Management of medical and psychosocial consequences of a radiological or nuclear terrorist event

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Abstract. Medical, psychological, and social consequences of a terrorist event involving the release of ionizing radiation will differ significantly from attacks with “classical” explosives. Victims of a detonation of a “dirty bomb” or a nuclear device can actually or allegedly absorb various doses of radiation and should be viewed as radiologically contaminated patients. Hence, both first responders and medical personnel should behave and act accordingly. General rules, guidelines, and procedures are described that should be implemented at all levels of medical management from the on-site emergency care until admittance to and treatment of the victims at a specialist hospital ward. The causes, manifestations and management of psychosocial sequelae of radiological terrorist incidents are also discussed.

Key words: radiological/nuclear event • medical and psychosocial consequences • management

Introduction

Apparently, most national emergency response plans have been focused on accidents at nuclear reactor sites or other nuclear installations. Recently, however, possible threats by disaffected groups have shifted the focus to malevolent use of ionizing radiation aimed at creating disruption and panic in the society. Such malevolent acts have lately been categorized as the CBRN (chemical, biological, radiological, nuclear) terrorism which, according to some experts [6], “is a low-probability, high-consequence threat” that may be “serious and often underestimated, but not apocalyptic” [2]. Indeed, as judged by the outcomes of such radiological emergencies as the Chernobyl disaster in 1986 [8], or the radiation accidents in Goiânia (Brasil) in 1987 [1, 25] and in San Salvador (El Salvador) in 1989 [17], as well as based on the computer simulations thereof, radiological/nuclear terrorism may represent a difficult challenge for the authorities, responders, and the general public, but also the one which, when adequate planning and preparedness had been prearranged, can be effectively handled.

According to the current view, the most probable radiological/nuclear terrorist scenarios (“radioterror”) include spreading of radioactive material in the environment (air, water, plants, soil, food products etc.) performed either by a direct dispersal of the material (e.g., from a mobile system such as airplane, truck, train or otherwise) or by detonation at a populated location of
the so-called “dirty bomb” (composed of a conventional explosive such as trinitrotoluene – TNT, intermingled with one or more radioisotopes); both these methods fall under the category of the radiological dispersal device (RDD) [20–22, 24]. Possible sources of radioactive isotopes include theft from industrial, medical or scientific facilities or an attack on transport of radioactive material. In scenarios based on the dispersal of radioisotopes most likely only a small area (one or few city blocks in an urban milieu) will be affected and most exposures will be low-level (both from external irradiation and/or contamination with radioactive material). Another possibility, called the radiological exposure device (RED) [22] refers to a hidden radioactive source (typically emitting X or gamma rays) that will irradiate people externally.

More spectacular, but less plausible scenario involves detonation by terrorists of a stolen or self-made (improvised nuclear device – IND) atomic bomb. Indeed, most of these devices and material for their production are properly stored and protected from theft, but there are “nuclear” countries or regions where the security measures are much more lax. Although, in all probability, an atom bomb which the terrorists can take hold of will be a low-yield device, when detonated, it will certainly wreak havoc on the people and area at a considerable distance from the epicenter. In addition to ionizing radiation (both initial and residual which, in fact, will contribute to no more than 15% of all the issuing injuries) other effects such as the air blast (“shock wave”) and thermal effects will predominate and lead to about 85% of injuries in the victims. Consequently, most casualties of such a detonation will present with combined injuries including wounds, fractures, and burns compromised by absorption of various doses of ionizing radiation [7, 15, 20, 24].

Any attack involving the release of radiation will create significant uncertainty, fear, and terror among the affected (or purportedly affected) population. Indeed, such outcomes may predominate and overwhelm the available medical and social resources in the aftermath of an attack with a dirty bomb and a low-yield nuclear device [21, 24]. Terrorists, by definition, strive to provoke severe psychosocial and economic disruptions in the society, and radiation – an invisible, odorless, and poorly understood agent – is viewed as the extremely insidious and appalling threat. Hence, there are important differences between setting off a conventional explosive and use of a radiological or nuclear device by a terrorist (Table 1) which will determine the necessary medical and otherwise measures to treat the victims and cope with the consequences.

**Phases of the management of an attack**

Prior to or concomitantly with the introduction of a medical response the general objectives of the conse-

| Table 1. Differences between a conventional and a radiological/nuclear terrorist attack |
|-----------------------------------------------|-----------------------------------------------|
| **Conventional explosion**                    | **Radiological/nuclear attack**                |
| Victims only at the site of attack (the attack is bounded in time and space) | Possible victims also further away from the site of attack (the attack is unbounded) |
| The debris and the environment is not hazardous and the cleanup is localized | Not only the immediate site of the attack but also more remote areas may be radiologically contaminated and hazardous and cleanup will require appropriate monitoring equipment and trained personnel |
| Will require routine forensic investigation | Forensic investigation complicated by the need to wear protective equipment and by the contamination of evidence |
| No medical outcomes in witnesses without direct injuries | Postponed medical complications possible in victims with no visible injuries |
| No specific safety measures and treatment procedures necessary during first response and medical management along the evacuation chain | Specific safety measures and treatment procedures required during first response and medical management along the evacuation chain and final care provided by well trained and experienced personnel |
| The trauma and injuries experienced by the victims are familiar: wounds, burns, broken bones etc. | Injuries may be “hidden” and develop later in life |
| No stress associated with the prospect of late health effects | Specific stress associated with presumed or actual prospect of the development of late health effects resulting in neurological and psychological disturbances |
| No need for relocation (evacuation) of people and/or restrictions in water and food supplies | Relocation (evacuation) of people and/or restrictions in water and food supplies may be necessary |
| No stigmatization of the victims | Victims with the “stigma” of radiation exposure |
| Psychosocial consequences not likely to predominate | Psychosocial outcomes likely to dominate and overwhelm the available medical resources |
| Routine planning and preparedness for an emergency generally suffice to cope with the effects | Specific planning, preparedness, and training of the responders is necessary |
Medical management of the casualties

As in any other emergency, medical aid to victims of a radiological/nuclear terrorist event should be instituted as soon as possible, i.e., already on the site of the attack which should be pre-recognized and secured by the police and fire fighters. For the safe and effective operation on a potentially irradiated/contaminated area, all first responders and medical rescuers must be properly equipped with masks, gloves, and clothing to guard against inhalation and ingestion of the radioactive material or its deposition on the skin (the safety of first responders is a priority); all members of the personnel should also wear individual radiation dosimeters (Table 2) [10, 13]. Generally, when no serious intake of and/or contamination with radioisotopes have occurred responding personnel operating for as long as 5 h in the area around the detonated dirty bomb are not likely to incur doses of radiation in excess of 0.2 Gy [7]. In cases when significant amount of radiation is expected prophylactic administration of the radioprotector amiophosphate can be considered [23]. Optimally, the first contact medical team should be led by (or include) an individual with radiation protection training.

Each member of the responding medical personnel must be well aware that radioactive contamination (whether external or internal) is never immediately life-threatening and, therefore, radiological assessment or decontamination should never take precedence over significant medical conditions. In case of multiple casualties the on-scene triage should be performed in order to identify and stabilize victims with life-threatening injuries which always take precedence over measures to address the effects of radiation exposure and/or contamination; after stabilization, such victims should be immediately transported to a medical facility [3, 7–9, 14–16, 26]. All other victims with the preserved life functions should be removed from the irradiated and/or (potentially) contaminated area and should be sorted and treated according to standard medical triage guidelines with the exception that those who are

Table 2. Sequence of measures taken during the management of victims of a radiological/nuclear emergency

1. Ensure that all first responders are properly guarded against radioactive contamination and excess irradiation (protective clothing, face masks, double gloves, boots, individual dosimeters, work in shifts, etc.).
2. Assess and treat life-threatening injuries immediately (airways, bleeding, burns, fractures, etc.).
3. Move victims away from the radiation hazard area (stay within the controlled zone if contamination is suspected), remove victims’ clothing.
4. Take blood samples and a.s.a.p. order complete and differential blood counts.
5. Swab nostrils, oral cavity, and wounds to detect any internal contamination.
6. If possible, decontaminate the victims by thoroughly washing body surfaces or with showers; if it is not possible wrap victims up in blankets or sheets and transfer to decontamination places/facilities.
7. Collect and label urine and faeces of victims suspected of internal contamination.
8. In cases of risk of inhalation of radioactive iodine (after a nuclear accident) seek advice from the radiation protection authority for use of stable iodine tablets or Lugol’s solution.
9. Start pharmacological treatment of prodromal syndromes of radiation sickness (such as nausea, vomiting, diarrhea, weakness, headache, fever, hypotension) and psychotherapy (verbal and pharmacological).
10. Transfer irradiated/contaminated victims to a specialist medical facility.
11. Survey and decontaminate members of the medical team.
(presumably) contaminated should be separated so that they can receive a preliminary decontamination (more than 90% of contamination can be removed by removal of the clothing) before or during transport, if necessary, to a hospital [20]. The symptoms of individuals who have received large radiation doses will typically include nausea, vomiting, fatigue, diarrhea, and skin erythema. When such symptoms (especially – vomiting \([9]\)) appear within 4 h after exposure to radiation, the absorbed dose is likely to be very high (but still treatable). Even though some or all of the above symptoms may reflect an exposure to many toxic materials and are also common in victims experiencing only great psychological stress (which may certainly result from participation in a radiological/nuclear event), patients with such conditions should be treated as potentially severely irradiated and as quickly as possible referred to a specialist medical facility. Irrespective of the cause of the ailments, these and other victims and witnesses of a radio-terrorist attack should receive verbal advice and, if necessary, pharmacological treatment from a trained psychologist/psychiatrist who should complement the first contact medical team [20]: such psychotherapy should be continued during transportation to a medical facility, throughout the treatment period and often after the discharge from hospital.

In a mass casualty scenario, in order to avoid overwhelming of the existing medical facilities, “evacuation centers” [23] should be set up as close as possible to the site of the attack with primary objectives to receive and provide shelter to victims and the so-called “worried site of the attack with primary objectives to receive and medically stabilize those who require immediate life-saving surgery must be wrapped in blankets or sheets and universal precautions must be taken before transferring them to an operation room.

The sequence of treatment measures performed in the pre-organized emergency room is similar to those carried out on the site of the incident except that all the procedures can now be more thorough and complete. In the medically stable, contaminated patients special attention must be paid to decontamination of burns, wounds, orifices, and skin (preferably performed in a devoted separate room and radiologically monitored afterwards [23]), to collection and labelling of blood samples, swabs, and excreta, to treatment of prodromal symptoms and, last but not least, to psychological reassurance and comfort (which is all too often forgotten during the emergency management of such patients). When internal contamination is suspected application of emetics, laxatives, antacids, diuretics and/or gastric lavage can be helpful; if known radioisotopes have been deposited in the patient’s body administration of the appropriate blocking, diluting, mobilizing or chelating agents (such as potassium iodide, Prussian blue, pentetic acid – DTPA, ethylenediamintetraacetate acid – EDTA, sodium bicarbonate etc.; alas, most of these agents require experienced consultations, treatment, and management) as well as whole-body gamma counting may be recommended [14, 20].

Irradiated and/or contaminated patients who require specialized hospital treatment (especially those with combined injuries) should be “safely” transferred to an appropriate clinical ward; best suited for that purpose are oncology and haematology units, but clinics specializing in the therapy of burns and fractures may also fit the bill. When medium-to-high doses of radiation have been absorbed (a useful rule of thumb: if the number of blood lymphocytes have decreased by half and are less than \(1 \times 10^9\) per µL within 24–48 h and no other medical conditions that could be the cause thereof are apparent, the patient is at least moderately injured by radiation) all surgical treatment (other than life-saving) should be performed before or after the time window between the 25th and 35th days post exposure, when the risk of sepsis is the highest due to immunosuppression [23]. In order to more thoroughly estimate the absorbed dose biologic dosimetry is performed using cultures of blood lymphocytes obtained from the patient.

In all patients with a moderate to severe radiation injury (before and after the development of the symptoms of radiation sickness) prevention and management of infection is the mainstay of therapy (with emphasis on low-microbial content food and water, air filtration, reverse isolation etc). In most of these patients pharmacological treatment of early (prodromal) symptoms of the radiation sickness must be continued and intensified, accompanied by psychotherapy. In patients with the anticipated and already manifested haemato poetic and gastro-intestinal syndromes, in addition to fighting infections with antibiotics, specific clinical support must include transfusion of fresh, irradiated platelets and other blood products, stimulation of bone marrow restitution (with use of haematopoietic growth factors), selective gut decontamination (with antibiotics
that suppress aerobes, but preserve anaerobes) and boosting of the recovery of intestinal mucosa. In internally contaminated patients the particular incorporated radionuclide(s) should be recognized and specific treatment protocols tailored to that radionuclide must be introduced (or continued) to facilitate its excretion and/or reduce incorporation in the body [14, 20] (detailed procedures to dilute, purge and/or stimulate urinary and/or faecal elimination of radionuclides are discussed in Refs. [11, 19].

In the wake of a radiological or nuclear emergency, it is necessary to arrange for identification, tracking, and long-term follow-up of all, actually and potentially, irradiated or contaminated victims as well as all patients who have recovered from acute radiation syndromes in order to detect possible delayed health effects. Primarily, these effects will include radiogenic cancer and consequences of prenatal exposures [11], but other outcomes (e.g., cardiovascular disorders in individuals who sustained moderate doses of radiation) could also be tracked down. The long-term medical follow-up must consist in regular medical examinations including routine laboratory tests as well as the available screening and diagnostic tests for neoplasia (especially for leukemia and carcinomas of thyroid, breast, lung, ovary, colon, and urinary organs).

**Psychosocial effects**

Today, no direct data exist upon which to base the psychological and social impact of a malicious act involving radioactive material. However, the existing experience of non-radiological/nuclear terrorism suggests that the psychosocial effects of a radiation emergency can be very significant and far outnumber any direct effects.

A radiological incident can certainly produce profound psychosocial impacts at the individual, familial, communal, and even national levels. Indeed, for perpetrators of a terrorist attack a major goal is to purposely evoke fear, anxiety, and uncertainty not only in the directly affected individuals, but primarily among the general population [7, 13, 18, 20]. Compared to other types of terrorist events, the psychosocial sequelae (both immediate and delayed) of an attack that intentionally involves exposure of people to ionizing radiation will be amplified and will certainly pose one of the most difficult issues to cope with during the rescue, recovery, and restoration phases of the management of the incident [16, 20–22]. This is due to the fact that people regard situations involving exposure to ionizing radiation “a good deal more threatening than both natural hazards of even the most dangerous kind and mechanical mishaps of considerable power” [5]. Indeed, hazards are regarded as having higher risk if they are unfamiliar, uncontrollable, poorly understood, involuntary, irreversible, affect children and may affect future generations, and are associated with potentially unethical activities [4, 18]. Compounded by views and opinions presented in mass media, these factors perceived as typical for unintentional exposure to ionizing radiation, have created and sustain the aura of “radiophobia” among the general public (Table 3) – a state of mind which certainly enables terrorists reach their goals (and makes the media “their best friends”) [16, 20, 22].

Hence, a radiological or nuclear terrorist attack will have a powerful capacity to produce a range of both acute and chronic psychological effects manifested not only in victims and their families, but also in those who were not directly affected, termed “the worried well” (who may present with multiple idiopathic physical symptoms). In fact, the latter category of “victims” will most likely predominate and may easily overwhelm the capacity of the existing health and human services system. Among those at the highest risk of developing psychiatric disorders are: a) people directly exposed and those participating in rescue and recovery operations; b) pregnant women; c) mothers of young children and children; d) those who suffered resource losses and disruption of their family and social support; and e) people with a current or a prior history of psychiatric illness [7, 11, 13, 20].

Psychosocial consequences of any significant act of terror can be emotional, physical, cognitive or interpersonal in nature, ranging from fatigue, insomnia or impaired concentration to emotional numbing or social withdrawal [20]. When deliberate radiation releases are concerned, significant distress will be common and manifest as sadness, anger, fear, insomnia, impaired ability to concentrate, and disbelief; these may lead to substance abuse, social withdrawal, and/or aggressive behaviour. Notably, many patients who were not irradiated at all may present with psychosomatic symptoms that mimic those of prodromal phase of the acute radiation disease (e.g., nausea, vomiting, rashes) or show other psychological, behavioural, and cardiovascular-neuroendocrine effects [20]. Generally, affected individuals presenting psychological effects can be divided into three groups: a) those who are distressed; b) those who manifest behavioural changes; and c) those who develop psychiatric illness [13]. As indicated by the findings of the 2006 Chernobyl Forum, stress symptoms, increased levels of depression, anxiety (including post-traumatic stress syndromes), and medically unexplained

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<th>Table 3. Views and opinions causing the “specific stress” and “radiophobia”</th>
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<td><strong>A nuclear bomb is the “ultimate weapon”</strong>.</td>
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<td><strong>Nuclear threats are the riskiest and the most dreaded.</strong></td>
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<tr>
<td><strong>Ionizing radiation is a mysterious, invisible, and dreaded hazard which poses an unbounded (“open-ended”) threat.</strong></td>
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<td><strong>Exposure to ionizing radiation causes hidden and irreversible damage or death.</strong></td>
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<td><strong>People irradiated or contaminated with radionuclides are dangerous to others and are thus socially “stigmatized”</strong>.</td>
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<tr>
<td><strong>Calculated, intentional exposure of people to ionizing radiation by terrorists is an unusually repugnant and repulsive act of aggression.</strong></td>
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physical symptoms occurred more often in populations exposed to radiation in the wake of the Chernobyl disaster than in the control, unexposed groups (similar symptoms were also recorded in the survivors of the atomic bombings of Hiroshima and Nagasaki as well as in residents near the Three Mile Island nuclear power plant accident in 1979 [12]. In most cases, distress and psychological and behavioural symptoms caused by such events are subclinical and diminish over time, but in some of the affected they will persist and result in the post-traumatic stress disorder (PTSD), generalized anxiety disorder, and phobic and/or panic disorder [13, 20]. However, less complex symptoms of depression, distrust, bereavement, family conflict, alcohol and drug abuse, demoralization, and/or various forms of somatization will be much more common than the full-fledged PTSD or other maladaptive syndromes. At the community level, the contamination and radiation exposure-related stigma as well as conflict related to the cleanup may significantly hinder the social reassurance and recovery efforts. Over time, contaminated communities may manifest reduced cohesiveness, low morale, and decreased social service due to distress and economic losses [13]. At the broadest level, a radiological/nuclear incident has the potential to produce widespread fear, a heightened sense of vulnerability, loss of public trust, and an overall loss of public confidence in societal institutions and the government [20]. It is vital, therefore, that psychosocial considerations be a high-priority component of the consequence management efforts.

Management of the psychosocial impacts of a radiological/nuclear terrorist act is a difficult and complex task. Knowledge of radiation and its effects can definitely serve to reduce the fear, anxiety and other psychological effects of participation in/witnessing of a radiation emergency. Thus, clear and simple advice based on internationally endorsed guidance should be given to the public. Apparently, members of the public seek guidance and information from physicians and other health care professionals. Unfortunately, medical education does not generally provide these professionals with sufficient information to enable them to knowledgeably answer questions about ionizing radiation, health effects of radiation exposure (especially, of exposures to low doses of radiation), or protective actions needed in case of a radiation emergency [20]. Appropriate medical and emergency information should, therefore, be made available to them so that they can inform the concerned public before, during, and after an emergency. Physicians should make an effort to learn more about the diagnosis and treatment of radiation injury, even though such injuries are rare [11]. Emergency preparedness for a radiological/nuclear terrorist should also include an ongoing education programme for the general population, medical staff, public officials, teachers, ministers, psychologists and others who have the respect of the community and are in positions of trust [11]. Of utmost importance in this regard is the appropriate education and training of all first responders (police, fire fighters, paramedics, emergency room, decontamination and hospital staff, etc.) and cleanup workers.

Psychological and social support programmes (encompassing preplanned, grounded on reliable knowl-
disasters and terrorist acts [20]. This is largely due to the fact that at present there is no standard protocol or comprehensive manual available to deal with these issues. Indeed, brochures, fact sheets, and literature about self-management of the medically unexplained symptoms do not practically exist. These could and should be provided by the results of research on socio-behavioural aspects of radiological incidents devoted, among other things, to such issues as immediate and protracted psychosocial interventions after the incident, people’s reactions to decontamination and to physical contact with the exposed/contaminated individuals and the environment, better identification of groups with a high risk of developing psychological disorders as well as research on the post-radiation stigma and radiophobia and on ways of preventing and/or ameliorating these symptoms [20].

References