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Editorial

Radiation accidents and incidents. What do we know about the medical management of acute radiation syndrome?

Radiation injury in the general population due to accidents or incidents is a rare but remarkable event that merits serious study and planning in the health care system. A radiation accident is defined by the International Atomic Energy Agency as "an event that has led to significant consequences to people, the environment or the facility. They can be related to a wide spectrum of practices, including industrial use, use of radiation sources in hospitals, activity in nuclear facilities, and transport of radioactive material. Also, a war or a possible terrorism nuclear attack can occur. The main scenario of a "major nuclear accident" is one in which a reactor core is damaged and large amounts of radiation are released, such as the Chernobyl Disaster in 1986, or more recently, the Fukushima nuclear power plant accident in March 2011.

When planning this special issue a few months ago, we suspected nothing about the upcoming nuclear accident in Fukushima. Instead, we were thinking more about a possible nuclear terrorism attack. Sadly, the ongoing event in Japan makes this special issue totally appropriate, and it gives us the opportunity to draw the attention of the real risk of the radiation accidents to the health care community, and the need to implement appropriate management plans adapted to a specific place, without alarming anyone.

According to its magnitude, the International Nuclear and Radiological Event Scale (INES)[1] classifies the radiation events on seven levels: levels 1–3 are called "incidents", and levels 4–7 "accidents". The scale is designed so that the severity of an event is about ten times bigger for each increase in level on the scale. For instance, the Chernobyl reactor explosion was rated as a major, level 7 accident, because there was external release of massive nuclear products, resulting in high levels of exposure, bigger than 2 Gy. About 150 workers were diagnosed with acute radiation syndrome with 30 dying early and another 14 dying over the next 10 years. Several publications in recent years[2] have provided scientific evidence that excess childhood thyroid cancer has been a result of the accident. Other cancers, such as leukemia, are more difficult to correlate with the past accident, due to epidemiologic difficulties in the affected countries. In the Fukushima-Daiichi nuclear plant in Japan, the loss of power to cooling systems resulted in severe damage to the nuclear core, with release of radioactive iodine and cesium outside of the reinforced shell, with high risk of contamination of the area. Despite the devastation of the site, only one suspected radiation-related death has been reported at Fukushima so far. Two more workers were found dead in the plant, but apparently, the earthquake itself was the cause of death. The event has been officially raised to level 6 on INES scale.

The registry of serious radiation accidents maintained by the Radiation Emergency Assistance Centre/Training Site (REACTS/TS)[3] has registered two other serious, Center level 6, accidents. The Kyshtym accident, in Russia, 1957, where there was significant release of radioactive material to the environment from explosion of a high activity waste tank, and the Brazil accident, when four people died and six received doses of a few Gy from an abandoned highly radioactive Cesium-137 source. In other cases, relatively low numbers of individuals have been exposed, such as the reactor breach at Three Mile Island, USA, 1979, that resulted in no more than 50–70 mrem of additional exposure to any individual within range (level 5), the Saint Lauren des Aux, in France, 1980, where a channel of fuel melted in the reactor, with no release outside the site, and the Tokaimura accident, Japan, in 1999, with fatal overexposures of workers following a critical event at a nuclear facility (level 4).

The INES scale[1] takes into consideration the radiation dose to people and the environment close to the location, the spread of radioactive materials confined within an installation, and the events for which the prevention measures did not function (defence-in-depth). In case of a nuclear accident, the head of the nuclear plant must declare the category of the event, in conjunction with the Nuclear Safety Agency, and activate the emergency plan. To facilitate international communications, the IAEA maintains a web-based network that allows details of the event to be made immediately available to the public.[1] This communication system makes the safety significance of nuclear and radiation events quite clear.

The main consequence of a radiation accident is the damage to people who were in that place and in the neighborhood. Acute radiation syndrome is a term used to describe a group of signs and symptoms that occur after whole-body or significant partial-body irradiation of certain amount of radiation (>1 Gy) delivered at high-dose rate. The first description of acute radiation syndrome was made by De-Coursey after the atomic bomb explosions in Japan during World War II in 1945.[4] The global damage results from the sensitivity of cells to radiation, with the most rapidly dividing cells being the most sensitive to the acute effects of radiation. We will not discuss here the chronic changes, which may take many months or years to become evident.

In spite of the widespread use of radiation for industrial, military and medical fields, and its known potential hazards, few clinical guidelines related to radiation victim management have been published until now. In the present issue the authors cover how to deal with the acute radiation syndrome from different aspects, starting with a review of the radiobiology to understand the main effects of a massive irradiation, followed by an explanation of how to assess the dose received by the irradiated victims, and how to perform the decontamination in the hospital or in a place near the nuclear accident. The medical treatment of the radiation syndrome in the emergency context will be detailed and, finally, a revision of the available radioprotective agents will be summarized.

1. Responding to a nuclear emergency

Radiation injury can occur from external irradiation, external contamination with radioactive materials, and internal contamination by inhalation, ingestion, or transdermal absorption with incorporation of radiologic materials into the body's tissues.[5] The first measures that need to be taken in case of a radiation accident are to control the access to the nuclear or radiological place, to start the confinement protocols and to evacuate people that need specific medical attention. Then, it will be necessary to establish a controlled area large enough to hold the anticipated number of victims.

Effective care requires implementation of well-organized disaster plans. Emergency evacuation plans to control the crisis at Fukushima Daiichi have proven well established, in spite of the initial press alarm, saying that Japanese Government was not rapid enough. Since hydrogen explosions rocked the plan after the tsunami of March 11, a 20 km exclusion zone was placed, evacuating the residents living within that limit, based on short-term radiation exposure. The community living within 20–30 km of the plant asked to remain indoors and was closely monitored. In April, the evacuation was extended beyond a distance of 30 km from the plant. Radiation monitoring for iodine-131 and cesium-137 is periodically performed in the area, as well as food control, specially water, milk and green leaf vegetables.

Physicians and other health personnel who treat patients that have been exposed to radiation must understand the biologic effects of the various types of radiation in order to determine which patients are at risk of radiation injury, to manage patients with radiation exposure, and to minimize the risk of contamination of hospital equipment and personnel. Careful documentation of clinical signs and symptoms and estimation of individual radiation dose are required for medical triage.

Several important consensus have been created to help physicians who may be involved in evaluation, triage, or medical management of victims with acute radiation injury. The Strategic National Stockpile Radiation Working Group released their recommendations in 2004 for terrorist and accidental events involving exposure to radioiodines.[6] Also, the European consensus concerning the medical management of mass radiation exposure was obtained in 2005 (METREPOL) during a conference held by the European Group for Blood and Bone Marrow Transplantation, the Institute of Radioprotection and Nuclear Safety, and the University of Ulm.[7]

2. Medical planning

Since the physical, medical, economic, and psychologic consequences can be catastrophic, appropriate planning is absolutely essential. The first step of radiation emergency response is to plan ahead and prepare for possible crisis. Emergency plans should be designed to allow for a level of response commensurate with the number of patients potentially involved, from a few to hundreds or more. An emergency response plan should outline the respective roles and responsibilities of each participant and the various steps to be taken. Hospital planning and training should involve not only medical personnel, but also local public safety, public health, psychologic services, and emergency management officials, together with the rescue team from fire departments, emergency medical services, law enforcement, and other agencies. Communities with several hospitals or clinics should assure the capability for active collaboration among them.

Once patients are in a hospital, they should be distributed appropriately for specialist care according to the severity of organ damage, including the intensive care unit, the burns unit, and the haematological department. Supportive care can be administered by trained physicians and nurses. Several organizations have produced planning templates to assist health care facilities in developing radiation emergency plans, such as the Radiation Emergency Assistance Centre/Training Site (REAC/TS)[3] and the Centre for Disease Control and Prevention.[7]

The Joint Commission for the Accreditation of Healthcare Organizations (JCAHO) requires every hospital to have a written plan in place to deal with the victims of a radiation accident.[9] To be able to handle such an emergency effectively, referral hospitals should drill the protocol until it is familiar to all staff members who may need to participate. All emergency departments should have ready access to the supplies and equipment necessary in the management of radiation accidents.

3. Treatment of acute radiation syndrome

According to the METREPOL protocol, the first 48 h after a radiological accident involving masses of people are crucial.[10] In that time period, the accident victims should be processed by an emergency triage system where the patients are scored on the basis of both clinical and biologic criteria.[11] If the radiation accident affects large numbers of people in an area that is not covered by medical systems familiarized with the medical treatment protocols for radiation accidents, emergency groups should be sent to help with the primary emergency triage. An exposure of the whole body, or a significant portion of it, to 4 or 5 Sv (or Gy) is potentially lethal, while a limb may be able to tolerate several times that dose. Specialized medical care can greatly enhance the likelihood of survival of those who receive whole-body doses of 3–7 Sv.[11]

Patients who are to be hospitalized are only those who need maximal medical attention. In the case of accidental contamination, patients are admitted only after having been decontaminated. Once patients are in a hospital, they should be distributed appropriately for specialist care according to the severity of organ damage. Thus, patients who have the highest probability of developing multi-organ failure should be placed in the intensive unit, patients with severe cutaneous injuries should be admitted to the burns unit, and the remaining patients should be placed in the haematology department. Providing general supportive measures to maintain the normal vital signs and assuring an open airway are required. Hematologic support by means of transfusion of blood components, cytokines or hematopoietic cell transplantation should be considered in those having received 2–10 Gy.

In the case of significant exposure to radioactive isotopes of iodine, like in a nuclear reactor incident or in an atomic blast, prevention of significant uptake of radioactive isotopes of Iodine by the thyroid is imperative, specially in children and the exposed fetus, who are most prone to the development of radiation-induced thyroid carcinoma.[12] Preventive treatment with potassium iodide to prevent thyroid cancer should be administered to irradiated patients and people who live around the radiation accident.

Another preventive attempt would be giving amifostine, a radioprotective compound commonly used in clinics to protect patients against the secondary effects of radiotherapy and chemotherapy. Melatonine is a pineal product which is also known to have robust radioprotective features. It seems to be the most feasible agent to reduce the risk of cancer and several other health problems.[12]

Finally, we must consider the psychological impact of radiation exposure, specially after an intentional terrorism attack. Usually, the number of individuals without significant radiation exposure who would require psychosocial support is far greater than the number of patients who would be physically injured. These people are better treated in the ambulatory setting, leaving room in hospitals to appropriately treat victims with serious radiation injuries. Also, in a natural nuclear disaster, the psychological burden on those affected is often serious, an effect worsened by poor information about health risks associated with radiation exposure. Clear and accessible information is essential to ensure that adequate safeguards, monitoring, and support are provided in the years following a nuclear accident of any type.[14]

Indeed, the main objective of this special issue on Medical Management of Acute Radiation Syndrome is to draw attention to the medical community of the real risk of a serious nuclear or radiologic emergency that would require specialized medical care. The scope of this issue includes medical centre administrators, emergency department physicians, haematologists, nuclear medicine specialists, radiation oncologists and others, some of them with limited knowledge of ionizing radiation and radioactivity. It is necessary to prepare in advance the specialized medical care that can greatly enhance the likelihood of survival of those who receive significant whole-body irradiation.

In addition, an Emergency Department planning process should involve radiation safety staff, the radiology and radiation oncology departments, security and communications, hospital administration, clinical affairs, and public relations.

Management of radiation exposure, for an individual or a community, requires knowledge of the principles of radiation safety and advance preparation and planning at both the community and healthcare facility level. The main responsibility for optimizing outcome subsides in hospital staff and other health care facilities. Radiation oncologists, nuclear medicine specialists, haematologists, and health physicists, in particular, will be looked to for leadership and expertise because of their knowledge of radiation and its acute and late effects.

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