After the 1988 Armenian earthquake, the International Society of Nephrology (ISN) established the Renal Disaster Relief Task Force (RDRTF) to organize renal care in large disasters; this approach proved to be useful in several recent disasters. This paper depicts the organizational aspects of the rescue intervention during the Kashmir earthquake, in 2005. Specific problems were fierce geographic circumstances, lack of pre-registered local keymen, transportation problems, and inexperience of local teams to cope with problems related to mass disasters. Once treatment was installed, global outcomes were favorable. It is concluded that well-organized international help in renal disasters can be effective in saving many lives, but still necessitates conceptual adaptations owing to specific local circumstances.

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Disasters are sudden calamities causing extensive material damage and distress; inhabitants of the affected area may become homeless, be wounded or die. Although some disasters are man-made, most of them are natural geological, or meteorological phenomena. Recently, the South-East Asian tsunami, hurricane Katrina, and the Kashmir earthquake affected densely populated and/or geographically extended areas causing hundreds of thousands of deaths.

Mass disasters not only result in instant mortality, but also bring along a cluster of heavily wounded victims who are mostly extricated from the rubble after heroic efforts.[1]

CRUSH SYNDROME AND ACUTE KIDNEY INJURY IN DISASTERS

Acute renal failure has been well defined in crush casualties of mass disasters,[2] but the absence of a generally accepted definition has been a major drawback for estimating the incidence and prognosis. The term 'acute kidney injury' (AKI) has recently been proposed as a patho-physiologically more correct alternative to the previous term acute renal failure.[3,4] We suggest to use AKI for disaster crush casualties as well. AKI with impact on clinical outcome is accepted to be present in case of an abrupt (within 48 h) reduction in kidney function defined either as an absolute 1.5-fold increase in serum creatinine or by 0.5 mg/dl or a decrease in glomerular filtration rate by 50%, and/or a reduction in urine output to below 0.5 ml/kg/h for >6 h. This concept implies that even small alterations in kidney function may deeply affect the final outcome.

The AKI component of crush syndrome is often fatal if untreated, but one of the few preventable or reversible life-threatening disaster complications if appropriate medical treatment, fluid resuscitation, and/or dialysis are applied. Unfortunately, the condition is insufficiently known to rescue workers, medics, paramedics, and even nephrologists.

Recently, the general lines of crush-related rescue and its AKI component have been drawn,[5] but the consideration of problems and experiences, related to each specific disaster, might be helpful for future organization of renal rescue and

also of any rescue in general. In this publication, we review the experience gained with the renal relief intervention after one of the most recent mass disasters in Pakistani Kashmir.

RELIEF EFFORTS FOR CRUSH-RELATED AKI AND OTHER NEPHROLOGIC CONDITIONS

Large disasters may be linked to hundreds of AKI cases,[6–9] occur frequently in regions with insufficient dialytic infrastructure to cope with mass casualties,[10] and imply the deployment of expensive strategies in areas that do not always have sufficient financial resources.

Only during the last two decades, extrication, transport, dialytic possibilities, and logistics became sufficiently adequate to handle problems of the epidemic extent of mass disasters, if enough infrastructure is available on the spot.

The first disaster with known massive AKI casualties occurred in Spitak, Armenia, 1988.[6] Local dialysis infrastructure was inadequate, with no pre-conceived regional or international organizations for renal rescue available.[10] This resulted in a sudden influx of unprepared international dialysis personnel and of hardware, reaching their optimal capacity only when mild to moderate AKI cases had recovered and the severe ones had died.

This experience underscored the need for preplanned logistic organization to cope adequately with renal disaster rescue in the future. To address such problems, the International Society of Nephrology (ISN) created the 'Renal Disaster Relief Task Force' (RDRTF) in 1989,[11] organizing rescue structures for three areas: Northern, Central, and South America; South-East Asia; and Europe, Asia Minor, the Middle-East, and Africa.[12] This organization offers personnel, material, advice, and psychological support to medics and paramedics[11] (Table 1), for any disaster that involves renal disease. Lists of volunteers are registered in the headquarters of the organization.[12] In line with the World Health Organization's guidelines for health care equipment donations,[13] the quality of donated material is of standard European level.

Table 1 | Types of support offered by the RDRTF in this specific action

Personnel help
Doctors (nephrologists/intensivists)
Dialysis nurses
Dialysis technicians
Material help
Dialysis machines
Reverse osmosis machines
Dialyzers
Blood lines
Central vein catheters
Drugs (kayexalate/heparin)
Logistic advice
Medical education and training
Technical education and training
Psychologic support

RDRTF, Renal Disaster Relief Task Force.

The RDRTF (European Branch) offered substantial support in the Marmara earthquake in Turkey in 1999[1] and the Bam earthquake in Iran in 2003.[9] Other interventions included assessment missions and/or an advisory role like with hurricane Katrina, Louisiana (2005), the collapse of an exhibition hall in Katowice, Poland (2006), and the Yogyakarta earthquake in Indonesia (2006). Furthermore, material support was offered during the Israelo-Lebanese war (2006).

THE KASHMIR EXPERIENCE

The earthquake in Pakistani Kashmir

On 8 October, at 08:50:38 hours Pakistan Standard Time, the Kashmir area was struck by a severe earthquake with an intensity of 7.6 on the Richter scale. The disaster essentially affected Pakistan, together with neighboring parts of India and Afghanistan (Figure 1a).

Dimensions were extraordinary.[14] Mortality numbers increased quickly; confirmed mortality according to the United Nations was 73 000 with 100 000 wounded and an estimated 3.2–3.5 million people affected by the disaster and in need of assistance.[15] The number of affected people and transportation problems made this disaster a logistic challenge. Specific to this earthquake was its confinement to a remote mountainous area, with only few roads. Relief was rendered difficult because of transport problems hampering the evacuation of affected victims and the delivery of material for extrication and for primary treatment (Figure 1b).[16] During the initial phase, climatologic circumstances endangered the use of helicopters, which were already scarce. Two of them crashed in the first weeks further affecting the transport. It took more than 4 weeks for rescue teams to reach remote disaster areas, and up till early December 2005, some parts in the damaged area still had not been reached. Conceivably, in those remote areas, numerous AKI patients have died before renal help could be offered.

The intervention of the Renal Disaster Relief Task Force

Preparations for a renal intervention started a few hours after the earthquake (09:00 hours Western European time; 12:00 hours Pakistan time). A timeline providing more specific information on the sequential evolution of the rescue effort is given in Table 2. An assessment team from MSF, with two members from the RDRTF (one nephrologist/intensivist and one renal nurse) arrived at Islamabad at 05:30 hours on 11 October. Crush patients are often severely wounded with needs for ventilation and intensive support; dialysis necessitates the availability of purified tap water, electricity, and dialysis infrastructure. Unaffected cities close to the damaged area are considered the most appropriate for this type of mission.[5] Hence, for logistic reasons, the operation was centralized at the Pakistan Institute of Medical Science (PIMS) Hospital in Islamabad, one of the largest public facilities in the area, in collaboration with Pakistani colleagues and nurses (Figure 1c). Global evacuation of casualties had already been directed towards this hospital,

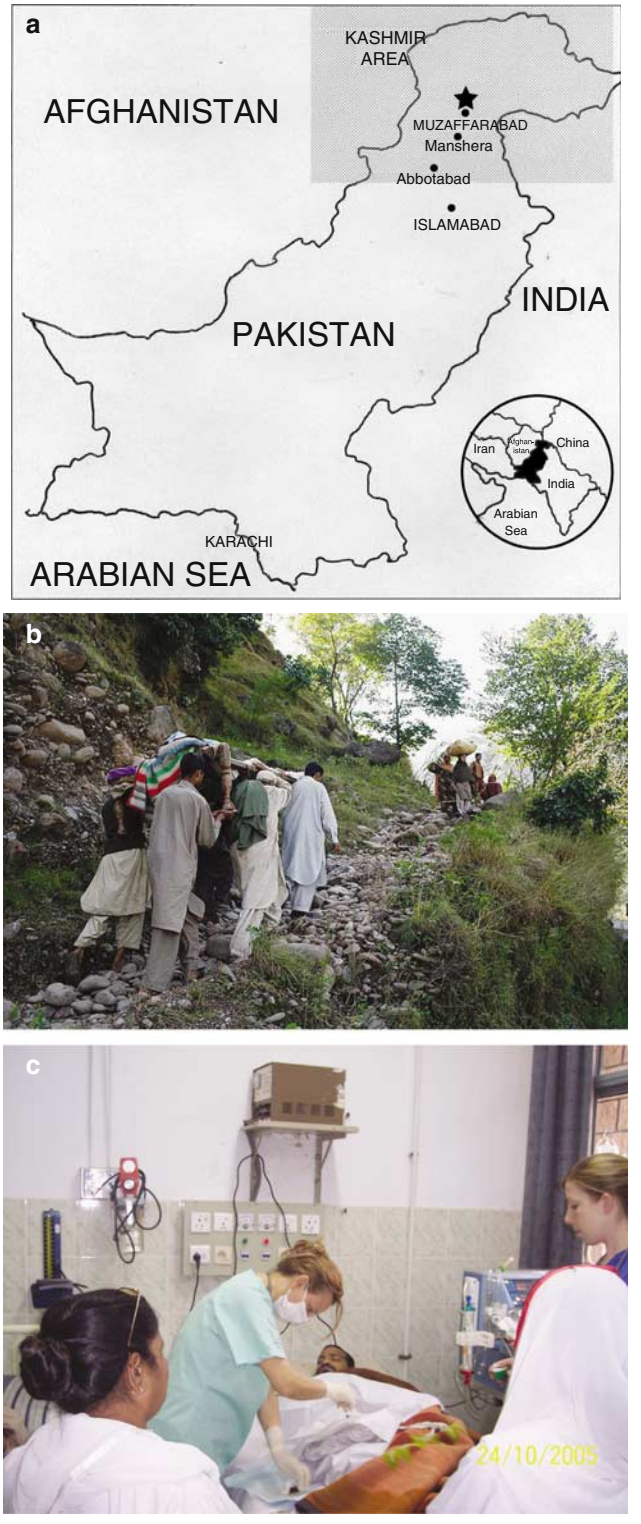

Figure 1 | Various aspects of Kashmir disaster. (**a**) Map of Pakistan, and the Kashmir area (shaded). Major affected cities, as well as Islamabad, the city to which most of the crush casualties were referred, are shown. The insert illustrates the countries surrounding Pakistan, which is indicated in black; (**b**) As the epicenter was located in a mountainous area, the evacuation of affected victims and the delivery of material for extrication and for primary treatment were highly problematic;[16] (**c**) Nurses from PIMS hospital and RDRTF dialyzing crush syndrome patients.

which possesses an intensive care unit and a nephrology section with dialysis facilities.

Data analysis

The entire Kashmir intervention of the RDRTF lasted for 22 days. Subsequent to the assessment team, two full rescue teams were dispatched; eight nurses, five doctors, and two dialysis technicians from five countries (France, Turkey, United Kingdom, The Netherlands, and Belgium). At least some members of each team had previous experience with disasters, as in previous events it became clear that inexperienced personnel cause a burden to local rescuers.[17,18]

In addition, eight dialysis machines, 335 dialyzers, 9 kg kayexalate, 85 blood line sets, 30 double-lumen dialysis catheters, and six pediatric peritoneal dialysis catheters were donated as material support.

In total, 88 victims with AKI were registered in the broad Islamabad area. Related to a global mortality of 73 000 in Kashmir, these figures are substantially lower than the ones observed in the Marmara earthquake in 1999 with 639 AKI cases for 17 480 deaths (ratio AKI/deaths $\times$ 1000:1.2 vs 36.6, $P = 0.001$) (Table 3). Of those 88, 55 (63%) needed dialysis (Table 3). If the number of those needing dialysis is related to the global mortality number, the figures are again substantially lower in Kashmir than the ones observed in the Marmara earthquake (0.8 vs 27.3, $P < 0.001$) (Tables 3 and 4). These low numbers of AKI cases compared to the number of fatalities underscore the difficulties in rescue and transportation.

Once rescued, the need for dialysis among victims with AKI was similar or even lower in Kashmir, as compared to other major earthquakes. In the Marmara earthquake, for example, need for dialysis was higher (74 vs 63%, $P = 0.016$) (Table 3). Overall mortality of AKI patients was 15/85 in Kashmir (19%) (Table 3) and this figure was similar to the frequencies observed after the Marmara (15%) (Table 3), Chi-Chi (17%), and Bam earthquakes (13%) ($P =$ NS). Considering the extreme circumstances, the overall mortality rate in Kashmir compares favorably to these previous disasters.[9,19,20] Of note, mortality figures after major disasters should be considered with care as they may be prone to many uncontrollable factors.

The first patient with AKI was hospitalized within the first 24 h after the disaster and the first dialysis session was started in the same patient, also during the first 24 h. Dialysis activity increased gradually. The maximal dialysis activity was reached at day 10, when there were 39 patients dialyzed, distributed over five hospitals. A total number of 54 victims received dialysis. The last dialysis took place at day 45. Daily dialysis was performed in 27 patients, whereas 21 patients received alternate day dialysis; in two patients, even longer intervals were respected, and dialysis frequency was not exactly known in four patients. Dialysis sessions lasted 3–4 h. Daily dialysis was more frequently performed at PIMS Hospital and in more heavily affected victims, such as those having undergone fasciotomy.

Table 2 | Timetable of rescue efforts

8 October	07:45[a]	First notification of earthquake and its extent
	09:00	ISN/RDRTF in stand-by
	21:45	Assessment team composed
9 October	14:00	First telephonic contact with Pakistan
	19:30	Preparation of bags with light material (dialyzers, catheters, kayexalate) and pamphlets about fluid administration
10 October	12:00	Departure assessment team
11 October	08:30	Arrival assessment team in Islamabad (local time: 05:30 hours)
	13:45	First contact with assessment team – visits local hospitals started
12 October	08:00	Start composition first rescue team
13 October	12:45	First notification of shortage of dialysis material in Islamabad
		Field rescue becoming effective only now
		First influx of AKI patients
14 October	08:30	Need for extra dialysis machines notified by assessment team
		Need for full rescue team notified
		Team should contain a technician (for repair local machines)
	09:30	Check dialysis machines in warehouse ISN/RDRTF (Brussels, Belgium) started
	15:25	Composition first rescue team finalized
	16:20	Number of AKI patients in Islamabad needing dialysis rising
15 October	09:00	Preparation second set of light material bags (dialyzers, kayexalate)
	15:00	Departure first rescue team
16 October	08:50	Arrival first rescue team (local time: 05:50 hours)
	10:00	Departure cargo heavy material with ISN/RDRTF dialysis machines
	12:00	Start repair local machines in Islamabad
17 October	15:00	Start composition second rescue team
	16:30	Arrival dialysis machines from ISN/RDRTF
		Not cleared by customs
	17:10	Return home MD from assessment team
18 October	14:00	Dialysis machines from ISN/RDRTF cleared and operational
		Local machines repaired and operational
19 October	12:15	Composition second rescue team finalized
	17:00	Return home RN from assessment team
21 October	23:00	Departure first members second rescue team[b]
22 October	23:00	Arrival in Islamabad first members second rescue team
1 November	19:00	Return home last nurses from second rescue team

[a]All time data are given in Belgium summer time (=Greenwich+2).
[b]Departure hours different from member to member as they left from several different places.
ISN, International Society of Nephrology; MD, medical doctor; RDRTF, Renal Disaster Relief Task Force; RN, registered nurse.

Table 3 | Outcomes of renal victims in the Kashmir earthquake as compared to the 1999 Marmara earthquake

	Kashmir (n=88)	Marmara (n=639)	P-value
AKI with dialysis need	55/88 (63%)	477/639 (74%)	0.016
Global mortality	16/85[a] (19%)	74/639 (15%)	NS
Mortality among the dialyzed	11/52[a] (21%)	83/477 (17%)	NS
AKI/deaths × 1000	1.2	36.6	$<$0.001
AKI dialyzed/deaths × 1000	0.8	27.3	$<$0.001

[a]Outcome unknown in three patients; statistics: χ^2.
AKI, acute kidney injury; NS, not significant.

Table 4 | Ratio of dialyzed AKI victims over number of deaths in nine recent earthquakes

Location	Country	Year	(Dialysed AKI/deaths) × 1000
Spitak	Armenia	1988	$\geqslant$9.0
Northern Iran[a]	Iran	1990	3.9
Kobe	Japan	1995	24.6
Marmara[a]	Turkey	1999	27.3
Chi-Chi	Taiwan	1999	13.3
Gujarat	India	2001	1.7
Boumerdes	Algeria	2003	6.6
Bam	Iran	2003	3.7
Kashmir[a]	Pakistan	2005	0.8

AKI, acute kidney injury.
Information extracted from Sever *et al.*[2]
[a]For the Northern Iran, Marmara, and Kashmir earthquake, the minimum estimated number of fatal victims was taken into account.

Specific aspects of the intervention

Not only the disaster area was remote, even the Islamabad base was difficult to reach, both for rescue workers and for support material. Cargo transportation and clearance took 4–5 days in total. Key decisions for dispatching were to be taken far in advance, at the risk that they would retrospectively seem redundant. Other measures came late even if timely anticipated. This problem was partly solved by dispatching light material as hand luggage with incoming team members, but bulky equipment, such as dialysis machines and reverse osmosis systems to purify dialysis water could not be transferred so easily. Attempts to obtain heavy material from industry appeared even more difficult, as different echelons were to be passed, both outside and inside

the country, whereas virtually no internal stores of dialysis material were available.

The brands of hardware imported by the RDRTF were not necessarily the ones in use in the area; therefore, an additional challenge was to introduce these unfamiliar devices to local staff. Unlike in previous interventions, all teams contained a dialysis technician. This was in part inspired by earlier experience, whereby some of our own machines broke down during transport. Next, several devices of the local machine park also needed repair.

A substantial number of renal rescue workers were deployed; the influx of patients in chaotic circumstances overwhelmed local medical and paramedical staff, in spite of lots of goodwill. Local health care workers were aware of the problem of crush injury and AKI, but the extent of the disaster surpassed the local logistic possibilities. Insufficient management of crush patients both owing to chaotic conditions[8,21] and lack of experience[7,22] have been noted after the Kobe and Marmara earthquakes, as well. The Task Force also played a didactic role with both bedside teaching and *ex cathedra* courses on patho-physiology, prevention, and treatment of crush-related rhabdomyolysis.

The ratio of dialyzed AKI vs total number of fatal victims was substantially lower than with most other recent earthquakes and can best be compared to that in Gujarat in India in 2003 (Table 4). It is conceivable that the highest relative numbers of crush cases can be anticipated in the areas with more complex and compact building structures, more infrastructure for rescue, and/or more extended dialysis facilities. All these are factors potentially increasing the number of severely affected but surviving crush victims. For Kashmir, difficulties in rescue, organization of first aid, and evacuation owing to the remoteness of the area played a central role, as in Gujarat.[23] Additional factors were: (1) the daytime occurrence, resulting in upright position of the victims, causing their instant death owing to head and/or thorax trauma, rather than muscle compression of the lower extremities, and (2) the essentially wooden and adobe composition of buildings in the rural area. The data show that each disaster is specific, rendering difficult predictions of number of expected AKI cases in function of mortality figures. Hospitalization numbers may offer a more reliable basis, with up to 23% of the hospitalized developing crush-related AKI.[24] There are, however, to the best of our knowledge, no data available on the hospitalization rate related to the Kashmir earthquake.

RECOMMENDATIONS BASED ON THE KASHMIR INTERVENTION

Need for local keymen

Usually, interventions of the RDRTF are organized concurrently from abroad and locally after consultation with local keymen, as was the case with the Marmara and Bam earthquakes. Unfortunately, in spite of repeated contact efforts, the RDRTF remains without keymen in many earthquake-prone countries. Hopefully, this paper will facilitate the extension of contacts in the nearby future.

Problems with transportation

Transportation of patients. The low number of AKI patients and their late admission are attributable to transportation difficulties; it is conceivable that many victims with AKI died from complications, essentially hyperkalemia,[25] before they could reach a hospital. The same conditions also hampered the transport of infusion fluids into the damaged area. Relevant numbers of AKI cases started being hospitalized only 5–7 days after the earthquake, which is late.[8,17,21,26–28] For the future, transportation possibilities should be optimized: the most realistic strategy is collaboration between army and civilian organizations,[18] as was the case in the Marmara earthquake.[8] Pre-planned protocols among various authorities of disaster-prone countries can be useful for minimizing the chaos and misunderstandings during the first days after a disaster, although this always will remain a bottleneck. Transport difficulties with supposed late arrival of AKI victims is one reason not to call back too soon the assessment team.

The alternative to transporting patients early is to install improvised dialysis units within the affected area. It is merely impossible, however, to embed such structures in efficiently working hospitals with major surgical and intensive care possibilities, which are indispensable in crush. Existing local hospitals in the affected area are frequently damaged or at risk of being damaged by afterquakes, creating major transportation problems in victims with life-threatening complications at a later stage.

Transportation of rescue personnel. In the Pakistan intervention, it turned out very difficult to organize appropriate and timely traveling schedules for rescue personnel. Therefore, team members should be maintained in the affected area long enough, that is, 7–10 days, with sufficient overlap among teams. However, too long stays were avoided to prevent burnout, and because all our volunteers have other professional obligations as well.

Transportation of medical material. Several light items were lacking due to heavy consumption and/or insufficient stocks, and were included in the hand luggage carried by the incoming team members. The RDRTF has scouting bags, containing dialyzers, kayexalate, central vein double-lumen hemodialysis and peritoneal dialysis catheters, and blood lines, continuously stand-by for emergencies, which easifies their transport.

The delay in the delivery of our heavy material was in part related to an initial optimistic vision of our Pakistanian colleagues on the local conditions. Everything was considered to be under control, although a shortage of material and personnel was developing. This misperception has been encountered during almost each intervention of the RDRTF. It is attributable to incorrect information of local contacts due to chaos leading to an understandable overestimation of own possibilities; this source of misconception

Table 5 | Topics covered by the questionnaire

Demography	Admission findings	Type of trauma	Medical and surgical interventions	Complications and outcome
Name	Blood pressure	Extremity trauma	Surgical interventions at admission	Complications
Age	First 24 h UV	Abdominal trauma	Medical interventions at admission	Outcome
Gender	First urine color	Thoracic trauma	Surgical interventions during the clinical course	Discharge/death
Chronic illness before disaster	CK	Other	Medical interventions during the clinical course	Date of discharge/death
	BUN		Features of dialysis	
City (of origin)	Creatinine		Features of transfusion	
City (where treated)	K			
Date of admission	Hb			
Time under rubble (h)	WBC			
	Plt			

BUN, blood urea nitrogen; CK, creatine kinase; Hb, hemoglobin; K, potassium; Plt, platelets; UV, urinary volume; WBC, white blood cells.

should be taken into account in future missions by external rescuers.

Interference with local rules

Local regulations prohibited the use of second hand material to repair broken down devices; this illustrates the need to become familiar with local rules and regulations, so that quick and compliant action can be undertaken. Rules and regulations are crucial to avoid inadequate drug donations and 'dumping' of sub-standard material. On the other hand, there may be situations where the coordinator can try to obtain specific modifications of local arrangements to allow progress.

Problems related to inadequate medical information

Triage and fluid resuscitation. Obviously, timely fluid administration to entrapped victims may be helpful to avoid AKI with dialysis need.[28,29] During the Kashmir intervention, preplanned flowcharts about how to apply fluid administration were available, but organizational structures of how to deploy these activities had only partly been developed. The elaboration of a sufficiently staffed body for triage and subsequent fluid administration in the field appeared essential for the future and will be conceived together with MSF, with a nephrologist/intensivist traveling to several locations and offering information to medics and paramedics on how to recognize and treat incipient AKI. Recommendations on how to deal with these aspects are being formulated by the RDRTF and will be published in the near future. This concept implies an earlier deployment of staff, days before reaching maximal dialysis needs.

Need for didactic material. Basic glossaries on the pathophysiology of crush-related AKI and therapeutic recommendations should be supplied both to nurses and doctors. The baseline package will from now on contain such texts, as well as a mission statement explaining the aim, approach, and philosophy of the RDRTF, a slide show on renal disaster rescue, and a CD-ROM with scanned brochures for dialysis technicians and nurses on currently available dialysis machines. Repetitive CME courses should be organized in the areas at risk to update medical information.

Contacts with the World Health Organization (WHO) will be helpful in disaster conditions to disseminate information on the existence of crush-syndrome, AKI, and the aims and role of the RDRTF in coping with these problems.

Support for statistical analysis. The information on crush syndrome in disasters is limited. Distribution of standard questionnaires to collect data for further analysis (Table 5) from the earliest stage of the disaster might be useful for local colleagues to register specific data that otherwise might be lost and to focus on essential clinical follow-up problems.

CONCLUSIONS

Effective treatment of crush casualties remains one of the most important measures in decreasing disaster-related death toll. Medical experience from past disasters may be helpful in preventing the repetition of previous mistakes and will improve outcomes. As every disaster is unique, developing different disaster scenarios for various parts of the world is important for decreasing logistic pitfalls of future catastrophes. We hope that our present analysis of the most recent Kashmir disaster may be helpful to reach this aim.

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