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INVITED REVIEW – OPEN ACCESS

Medical Planning and Care in Radiation Accidents

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ABSTRACT

To date, many major radiation accidents have occurred worldwide, mostly in nuclear reactors, and some other minors in radioactive isotope production facilities and during the transport of radioactive materials. Similarly, the majority of the radiation accidents in Turkey occurred in industrial radiology or during the use of sealed radioactive sources for the purpose of non-destructive testing. However, only a few of them happened in medical practices. In case of fire in buildings with radioactive material, terrorist incidents using radioactive materials, or accidents during transportation of radioactive materials, emergency response teams, first aiders and firefighters may be exposed to low-level radiation while performing their duties. Fortunately, very few victims of radiation accidents develop acute radiation syndrome and require medical intervention. On the other hand, some victims of radionuclear accidents may require urgent medical intervention since the adverse health effects may occur years after the event due to internal contamination and following incorporation. In this report, we aimed to define the basic concepts of radionuclear emergency and medical management of radionuclear victims.

Keywords: Radionuclear emergency, acute radiation syndrome, medical management

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INTRODUCTION

Nuclear and radiation accidents are defined by the International Atomic Energy Agency (IAEA) as “an event that has led to significant consequences to people, the environment or the facility” (1, p. 183). Accidents that cause casualties or the release of massive amounts of radioactive material into the environment are some of these serious consequences. Nuclear and radiation accidents/incidents may occur during operations in nuclear facilities, transport of radioactive materials, industrial and medical uses of radiation sources. Several factors, such as attack on nuclear power plants, malicious use of radiological devices, industrial radiography accidents, a dirty bomb used for terrorism, may result in radiation injury.

A scale was defined to determine the significance of nuclear/radiological accidents (1). Accidents and incidents are classified according to the International Nuclear and Radiological Event Scale (INES) based on their significance (Fig. 1). In INES, each level represents events that are 10 times more significant than the previous one. Events classified as levels 1, 2 and 3 according to the INES scale are more frequently encountered during the routine use of radiation and are less important for their consequences.

The prime example of major nuclear accidents is the Chernobyl disaster in 1986 in which a reactor core was damaged, and significant amounts of radioactivity were released into the environment (INES Level 7 (Major Accident)) (2). The Chernobyl disaster is considered the worst nuclear disaster in the world to date. In the Chernobyl disaster, two people died due to the explosion and more than 100 people received radiation dose that was high enough to cause acute radiation syndrome (ARS). Among 100 people, 29 died within a few months, and 18 more died in the following years. One of the major health consequences of the Chernobyl disaster is a significant increase in thyroid cancers, especially in childhood (3). The Fukushima nuclear accident that occurred in Japan in 2011 (INES Level 7 (Major Accident)) is the second most severe accident after the Chernobyl disaster (4). Nobody died of radiation; however, an increased risk of cancer can be expected in workers in the future. Apart from these, there have been significant radiation accidents in the world and in our country, and it has been aimed to take lessons to avoid their recurrence (5).

One of the most significant accidents in recent years in Turkey occurred in Sakarya in 2016 (INES Level 3 (serious incident)). An Ir-192 source with 15.67 Ci activity in a broken gammagraphy device separated from its safe position and dropped. It was later found by someone irrelevant, and this person was exposed to an effective dose of 1.17 Sv by carrying it in hand and back pocket. He experienced radiation burns in hands and bilateral buttocks and had to be hospitalized several weeks for reconstructive surgery (Fig. 2).

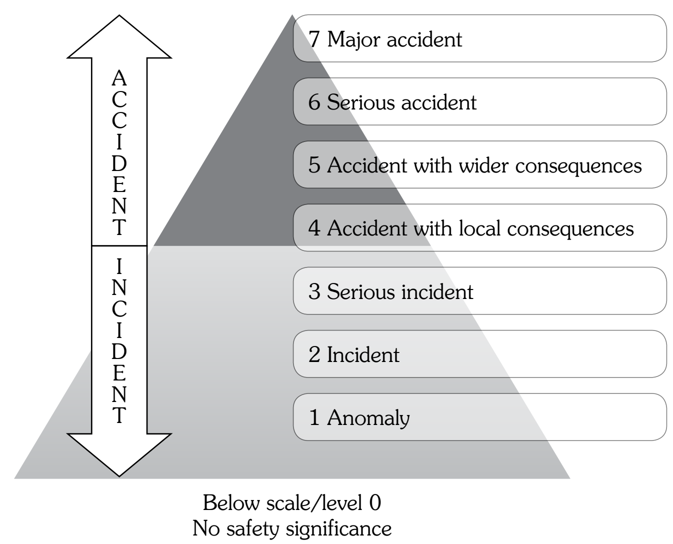

Figure 1. International Nuclear and Radiological Event Scale (INES)

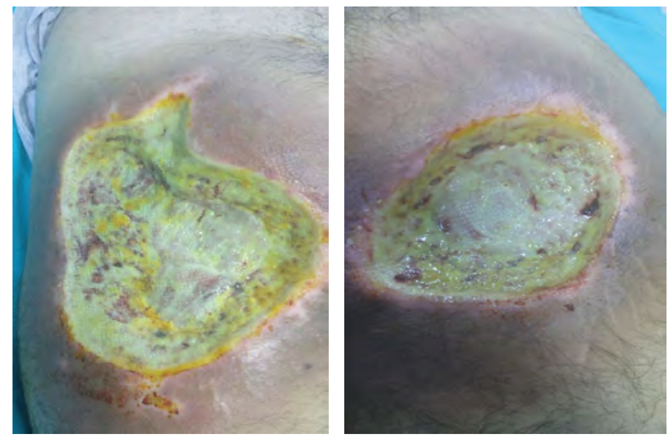

Figure 2. The changes occurred in both hips at four month as a result of carrying 50 Ci Ir-192 source in the two back pockets of the trousers alternately for about two hours. Painful deep ulcerations and deep tissue necrosis in the right and left gluteal regions

Clinical and Research Consequences

ARS is a clinical condition that occurs when a local region or whole body is exposed to very high doses (>1 Gy) of radiation within a very short period of time (6). Although the clinical symptoms may vary depending on the dose of radiation exposed, the type of radiation, the volume of irradiated tissue, the patient's age and current health status, or the medical intervention performed, symptoms of three systems, usually hematopoietic, gastrointestinal and cerebrovascular, are observed. Each of these symptoms is observed in four clinical stages as follows: prodrome, latency, manifest illness, and either recovery or death. The prodromal symptoms begin a few hours after exposure and, depending on the severity of the dose, nausea, vomiting, watery diarrhea and abdominal cramps occur within hours after radiation exposure. During the latent period, the patient may be relatively clinically normal or generally asymptomatic. In the manifest illness stage, the patient presents with hematopoietic symptoms, especially neutropenia and pancytopenia clinic. In conclusion, the common effects of radiation accidents can be seen as the dose-dependent development of multiple organ failure (7).

Rapidly dividing cells and the cells in the mitotic phase are most sensitive to ionizing radiation. When exposed to high doses of radiation, the precursor cells in the bone marrow with a high proliferation rate, spermatocytes in the testicles, and crypt cells in the intestinal tract are first affected. The clinical manifestation that arises when the total body or bone marrow dose is >1 Gy is referred to as hematopoietic syndrome, and a decrease in lymphocyte count is observed first. If the patient has hematopoietic syndrome accompanying the clinical manifestation, it may clinically become more complicated due to bleeding, infection and poor wound healing (Fig. 3a, b). The gastrointestinal syndrome occurs at doses of >5–6 Gy. Cerebrovascular syndrome generally occurs at doses of >10 Gy and results in death within 5-6 days as a result of hypotension, cerebral edema, increased intracranial pressure and cerebral anoxia (8).

The injury that arises from radiation accidents may occur in three different ways as follows: external irradiation, external contamination, or internal contamination with radioactive materials. These three types of radiation exposure may be accompanied by thermal or traumatic injuries. External irradiation (external dose exposure) means the person's exposure to radiation source without being contaminated with radioactive material. The difference between external exposure to radioactive source and contamination is that there is no physical contact or either direct or indirect contamination with the radioactive source (9).

External contamination occurs in the presence of physical contact with radioactive material on the human body, objects, or environment (10). The most common radioactive contaminants are alpha and beta emitters. While gamma emitters result in total body irradiation, beta emitters may cause cutaneous burns and scarring. On the other hand, although alpha emitters cannot penetrate the epithelium, it may cause organ and tissue damage in case of internal contamination. Radioactive substances that cause contamination may be in solid, liquid, gas and aerosol form and may enter the human body through various routes (such as skin, eyes, lungs, digestive tract, injection route). The sources of external radioactive contamination may include accidents in medical treatment units (radiotherapy, nuclear medicine), nuclear reactors, industrial radiation, lost/stolen medical/industrial radioactive sources, terrorist attacks and dirty bomb (11). The first rule of taking radioactive contamination under control is to limit the spread of the material. Decontamination performed within the first few minutes after exposure is the most effective way to protect the victim. The first and most effective decontamination is the physical removal of the chemical agent. Detoxification is the second goal, but not always possible. After removing the victim from the contaminated area, their clothes and accessories should be taken off, and hair and skin decontamination should be performed with soap and water. In most cases, these procedures provide the required decontamination.

Local radiation injury may also occur as a result of exposure of a local body part to high doses of ionizing radiation (11). Following exposure to high doses, it is not only the skin involved but also subcutaneous tissue and even muscles and bones (more than cuta-

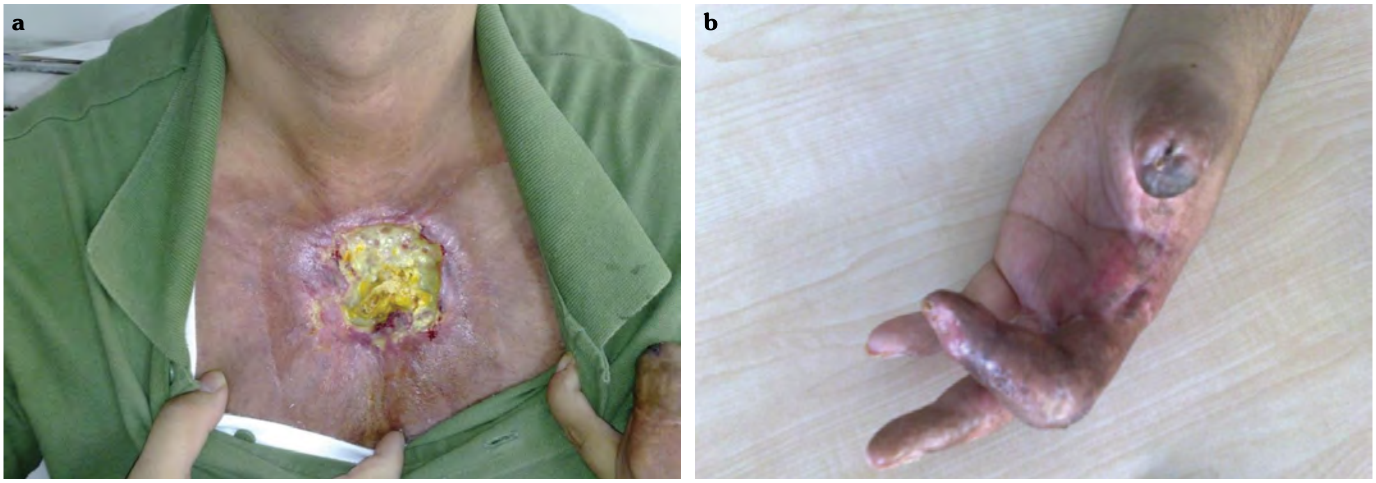

Figure 3. **(a) The changes occurred on the anterior thoracic wall at six month as a result of keeping 50 Ci Ir-192 source in the left hand and adjacent to the anterior thoracic wall for approximately five minutes. Painful deep ulcerations, chronic radiation dermatitis and deep tissue necrosis on the anterior thoracic wall. It was determined that the anterior chest wall was exposed to >1000 rad local radiation dose. (b) The changes occurred in the left hand at 1 year as a result of keeping 50 Ci Ir-192 source in the left hand for about five minutes. Onychodystrophy, chronic radiation dermatitis and ulcerated necrotic lesions are seen in the third and fourth digits of the left hand of the patient who underwent the first and second digit amputation of the left hand. It was determined that the fingers of the left hand were exposed to >3000 rad local radiation dose**

neous). Local radiation injury usually progresses slowly (may take weeks or months). The key points of the treatment are infection control, wound care and pain management. The contribution of a plastic-reconstructive surgeon is of importance in the early period of clinical course (12).

Internal contamination is a more serious problem than external contamination. The radioactive substance can enter the body by passing through the skin, inspiration, or oral route. The treatment is more challenging for internal contamination because the radioactive material could enter the metabolic pathways and incorporate organs and systems. The knowledge of interventions that accelerate the excretion of these substances is necessary for internal decontamination (13). Reducing the gastrointestinal absorption or accelerating the excretion of the isotope that is not dissolved by gastric lavage, laxatives, activated charcoal etc., diluting the isotope with aggressive hydration, blocking the target organ of the isotope (e.g., reducing the radioactive iodine uptake of the thyroid gland using potassium iodide) and conventional chelation techniques are the medical approaches to be used in internal contamination.

In the case of a radiation accident, a very detailed history of the victim should be taken to rapidly determine the severity of radiation injury that may emerge within the first 48 hours and to be prepared for appropriate medical treatment. Absorbed radiation dose can be estimated by time to onset of vomiting, rate/depth of the decline in lymphocyte count and chromosome aberration tests (14). Complete blood counts (lymphocyte, granulocyte, platelet) should be studied in the first 24 hours at 4 to 8-hour intervals, and these tests should be repeated at 12-hour intervals after the first day. Blood samples should be certainly taken for chromosome aberration test, and if radiation contamination is suspected, stool and urine samples should be taken. The medical treatment to be administered in the first six weeks should be especially aimed to prevent pancytopenia and infections. Although short-term treatment with cytokines may be possible in cases of low radiation exposure (<3 Gy), higher radiation exposures (>7 Gy) require long-term treatments, such as cytokines, blood transfusions, and bone marrow transplantation. If surgical intervention is considered, it should be performed within the first 48 hours or it should be waited at least six weeks after exposure to recover from any hematological complications (15).

CONCLUSION

An accurate evaluation of acute radiation syndrome and initiation of treatment as soon as possible are of utmost importance for patient management in radionuclear hazards. All radiation workers, radiation protection officers and medical professionals who will take action in radionuclear emergencies should be trained periodically in radiation safety.

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