

A management plan for hospitals and medical centers facing radiation incidents

Fereshteh Davari, Arash Zahed¹

Health Management and Economics Research Center, ¹Vice-chancellery for Research and Technology, Isfahan University of Medical Sciences, Isfahan, Iran

Background: Nowadays, application of nuclear technology in different industries has largely expanded worldwide. Proportionately, the risk of nuclear incidents and the resulting injuries have, therefore, increased in recent years. Preparedness is an important part of the crisis management cycle; therefore efficient preplanning seems crucial to any crisis management plan. Equipped with facilities and experienced personnel, hospitals naturally engage with the response to disasters. The main purpose of our study was to present a practical management pattern for hospitals and medical centers in case they encounter a nuclear emergency. **Materials and Methods:** In this descriptive qualitative study, data were collected through experimental observations, sources like Safety manuals released by the International Atomic Energy Agency and interviews with experts to gather their ideas along with Delphi method for polling, and brainstorming. In addition, the 45 experts were interviewed on three targeted using brainstorming and Delphi method. **Results:** We finally proposed a management plan along with a set of practicality standards for hospitals and medical centers to optimally respond to nuclear medical emergencies when a radiation incident happens nearby. **Conclusion:** With respect to the great importance of preparedness against nuclear incidents adoption and regular practice of nuclear crisis management codes for hospitals and medical centers seems quite necessary.

Key words: Crisis management, disasters, hospital management, nuclear incidents, preparedness for incidents

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INTRODUCTION

Preparedness of emergency medical staff and health care units against nuclear incidents is nowadays a global concern.^[1] Despite numerous useful applications of radioactive isotopes and nuclear energy in medicine, science, industries and technologies, and radiation injuries on human organs remain to be a growing nightmare even for pioneers of nuclear technology.^[2] Nuclear incidents may also occur via the use of atomic warfare or as an act of terrorism.^[3] Hospitals and health care centers are among first responding units in times of crisis. It is simply because when a crisis breaks out, people rush into hospitals to seek not only medical attention but also a safe refuge.^[4] Therefore, it is wise to assume hospitals as an integral part of the first

line of response to any nuclear incident regardless of its domain and severity.^[1] In most countries of the world, there are emergency medical services that play a fundamental role in managing the response to critical incidents.^[5] In Canada, for example, there are infrastructures at the federal level to plan and educate staff for such incidents. The Canadian Emergency Management College specially conducts training programs on chemical, biological, radiological, and nuclear emergencies. Of course in this country, the best teams of responders are formed as a result of continuous short-term training.^[6] The main objective of an emergency medical team in a nuclear incident is to save as many lives of the severely injured casualties as possible. In order to achieve this goal, it would be inevitable to actively engage all levels of medical services in training, exercises, and maneuvers aimed to improve preparedness against nuclear events.^[7]

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Address for correspondence: Dr. Arash Zahed, Vice-chancellery for Research and Technology, Isfahan University of Medical Sciences, Isfahan, Iran. E-mail: zahed@mui.ac.ir

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Training programs for preparedness against chemical, microbiological, and nuclear threats are now integral parts of medical education worldwide.^[8] Lack of trained personnel in many nuclear incidents has given rise to morbidity and mortality. According to some reports, in some instances, medical staff refused to attend to nuclear victims since they were too scared of being contaminated or radiated from their patients.^[1]

The International Atomic Energy Agency (IAEA) has repeatedly requested countries with nuclear technology to take precautionary measures and gain preparedness against the potential life hazards and the consequences of radioactive incidents.^[1] Therefore, despite all progresses made to date, a constant need to improve both knowledge and skills of emergency medical staff, physicians, nurses, radiation biologists, and the police in managing nuclear incidents is highly felt.^[3] Above all, management needs experience, skill, intelligence, speed in reaction, and the ability to make wise decisions quickly.^[9] In this study, our main objective was to propose a management model through which medical centers management system would enjoy greater managerial abilities and a more comprehensive state of planning and preparedness, in case they encounter a nuclear emergency.

MATERIALS AND METHODS

This descriptive qualitative study was based on Delphi interview method and formed part of a Master's degree thesis at Payame Noor University, Tehran, Iran registered under 1495/13/100248. Delphi method is an attractive research tool with great flexibility. It forms a process to collect and distil anonymous judgments of specialists and experts using a series of data collection and analysis techniques. The Delphi method is well suited as a research instrument when there is incomplete knowledge about a problem or a phenomenon.^[10] Our study took an applied approach of Delphi with the researcher being a participant as an observer. While participating in group activities, the observer informed principle members and participants of his own identity and objectives of the study.

Statistical population

The study population consisted of the research group on medical consequences of nuclear incident ($n = 30$) and the task group on health management in disasters ($n = 15$) considering the aim of the study, that is, to design and plan a model, and the small statistical population, the census method was used, and thus the whole population was included.

Study tools

Data were collected through experimental observations, sources such as safety manuals released by IAEA^[11] and interviews with experts to gather their ideas along with Delphi method for polling, and brainstorming.

RESULTS

The primary objective of the study was to predict the conditions for the occurrence of a nuclear incident that to achieve this objective, the opinions of experts using the Delphi questionnaire were prepared. First, the following questions were raised and answered:

1. Under what conditions would a nuclear accident occur?

Answer:

A. Intentional injuries caused by terrorist groups included:

- Using dirty bombs.
- Attacks on nuclear facilities.
- Attack on vehicles carrying radioactive materials.

B. Accident that is caused by recklessness. Included:

- Nuclear explosions caused by industrial accidents.
- Accidents while transferring radioactive materials.
- In medical centers, and in radiotherapy due to use of toxic doses.
- Theft of radioactive materials.

2. What type will the possible accident be (nuclear, chemical, or both)?

Answer: Both chemical and radiation accident is likely to occur.

3. What caused the accident? What is the highest level possible threat?

Answer: Occurrence of an event of limited nuclear safety standards broken, Faced with the possibility of staff but there is the possibility to control the center. The biggest threat may be the possibility of radioactive and chemical contamination, there are 1000 people.

In the second stage, the following questions were answered:

1. What is an appropriate geographical location for a desirable medical center?

Answer: It is about 10 km from the center of prehospital emergency facility and from Advanced Medical Center (hospital) is about 30-40 km.

2. What conditions are necessary to provide appropriate medical response to nuclear accidents possible at a treatment center?

Answer: Preparation of nuclear emergency by:

- Create an appropriate physical space.
- Supply requirements.
- Human resources needed.
- Training of human resources.
- Hospital Disaster Committee.

In the third stage, the following questions were answered:

1. What physical properties should an apt medical center for individuals suspected of chemical or radioactive contamination have?
The answer to this question is presented in Figure 1.
2. What medical equipment is required for treating 1000 possible casualties in a nuclear emergency center?
The answer is as presented in Table 1.
3. How much medication do you predict a nuclear emergency center with 1000 possible casualties will need?
The answer to this question is presented in Table 2.
4. What specialties should the personnel of a medical center have? How many of each?
The answer to this question is provided in Table 3.
5. What are the duties of the radiation emergency response team?
The answer to this question is provided in Table 4.
6. What knowledge and skills should the personnel of a medical center have?

The answer to this question is presented in Table 5.

7. How should the casualties be transferred from the scene to the medical center?

Answer: Decontamination and treatment of skin infection with HF is necessary for people who are infected by HF in the ambulances are used to transport

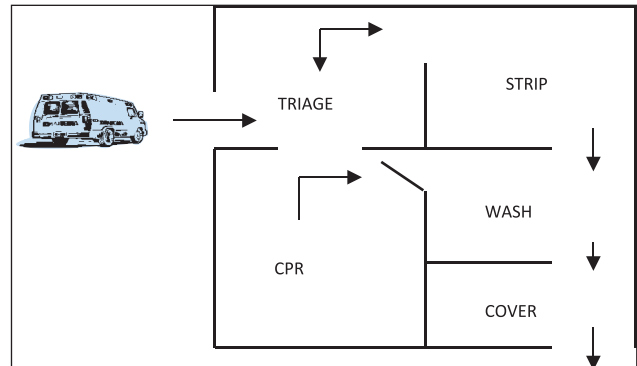


Figure 1: Prehospital Emergency Department plan

Table 1: Required medical equipment for 1000 potential casualties

| Equipment | Quantity | Equipment | Quantity | Equipment | Quantity |
|---|-----------------|--|-------------|---|--------------|
| Projector | 5 | Sterile gloves | 2000 pairs | Soap bar | 1000 |
| Water-resistant fabric | 3000 m | Disposable dressing set | 500 | Liquid soap | 500 lit |
| Scissors | 100 pair | Airway, different sizes | 300 | Shampoo | 1000 |
| Large sturdy garbage bags | 1000 kg | Lubricating gel | 300 | Vests, in different colors | 300 |
| Wide adhesive tape | 100 rolls | Scalpel | 1000 | Tongues forceps | 10 pairs |
| Flashlight and battery | 100 | Foley catheter | 500 | Long pliers | 10 pairs |
| Wide, disposable bed sheets | 2000 m | Test tube | 3000 | Toothbrush and toothpaste | 1000 |
| Bin | 20 | Scrub brush | 100 | Cotton gloves | 20 pairs |
| Rope | 300 m | Latex gloves | 500 packs | Tall boots | 500 pairs |
| Plastic badges with neck straps in 4 colors | 1000 each | Lead container to collect radioactive contaminated materials | 10 | Branol in green, pink and blue | 1000 |
| Saline solution | 3000 bags | Urine bag | 3000 | 15 cm plaster | 1500 |
| Ringer's solution | 2000 bags | Normal and vaseline gauze | 20000 packs | 20 cm plaster | 500 |
| 1/3 and 2/3 IV solution | 2000 bags | Serum Tee | 500 | Chest tube set | 30 |
| IV normal saline | 4000 bags | Nasal canola | 500 | Suture set | 200 |
| Saline solution | 1000 | Two-ply mask for staff | 500 | Neurosurgery set | 2 |
| Dextrose 5% solution | 1000 | Suture, different sizes | 3000 | Orthopedic bin | 50 |
| Infusion set | 10000 | Peripheral blood slide | 15 | Orthopedic drill | 4 |
| 10 cm plaster | 1000 | Chest lead | 3000 packs | Finger pulse oximetry | 100 |
| Yellow angiocath | 300 | Blue van set | 1000 | Surgery gown | 200 |
| Anti-allergic tape | 2000 | Nelaton catheter | 1500 | Sterile gauze | 2000 packs |
| Leucoplast | 2000 | Disposable chest tube | 20 | Sterile gauze sponge | 1000 packs |
| Suction head | 3000 | Eye pad | 1000 | 10 and 15 cm Orthopedic padding bandage | 2000 |
| Syringe (all sizes) and insulin syringe | 20,000 in total | Gown packs, drapes, and disposable sheet | 300 packs | Bandage (elastic, ordinary, burn) | 20,000 packs |
| Abeslang | 1000 | Micro-set | 500 | Plaster saw | 5 |
| Adult chamber pot | 20 | Electroshock paper | 100 rolls | Electric tourniquet | 10 |
| X-ray developer and fixer | 3 sets | Suction pipe | 3000 | Vascular surgery set | 5 |
| NG tube, blue, orange, green | 2000 | Cheatele forceps and dish | 200 | Rechargeable lamp | 5 |
| Endotracheal tube (different sizes) | 1000 | X-ray film | 5 cartons | Tissue paper | 100 boxes |
| Portable radio | 4 | Color markers | 10 | Cabled 3-way outlet | 5 |
| Cotton | 100 packs | Disposable glass | 1000 | Noninfectious waste bin | 200 |
| Large gas cylinder | 20 kg | Infectious waste bin | 200 | Blanket | 3000 |

Table 2: Required medications in nuclear emergency center for 1000 potential casualties

| Drug | Quantity | Drug | Quantity | Drug | Quantity |
|-----------------------------|-----------|-------------------------|----------|---------------------------------|-----------|
| Acetic acid | 20 lit | Xylocaine 2% ampoule | 300 | Glucose vial 2% | 40 |
| Morphine | Unlimited | Xylocaine 1% | 10 | Glucose vial 50% | 60 |
| Fentanyl | Unlimited | Xylocaine 2% vial | 10 | Xylocaine spray | 10 |
| Midazolam ampoule | 1000 | Inderal ampoule | 30 | Pearl TNG | 200 |
| Alprozolam tablets 5 mg | 1000 | Amiodarone ampoule | 30 | Hydrogen peroxide | 20 lit |
| Ceftriaxone vial 1 g | 100 | Procainamide ampoule | 10 | Benzalconium | Unlimited |
| Cefixime 400 | 500 | Dopamine ampoule | 60 | Leolak | 200 |
| Ciprofloxacin 500 | 500 | Dubotamine vial | 60 | Plazyl ampoule | 150 |
| Azithromycin capsules | 200 | TNG ampoule | 15 | Alcohol 96% | 30 lit |
| Gentamicin 80 ampoule | 500 | Verapamil ampoule | 15 | Green betadine 1 lit | 60 |
| Cefazolin 1 g | 500 | Frosomide ampoule | 50 | Betadine scrub | |
| Topical tetracycline gel | 100 | Sodium nitroprusside | 20 | Sulfastamide 20% | 10 |
| Captopril 25 tablets | 500 | Heparin ampoule | 40 | Calcium bicarbonate drops | 40 |
| Enalapril 5 tablets | 500 | Hydrocortisone ampoule | 100 | Ciprofloxacin drops | 10 |
| Adalat capsules | 500 | Dexamethasone ampoule | 100 | Atropine ampoule | 150 |
| Prazosin 1 tablets | 500 | Aminofilin ampoule | 50 | Intravenous epinephrine ampoule | 150 |
| Atenolol 100 tablets | 1000 | Diazepam ampoule | 50 | Calcium gluconate | Unlimited |
| Trymetrin H tablets | 500 | Phenytoin ampoule | 100 | Ondansetron ampoule | 150 |
| Hydrochlorothiazide tablets | 500 | Phenobarbital ampoule | 50 | Tetracycline eye ointment | 50 |
| Tetracaine drops | 20 | Distilled water | 1000 | Calcium gel | unlimited |
| Methylprednisolone ampoule | 30 | Sodium bicarbonate vial | 200 | Cutaneous gentamicin ointment | 50 |
| Nephazolin eye drops | 10 | Sodium chloride vial | 50 | Pethidine 50 | unlimited |

Table 3: Required personnel numbers and specialties of the nuclear emergency center

| Gate | Specialist physician | General practitioner | Skilled nurse | Semi-skilled nurse | Service staff | Patient ambulant |
|---------|----------------------|----------------------|---------------|--------------------|---------------|------------------|
| Gate 1 | 1 | - | 2 | 2 | 1 | 6 |
| Gate 2 | - | - | - | 2 | 2 | 6 |
| Gate 3 | - | - | 1 | 3 | 3 | 6 |
| Gate 4 | 3 | 20 | 52 | 100 | 3 | 30 |
| Gate 5 | 3 | - | 2 | 2 | 1 | 6 |
| Gate 6 | 3 | 5 | 10 | 20 | 4 | 4 |
| Gate 7 | 2 | 5 | 9 | 20 | 4 | 4 |
| Gate 8 | 2 | 5 | 9 | 20 | 4 | 4 |
| Gate 9 | 2 | 5 | 9 | 20 | 4 | 4 |
| Gate 10 | - | - | - | - | 4 | - |
| Total | 16 | 40 | 94 | 189 | 30 | 70 |

Table 4: Duties of radiation emergency response team

| Personnel | Duties |
|-----------------------------------|--|
| Group coordinator (head) | Leadership, consultation, and coordination of affairs |
| Emergency physician | Diagnosis, treatment, and emergency care, and as team coordinator or triage official |
| Triage official | Triage |
| Nurse | Nursing care, sample collection, decontamination, patients' needs assessment, required interventions |
| Medical documents official | Recording medical and radiation information and reporting to authorities |
| Radiation protection official | Contamination control |
| Radiation protection personnel | Patient control, environmental control with monitoring system and radiation measuring equipment's |
| Information announcement official | Transfer of information to mass media |
| Management | Interdepartmental coordination |
| Physical security | traffic control |
| Maintenance personnel | Nuclear emergency decontamination readiness |
| Laboratory technician | Analysis of test samples |

patients.

of hospital management system)?

8. Determine the hospital committee structure (diagram The answer to this question is presented in Figure 2.

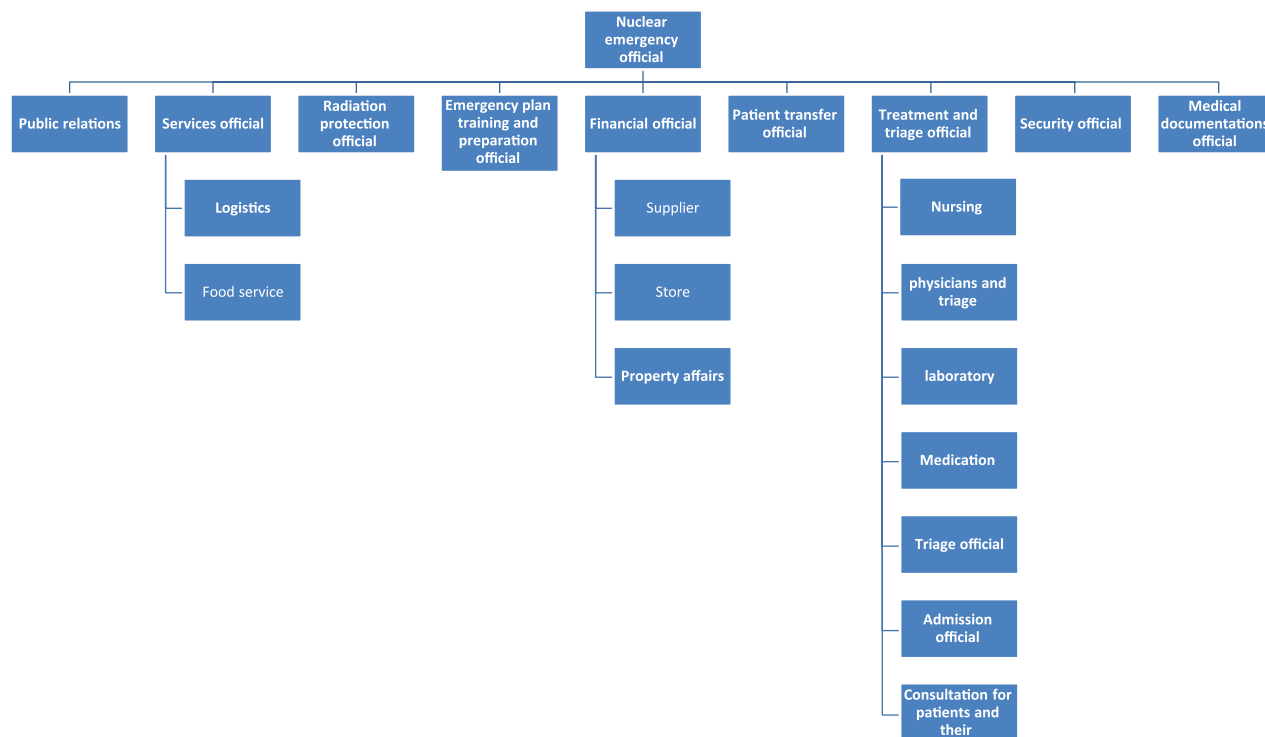


Figure 2: Hospital committee structure

Table 5: Required training headings

Headings for dealing with nuclear accident

Radiation physics, radiation types, forms of exposure and complications
 Types of nuclear accidents and different danger levels
 Hospital disaster management system
 Preparation of hospitals for radiation incidents
 Care for radiation casualties
 Radiation exposure diagnostic methods
 Self-protection against radiation

 Radiation casualty triage
 Radiation contamination complications on different body systems
 Symptoms and treatment of patients with ARS
 Decontamination of radiation casualties
 Decontamination of radioactive materials casualties
 Medications used for nuclear casualties
 Ambulation of nuclear casualties

ARS = Acute radiation syndrome; HF = Hydrogen fluoride

Headings for dealing with nuclear-related chemical accidents

Hydrofluoric acid properties
 Self-care against hydrofluoric acid
 Diagnostic methods of exposure to hydrofluoric acid
 Decontamination of chemical casualties of HF
 Ambulation of chemical casualties
 Treatment of chemical casualties
 Hydrofluoric acid contamination complications for body systems (skin, eye, gastrointestinal tract, and lungs)

DISCUSSION

Intentional and unintentional nuclear incidents are likely in such cases as acts of terrorism using dirty bombs, attacks on nuclear facilities, attack on vehicles carrying radioactive materials, theft of radioactive materials, nuclear explosions caused by industrial accidents, accidents while transferring radioactive materials, loss, release in medical centers, and in radiotherapy due to use of toxic doses.^[11] Emergency Department Clinicians play an important role in the management of terrorist incidents

involving radioactive materials. Emergency Department is considered the frontline department for primary care of patients transferred to the hospital and those attending on their own. From diagnosis to treatment, actions of Emergency Department Clinicians are observed by the patients, and success or failure of incident management and health outcomes stays in their minds.^[4] Implementation of appropriate treatment protocols for nuclear accident casualties and research to find more effective treatment protocols, the right and accurate understanding of mechanisms of radiation and other issues related to

nuclear casualties, all require training of expert manpower, or more accurately, team making.^[1] A study by Kollek *et al.* conducted to assess scientific and practical readiness of emergency medical services in Canada to deal with chemical, biological, radiological, and nuclear accidents showed that out of 1028 respondents, only 63% had received theoretical and practical training for working in contaminated areas, and 37% had received no training at all.^[6] Furthermore, Niska *et al.* in a study aimed to assess readiness for terrorist incidents emergency response programs in 66 hospitals across the USA reported nearly all hospitals (97.3%) had natural crisis response plan, but readiness to respond to chemical incidents was 85.5%, microbial incidents 84.8%, nuclear and radiological incidents 77.2%, and other potential incidents 76.9%. Hospital incident command and microbial, chemical, and radiological exposures were among topics of their training, and hospital staff training percentage varied from 92.1% for nurses to 49.2% for residents, and natural crisis maneuvers had been practiced more than nuclear, microbial, or chemical incidents. Terrorist incidents maneuver had been practiced only in 1/5th of hospitals. Hospitals often cooperated with emergency medical services, fire department, and legal agencies in their maneuvers.^[12] Rubinshtein *et al.* (2002) suggested the training needs of emergency medical personnel to care for mass casualties of chemical, microbial, and nuclear accidents that had been extracted by the American College of Emergency Physicians in 2001 in collaboration with emergency centers and other national organizations as follows:

- Medical response to microbial terrorist incidents.
- Medical response to chemical terrorist incidents.
- Medical care planning for radiological incidents.
- Readiness of hospital backup system.
- Readiness of medical emergency system's technicians.
- Emergency response to terrorism.^[8]

The design of hospitals for treatment of nuclear casualties is slightly different from other hospitals. These centers have special decontamination sections with separate drainage to store contaminated waters.^[13] With radioactive contamination on accident site, the contamination is likely to spread throughout the hospital, personnel, and facilities. It should be noted that radioactive contamination may be widespread. Thus, a radiation emergency area should be set up, so that radioactive contamination materials can be controlled.^[14] There should be a roofed space for ambulances in a well-equipped center, with decontamination facilities. Treatment priorities are decided aboard the ambulance or on the stretcher. Irradiated people are monitored on entry to the institution. Contaminated clothing is removed and bagged. Waiting room, surgery, and care units are located near the entrance. Irradiated people are then transferred to the next section for decontamination.^[15] The best radioactive

contamination control center should have the following conditions:

- The center should have appropriate equipment for primary measures for rescuing patients and for cardiopulmonary resuscitation.
- The center should have direct contact with the outside, so that patients can enter this area directly from the ambulance, to avoid spread of contamination to the environment.
- This area should be decontaminated and close to a specialized center for treatment of patients, or if possible, should have a door for patients' entry to that section.^[13]

Center for Disease Control and National Center for Prevention of Environmental Risks and Radiation Effects on Health Group in Atlanta in 2003 proposed the following hospital emergency programs:

- Care for hospital staff.
- Care for staff families.
- Staff training.
- Role and duties of response team.
- Attention to staff using a checklist and reviewing it during mass casualty incidents.
- Establishing and testing communication systems.
- Appropriate physical space in hospitals.
- Monitoring staff while performing duties through extension of registration system.
- Creating a secondary assessment center.^[16]

Population monitoring should begin immediately after report of a nuclear incident and continue until full assessment.^[17] Primary and secondary assessment stages should be repeated frequently and continue until occurrence of any changes or intensification of victim's symptoms and necessary actions as these symptoms occur.^[18]

Casualties are classified according to what has happened to them:

- External exposure to radiation.
- Contamination after external exposure.
- Physical injury.

Classification of casualties of radiological incident is performed by emergency physicians and radiation safety officer.^[19] Generally, depending on intensity of incident, available resources, and intensity of incident consequences, there are three levels of treatment for radiation incident patients:

- First aids, available on the scene of accident.
- Primary medical examinations, minor investigations, and treatment in general hospitals.
- Full examinations, tests, and treatment of irradiated people in specialized hospitals.^[7]

The primary objective of initial response is to preserve lives,^[20] and that of decontamination is to reduce or prevent further absorption and toxicity of nuclear, microbial, and chemical patients, and to avoid patients' secondary contamination.^[21] Radioactive contamination is not an immediate threat to life, and decontamination can usually be done after emergency treatment. Therefore, medical care should take priority.^[22]

Siegel also considers objectives of treatment of irradiation as prevention of further radioactive contamination, treatment of harmed organs, reducing symptoms, and pain management.^[23]

Saenger in expressing physician's role cites the followings:

First: Physician has full authority in the diagnosis, treatment, and education of the patient.

Second: Physician should assure citizens that treatment techniques employed are successful.

Third: Physician should play a consulting role in Incident Management Committee.^[24]

CONCLUSION

With respect to the great importance of preparedness against nuclear incidents especially in countries where nuclear technology is either applied or is being developed, adoption, and regular practice of nuclear crisis management codes for hospitals and medical centers seems quite necessary. Drilling the proposed plan in simulated nuclear emergency maneuvers can help improve this model and reveal its probable defects in real settings.

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Conflicts of interest

There are no conflicts of interest.

AUTHOR'S CONTRIBUTIONS

FD and AZ contributed in the conception of the work, conducting the study, revising the draft, approval of the final version of the manuscript, and agreed for all aspects of the work.

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