وقايـــة
Weqaya
المركز الوطني للوقاية من الأمراض ومكافحتها
Saudi Center for Disease Prevention and Control

A GUIDE TO MEDICAL MANAGEMENT DURING RADIATION EMERGENCIES

وقايـــة
Weqaya
المركز الوطني للوقـايـة من الأمـراض ومكافحتهـا
Saudi Center for Disease Prevention and Control

وقايـــة
Weqaya
المركز الوطني للوقـايـة من الأمـراض ومكافحتهـا
Saudi Center for Disease Prevention and Control

A GUIDE TO MEDICAL MANAGEMENT DURING RADIATION EMERGENCIES

Prepared for use by Radiation Protection Officers,
Medical Doctors, ER Team and Allied Health Personnel

Prepared by:

Musaed Alie Almalki, PhD, MSNE, RPO, RSci
Consultant and Radiation Protection Expert
General Director of Radiation Protection Program
Assistant Deputy Minister for Preventive Health
Ministry of Health

ABDALLA N. AL-HAJ, PhD, FIPEM, CSci, CRadP, MSRP
Consultant Medical/Health Physicist
Radiation Protection Expert

First Edition
2019

King Fahd National Library Cataloging-in-Publication Data

Almalki, Musaed Alie

A GUIDE TO MEDICAL MANAGEMENT DURING RADIATION EMERGENCIES. / Musaed Alie Almalki.- Riyadh , 2019

36p ; ..cm

ISBN: 978-603-03-2279-4

1- Radiation I-Title

539.77 dc 1441/2001

L.D. no. 1441/2001

ISBN: 978-603-03-2279-4

وقايـــة
Weqaya
المركز الوطني للوقـايـة من الأمـراض ومكافحتها
Saudi Center for Disease Prevention and Control

TABLE OF CONTENTS

INTRODUCTION

An individual may receive radiation dose from an external source, by loose radioactive material deposited on the skin, or by ingesting or inhaling radioactive materials. Ingestion or inhalation of radioactive material may cause internal dose to the whole body or to a specific organ over a period of time. The dose received through inhalation or ingestion is not lethal.

Internal doses are assessed differently than external doses. The two primary differences are: 1) Internal doses are calculated, not measured, and 2) The doses are committed doses. Internal doses are based on the intake, or the amount of radioactive material that initially enters the body. When a bioassay is performed, one can ascertain the activity in the urine, for example, at that particular time. Calculations are then performed to determine how much activity initially entered the body to result in the concentration of radioactive material in the urine at the present time. The same applies to whole body counts, lung counts, or other methods for internal dose assessment.

In the event of a radiation emergency, the externally irradiated accident victim is only exposed to or remote source of ionizing radiation and no contamination is present. The injured individual can also be not radioactive and does not emit ionizing radiation or radioactive thus emitting radiation.

Management and provision of care to injured individual vary on the extent of the radiation exposure. The externally irradiated victim is uncomplicated since the likelihood of immediate severe morbidity is usually minimal. The victim can be treated in the common emergency room. If there is any associated traumatic injury or accompanying illness, it should be treated first. Internally exposed individuals require a more intensive study on how he will be managed and should be assessed by the Emergency Attending Physician (EAP) for appropriate treatment and proper management. The Radiation Protection Officer (RPO) should perform radiation and contamination surveys prior to any intervention.

The Ministry of Health (MOH) prepared this Guide to guide medical practitioners, hospital administrators and the concerned government agencies and sectors on providing medical treatment and management of radiation injured individuals.

OVERVIEW

Response actions are divided into three phases:

Phase 1 - Receipt of the request for accepting radiation injured persons and arrival at the RER.

Phase 2 - Medical management and treatment of radiation injured persons and decontamination of persons, equipment and areas.

Phase 3 - Clearing of persons, equipment and areas, evaluation of response and report submission.

The initial signs and symptoms are not devastating and require little active care during the first 48 hours. The clinical course of radiation injury unfolds over a period of time, usually days or weeks and is usually very predictable.

The severity of the clinical manifestation will depend on a number of factors such as:

a. Time during which the exposure took place

b. Total accumulated dose

c. Nature of radiation

The clinical manifestations of external ionizing radiation injury, which can be classified as:

1. Acute radiation syndrome
2. Acute localized radiation injury
3. Internal Contamination

The categories of injured patients are listed in Appendix 1.

Chapter 1

Doses and Effects of Ionizing Radiation

Radiation damage to cells occurs within microseconds of radiation exposure. Cellular damage is generally most severe in rapidly reproducing cell types. Stem cells in the bone marrow, intestinal crypt cells, and the basal layer of skin are particularly susceptible to radiation injury.

Acute Radiation Syndromes (ARS)

Immediate manifestations of radiation injury require a large, single (usually whole body) dose of penetrating radiation that comes from a radioactive source or machine that emits radiation (Appendix 2). This may occur in accidents involving nuclear power plants but it can also occur in medical treatment facilities or industrial radiography facilities.

The symptom complex is an expression of damage or death to many important organs particularly the rapidly dividing cells and stem cells such as in the bone marrow. The signs and symptoms of this syndrome are non-specific and may be indistinguishable from those of other injuries or illnesses.

Three major organ systems, having different levels of radiation sensitivities respond to high exposures with the following signs and symptoms:

- **Haematopoietic** – doses from 1 – 8 Gy; signs and symptoms become increasingly severe with dose and pass through four distinct phases:
  - A prodromal phase consists of nausea, vomiting and anorexia within a few hours at the higher dose level, or after 6 to 12 hours at the lower dose level. These symptoms last 24 to 48 hours, after which time the patient is asymptomatic and may feel well.
  - A latent phase may last from few days to as long as 2 to 3 weeks at the lower dose levels. The patient is asymptomatic with apparent recovery from radiation exposure but will have a characteristic sequence of changes in the blood elements, the

most obvious of which is lymphocyte depression. Stem cells in the bone marrow will replicate in the recovery phase and eventually produce the normal amount of blood elements. Supportive therapy is required until the blood returns to normal.

- **Gastrointestinal** - 8 – 30 Gy, (High dose).
  - Distinguishable from the hematopoietic syndrome by the immediate, prompt and profuse onset of nausea, vomiting and diarrhea, followed by a latent period of about 1 week; GI symptoms recur and lead to marked dehydration, vascular effects and death in two weeks.
  - The GI mucosa becomes increasingly atrophic, and massive amounts of plasma are lost to the intestine.
  - Despite clinical treatment, death may occur due to massive denuding of the GI tract and accompanying septicemia and dehydration.
  - If the patient survives long enough, the hematopoietic system depression occurs and complicates the clinical course.
- **Cardiovascular/CNS** Over 30 Gy, an extremely high dose, to the whole body.
  - It is always fatal. There is immediate nausea, vomiting, anorexia and prostration, within hours after exposure. The victim, will be listless, drowsy, tremulous, convulsive and ataxic.
  - Death will occur within a matter of hours (24 to 48 hours). The cause of death may be due to changes in the permeability of small blood vessels in the brain.

Local Radiation Injury

Occurs when a high dose of radiation is delivered to a small area in a short period of time. High dose is delivered to superficial tissues with rapid drop in dose as the radiation penetrates the deeper tissues. As only a small part of the body is involved, normal functions of the body continues after the exposure.

Systemic symptoms, if it occurs at all are mild in comparison if the local area irradiated is the epigastrium. Generally major organs systems are not involved although sometimes muscle and bone necrosis can occur. The following are the usual manifestations of local injuries:

1. **Epilation of the Hair:**
   Single doses of 4 to 10 Gy result in transient or permanent hair loss. Appears about 17-21 days after exposure and continues for several days thereafter.

2. **Erythema:**
   Threshold for this is about 3 - 10 Gy. It appears within hours to days after exposure and remains for a short period of time and disappears. It can appear 2- 3 weeks after exposure and last for 20-30 days.

3. **Dry Desquamation:**
   Occurs in the dose range of 10-15 Gy and appears in about 2-4 weeks after exposure. May last for days or weeks.

4. **Wet Desquamation:**
   This may occur in the dose range between 20 – 50 Gy and appears in 3 – 4 weeks after the exposure.

5. **Blister:**
   Can arise in the dose range about 15 - 25 Gy directly from radiation exposure. It appears about 3 weeks after exposure, has a well-defined edges.

6. **Radio necrotic Lesion:**
   Occurs at doses above 25 Gy. Onset may be between a few weeks to several months.

7. **Other Lesions:**
   Damage to subcutaneous tissues may result in edema and sclerosis. The effect of radiation will depend on a number of factors including the types and the energy of the radiation.

Skin Injuries:

Abrasions:

A contaminated abrasion presents considerable potential for absorption since the surface is often raw and bleeding, and the epidermal barrier is no longer intact. Usually such surfaces can be cleaned with a detergent and, if necessary, a topical anesthetic, such as 4% lidocaine, can be used to allow more vigorous cleansing. After a reasonable effort, there is no need to attempt to remove all contamination since the residue that remains on the surface will probably be incorporated in the scab. When the scab sloughs it should be saved for measurement of radioactivity and proper disposal.

Punctures:

Punctures may result from contaminated metal or glass slivers, small tools, or accidentally by hypodermic needles broken during injection. In explosions a small missile may be driven through the skin and may leave only a small entry wound. Its exact position may be difficult to locate and thus require considerable surgical excision of the wound. Ultrasound may be used to locate the site of the embedded object.

Lacerations:

A simple clean laceration made superficially by a contaminated sharp object is probably the least difficult type of wound in which contamination has to be detected and then

decontaminated. Often much of the contamination is deposited on the lips of the wound. When lacerations are ragged and deep, contamination may be deposited in fascial planes with subsequent migration that makes difficult the detection of the contamination and subsequent decontamination into a blood vessel or major lymph channel.

Burns:

Contaminated burns present considerable potential for absorption since the surface is often raw and bleeding and the epidermal barrier is no longer intact. Primary attention should be given to the treatment of the burn and, if appropriate, the contamination could be treated as mentioned in abrasions, punctures or lacerations depending on the depth of the contaminant and the extent of the burn. However, caution should be exercised to avoid vigorous rubbing or cleansing. In any case most of the insoluble contaminant will be shed with the scab. These cases should be treated in the usual way as contaminated thermal and chemical burns. Frequent dressings should be used during the first few days to allow the contaminant to be shed with scabs and dressings themselves.

Injury to other organs

Organs that are susceptible damage caused by ionizing radiation are lungs, liver, kidneys, and other organs. Multi-organ failure (MOF) results from maldistribution of blood flow that occurs after radiation-induced systemic inflammatory response syndrome (SIRS). The pathogenesis of MOF should be under active investigation.

CHAPTER 2
Medical Management of Injuries

Radiation damage to cells occurs within microseconds of exposure. Cellular damage is generally most severe in rapidly reproducing cell types. Stem cells in the bone marrow, intestinal crypt cells, and the basal layer of skin are particularly susceptible to radiation injury.

Acute Radiation Syndrome (ARS)

The support and recovery of the hematologic system is the main goal for medical management of ARS. Two major aims of medical management are efforts to prevent neutropenia and sepsis. There could be an early onset of anorexia, nausea, vomiting, and malaise which are indications of higher doses. It is important that collection of blood samples be performed repeatedly every 6 to 12 hours to monitor the decrease in lymphocyte count to indicate high doses and decrease in neutrophil counts to indicate inflammation.

Low-risk patients as declared by the EAP should receive prophylactic oral antibiotics (a fluoroquinolone or amoxicillin/clavulanate), unless they are unable to tolerate oral therapy. If there is vomiting or a documented infection, they should receive parenteral antibiotics, using appropriate monotherapy (Appendix 3).

GI Syndrome

Medical and clinical management of the GI syndrome as prescribed by the EAP includes administration of a fluoroquinolone (such as ciprofloxacin) or similar antibiotic from 2-4 days after exposure. Parenteral antibiotics and alteration of the bowel flora (reduction in aerobes while maintaining beneficial anaerobes) with oral antimicrobial agents may be useful, if resources permit. Bowel decontamination is not recommended without the concomitant use of intravenous antibiotics. Protracted vomiting should be treated with a serotonin receptor antagonist (5-HT3). In severe cases, enteral or parenteral nutrition. Diarrhea may be controlled with loperamide. Replacement of lost fluids and electrolytes is essential for a favorable outcome.

Local Radiation Injuries:

In most instances a “wait and see” policy is adequate. No intervention is required particularly for epilation, erythema, dry desquamation and intact blisters. Keep the area clean and do not apply any irritating agent. Blind lotion/ aqueous cream can be applied to “dry desquamated” lesions and loose fitting cloth might be helpful.

- Symptomatic treatment requires relief of pain, if pain is the symptom. Avoid using drugs that will cause marrow depression.
- Skin grafting may be necessary for skin lesion. The skin graft provides cover for the area, relieve pain and restores function of the area. The patient need to be seen in collaboration with a plastic surgeon to assess the need for the skin graft.
- Amputation of the gangrenous area may be necessary when all other measures fail and there is no likelihood recovery. Timing of amputation is critical and should be done after adequate assessment of the condition. This decision needs to be made in collaboration with an orthopedic surgeon.

Internal Contamination

Principles of treatment:

Medical management is specific and isotope-dependent therefore identifying the isotope is crucial. Both radioactive decay and biological elimination from the body of radioactive materials are considered. Combining both elimination rates provides the effective half- life, which is always shorter that either the physical or biological half-life. Metabolism and elimination kinetics of the non-radioactive analog determine the metabolic pathway of the radionuclide. The major routes of intake are inhalation, ingestion, absorption through an open wound contamination, and transdermal absorption.

The procedures recommended for the treatment of persons with acute internally deposited radionuclides are intended to reduce the absorbed radiation dose and hence the risk of possible future biological effects.

These aims can be accomplished by the use of two general processes:

a. Reduction of absorption and internal deposition and

b. Enhanced elimination or excretion of absorbed nuclides

Both are more effective when begun at the earliest time after exposure.

Treatment is most effective if the uptake of contaminants into the systemic circulation is prevented. Administration of diluting and blocking agents is effective in some instances because it may also enhance the elimination rates of the radionuclide or reduce the quantity of radionuclide deposited in tissue. Therapeutic measures that use mobilizing agents or chelating drugs are less effective when the radionuclide has already moved into the tissue cells.

The most important considerations in treatment are:

- Selection of the proper drug for the particular radionuclide (Appendix 3)
- Timely administration after exposure
- Identification of radiation material
- Identification of antidote

The medical management of internal contamination falls into several major categories:

- Reduction and/or inhibition of absorption of the isotope in the GI tract
  Examples: Prussian blue, Barium sulfide.
- Blocking uptake to the organ of interest
  Example: Within 4-6 hours of exposure, administer potassium iodide (KI) to block uptake of radioactive iodine by the thyroid

- Isotopic dilution
  Example: Increase fluid hydration for internal tritium contamination.
- Altering the chemistry of the substance
  Example: Prevent binding of uranylions with the renal tubule surface proteins by use of sodium bicarbonate that causes alkalinization of the urine
- Displacing the isotope from receptors
  Example: Using calcium to compete with strontium
- Chelation techniques
  Example: Administer DTPA for internal deposition of plutonium.
- Early excision of radionuclides from wounds to minimize absorption.
- Bronchoalveolarlavageforseverecasesofinsolubleinhaledparticles.Thiswould be a technique rarely used and expected only in a case with a very large lung burden of an insoluble alpha emitter such as plutonium.

Management at Emergency Department for Internal Contamination

There is no need to use a Decontamination Area. Patient can be seen in the ordinary emergency section. If medical and surgical emergency exists, it has to be attended first.

a. Obtain detail history of circumstances of exposure
b. Perform comprehensive physical examination. Systematic examination of each system should be done and recorded on a chart. Both normal and abnormal findings are recorded.
c. Proceed to laboratory investigations if history indicates that patient was exposed to a significant amount of radiation.

Blood Investigation

Complete blood count, including absolute lymphocyte count, total white blood count, Rbc and platelets. Repeat every 6 hours for the first 48 hours, then daily for one week.

- Blood group and cross matching
- Blood for cytogenetic study: 10ml
- A total of 30 ml blood sample is adequate for all the investigations.

- A total of 30 ml blood sample is adequate for all the investigations.

Dose Estimation

Estimate the dose received by the patient. Dose estimate is done based on history, symptoms, physical examination and laboratory investigation particularly the lymphocyte count. If the dose is estimated to be more than 100 rad, admit the patient.

Dose Estimation from Urine Sample

NCRP Report No. 161 also addresses the use of spot urine samples. Care should be taken when analyzing spot urines for a number of reasons including, but not limited to: 1) Has there been adequate time for the radionuclide to become systemic and to allow for excretion? 2) If using a handheld meter for counting the specimen, is the radiation of a type that can be detected? 3) Is the excretion pathway appropriate for the chemical compound of interest? The data in Appendices 4 and 5 are adapted from NCRP Report No. 161.

Management in the Ward for Internal Contamination

- Continue to estimate the dose if it is still not completed.
- Continue to monitor blood count for evidence of hemopeitic depression.
- Prescribe symptomatic treatment to the patient based on the symptoms.
    i. Give anti emetic for nausea and vomiting.
    ii. Anxiolytic for anxiety.
    iii. Replace fluid and electrolyte if significant diarrhea and vomiting have taken place.
- If significant hemopoietic depression is demonstrated:
    i. Isolate the patient.
    ii. Use barrier Nursing, preferably Reverse Barrier Nursing or Laminar Air flow;
    iii. In severe hemopoietic depression, hemopoietic support using growth factor such as GM-CSF (Granulocyte Monocyte Colony Stimulating Factor) and the

G-CSF(Granulocyte Colony Stimulating Factor) can be considered.

iv. Consider platelet transfusion if the level of platelets falls below 30,000/microliter, preferably with irradiated platelets.

- Treat infection early if there are signs of infection developing.

i. Use broad spectrum antibiotic after bacterial 'work out' has been done;
ii. Consider antiviral agent if viral infection is suspected;
iii. Use antifungal for fungal infection e.g. Candida of the mouth and GIT tract.
iv. Anti helminthic if indicated.

The schedule for drug administration with the corresponding doses are given in Appendix 6.

Patients with Life-threatening Condition in Radiation Incident

Patients with life-threatening condition needing urgent medical care may be passed to the medical team without being decontaminated. In this situation, immediate medical care given and patient will have to be transported immediately to the nearest that can provide the appropriate medical management. Transportation can be should hospital via ambulance prepared PPE and absorbent pads to prevent contamination. The RPO from the ambulance team may do the radiation screening en-route and provide advice to the health provider.

In this situation, decontamination will be done in the receiving hospital. The emergency department is to be informed before patient is sent to the hospital so that preparation could be made.

At all time when handling radiation patient, personal protective equipment should be applied (head cover, goggle or eye shield, gown and apron).

Iodine Prophylaxis:

For nuclear reactor accidents, our main concern is radioactive iodine isotopes (mainly Iodine-129 and Iodine-131) which are products from fission process in the nuclear reactor. The short-lived isotopes of iodine are particularly harmful because the thyroid collects and concentrates iodide — radioactive as well as stable. Absorption of radioiodine can lead to acute, chronic, and delayed effects. Acute effects from high doses include thyroiditis, while chronic and delayed effects include hypothyroidism, thyroid nodules, and thyroid cancer.

Iodine prophylaxis has been shown to prevent cancer during the Chernobyl incident. The Russians then only distributed potassium iodide tablets to those living within 30 miles of the nuclear plant. Although iodine prophylaxis is recommended more for people living near the area of nuclear plants, during the Chernobyl incident, thyroid cancer incidents have been reported to be lower in Poland (300 miles from the site) which prescribed 18 million tablets to its population.

- The WHO recommends dose of 130mg Potassium Iodide for those >12 years old, 65mg for those between 3-12 years old, 32mg for those between 1-36 months old and 16mg for those less than 1 month old.
- The WHO does not recommend iodine prophylaxis for those who are more than 40 years old.
- Alternatively, if Potassium Iodide tablets are not available, 2 mls of SSKI (suspended solution of Potassium Iodide) will provide 130mg of Potassium Iodide.
- Alternatively in situations where no Potassium Iodide tablets or SSKI is available, Lugol's Iodine may be used with good efficacy.
  1.3 ml of 5% Lugol's iodine (which is the standard solution available in hospital pharmacies in Malaysia) will provide 130 mg of Potassium Iodide. Potassium perchlorate is used for those with allergic to iodine.
- The IAEA guideline only recommends Iodine prophylaxis when the avertable radiation dose is 100mSv. Temporary Evacuation is recommended if the dose is 50-100mSv whereas sheltering (stay in home with windows closed) if the dose is 10mSv.

Precautions:

Large amounts of beta-gamma emitting contaminants may present a radiation hazard to physicians, nurses and other attendants. The potential exposure situation can always be evaluated rapidly with portable beta-gamma survey instruments. Improvised shielding may be necessary if a special shielded decontamination facility is not available. In order to estimate the skin exposure on the hands of the surgeon, thermoluminescent dosimeters can be taped at a location on the palmar side of the hand that will not interfere with tactile sensation or grip. If the contaminant is a weak beta emitter such as 3H or ‘4C, double gloves should provide sufficient protection.

Conclusion of Emergency Procedures Guidelines

Upon completion of emergency procedures, patient should be handled according to the following guidelines.

- Decontaminated and no injuries requiring hospitalization - Discharge.
- Decontaminated and injured – Admit to designated room.
- Irradiated - Admit to designated room for radioactive patients.
- Serious radiation exposure, serious internal contamination, and/or external wound contamination not responsive to decontamination
- Admit to designated room for radioactive patients with special contamination control procedures

Report on the contamination should be submitted using the report form in Appendix 7.

CHAPTER 3

Plan of Action

Objectives of Population Monitoring

The objectives of the population monitoring are the following:

- Identify individuals whose health is in immediate danger and who need immediate care, medical attention (whether radiation-related or not), or decontamination.
- Identify people who may need medical treatment for contamination or exposure, further evaluation, or short-term health monitoring.
- Recommend (and to the extent possible, facilitate) practical steps to minimize the risk of future health consequences (e.g., cancer).
- Register potentially affected populations for long-term health monitoring. With these objectives in mind, this guide may be used to work through the planning process for population monitoring.

Identifying and Prioritizing the Affected Population

The highest treatment priority is for people who have life- threatening injuries or who are in need of immediate medical care, which may or may not be related to the radiation incident (e.g., heart attack or a pre-existing critical condition). As will be discussed later, effective public communication is a key component of the emergency response. In a mass casualty incident, uninjured people can be encouraged to go home, self-decontaminate, and then return for monitoring at designated locations according to a priority schedule.
The triage process should identify and prioritize people for external contamination screening and identify and prioritize a subset of those individuals for internal contamination screening and medical follow-up, if needed.

Identification of Capabilities

The EAP and the RPO should ensure that the following capabilities are available within the first 24 to 48 hours:

- Making radiation dose projections (external irradiation and plume predictions).
- Assessing the risk of exposure by time and location.
- Identifying victims within range, location, and proximity to the incident.
- Identifying potential acute symptoms (nausea, vomiting, etc.).
- Providing radiation detection equipment to detect the evidence of external beta, gamma, or alpha contamination as applicable, and following up with decontamination.
- Performing periodic blood tests (CBC with differential white cell count) for direct exposure assessment if large, whole-body doses are suspected.
- Collecting urine samples for bioassays if internal contamination is suspected (not a priority after an IND scenario).

The prioritization scheme to identify individuals for monitoring can be based on the following:

- Radiation dose projections, if available (external irradiation and plume predictions).
- Specific times and locations where people may have had a higher probability of being exposed or contaminated.
- Presentation of clinical symptoms consistent with acute radiation syndrome, especially if this is correlated with relevant times and locations specified above.
- Other factors, such as age and pregnancy .

Roles of the Ministry of Health and Responder

The Ministry of Health shall ensure that arrangements are in place in the responding hospitals for the provision of appropriate medical screening and triage, medical treatment and longer term medical actions for those people who could be affected radiological emergency. Upon the arrival of the individual of clinical symptoms of radiation exposure or other indications associated with a possible radiation emergency, the EAP and other medical personnel in the Emergency Department or other clinicians who identify the clinical symptoms or other indications shall notify the MOH and shall take medical actions as appropriate.

All medical personnel, both general practitioners and emergency medical staff shall be aware of the clinical symptoms of radiation exposure, and of the appropriate procedures and other emergency response actions to be taken if a radiation emergency arises or is suspected. They should be trained on the radiation protection practices during their response actions.

The responding hospital headed by the EAP shall provide immediate medical attention to those who are radioactively contaminated and would need medical management. They should have:

- Guidelines for effective diagnosis and treatment
- Designation of medical personnel for the medical management
- Arrangement with other institutions for patients who will need longer clinical treatment and care.

REFERENCES

1. International Atomic Energy Agency, IAEA-TECDOC-1162 “Generic procedures for assessment and response during a radiological emergency “, 2000.
2. US Environmental Protection Agency, PAG Manual Protective Action Guides and Planning Guidance for Radiological Incidents.
3. Hospital of Kuala Lumpur, “Medical Response for Radiation Emergency”, Draft, 2011.
4. Oak Ridge Institute of Science and Education, The Medical Aspects Of Radiation Incidents, 2017.
5. A Guide to Medical Response During Radiation Emergencies, 2019.
6. National Council on Radiation Protection and Measurements, NCRP Report No. 161, Management of Persons Contaminated with Radionuclides

Definition of Terms

Contamination - Presence of radioactive substances or materials on surfaces, or within solids, liquids or gases (including the human body), where they are unintended or undesirable.

Decontamination - complete or partial removal of contamination.

Emergency - Any natural or man-caused situation that results in or may result in substantial injured or harm to people, property or the environment, and which prompt action is needed to protect people, property or the environment.

Iodine prophylaxis - Ingestion of a compound of stable iodine (usually potassium iodine) to prevent or reduce the uptake of radioactive isotopes of iodine by the thyroid in the event of an accident involving radioactive iodine. The term blocking is used in the literature as a synonym.

APPENDIX 1
Categories of Injured Patients

CATEGORY	DESCRIPTION / ACTION
Category A	No irradiation and no radioactive contamination. Does not constitute radiation hazard to both attendants and patients. Should be treated like any other patient with physical trauma.
Category B	Patient expose to external radiation only. No radioactive contamination. Exposure can be to a part of the body or whole body. Does not constitute a risk to attendants or public. Irradiation can occur following an exposure to a radioactive source or as an accidental exposure to X-rays in radiology and radiotherapy departments.
Category C	Patients with internal contamination only (those patients who inhaled/swallowed radioactive material). Urgent measures to prevent incorporation of radioactive substance are required. The inhaled dose is usually not high enough to produce risks to the patient's attendants. Its effect on the patient will depend on the types and activity of radioactive material. There is a need careful examination to access external contaminations. There is a need for specific measures to minimize the effects of internal contamination.
Category D	Patients with external contamination of the skin and clothing. This constitutes a potential risk to both patients and the patient's attendants. Adequate protective measures need to be taken and the treatment should be in a specially designated area and away from other patients and public. Immediate protective measures such as removal of clothes and washing of the skin should be done after patient has been stabilized. Items removed need to be collected in radiation hazard labeled plastic bags and sent to radiation laboratory for analysis.
Category E	Patients with contaminated wound and possible internal contamination. Like category D there is slight risk to patient's attendants and public. Procedures similar to those in category D should be carried out. Care must be taken not to cross contaminate the cleaner part of the skin from the wounded areas or-vice versa. Any wound excision/debris should also be sent for analysis. Measures to minimize the internal contamination and incorporation of radioactive substances are required.

APPENDIX 2
Acute Radiation Syndrome and Doses

Radiation Effects	Gy
Haematopoietic syndrome	3-8
Gastrointestinal syndrome	10
Cerebrovascular syndrome	100
Dose that is lethal to 50% of those exposed without medical intervention	3-4

APPENDIX 3

Recommendations for Antibiotic Therapy

Prophylaxis	Low Risk Patient	High Risk Patient
Antibiotics	Ciprofloxacin (Oral) or Amoxicillin/Clavulanate	IV monotherapy with Cefepime, Ceftazidime or Piperacillin/Tazobactam

Bacterial Infection	Therapy to Add to Prophylaxis
Pneumonia Skin/Soft Tissue Infections (SSTI)	Vancomycin or linezolid See latest ISDA recommendations
Gram Negative sepsis and/or Gram Negative pneumonia	Aminoglycoside
Abdominal symptoms and/or suspected C.Difficile	Metronidazole

APPENDIX 4

Radionuclides and Antidotes

Radionuclides	Antidotes & Decorporation Agents	Dose	Route
Plutonium (Pu) Americium (Am) Curium (Cm) Californium (Cf) Neptunium (Np) Lanthanum (La)	 Calcium DTPA Zinc DTPA	○ 1 gm in 250 ml normal saline or 5% dextrose in water, IV over 1 hour OD for several days to a week in most cases without toxic effects. ○ Inhaled plutonium will need nebuliser DTPA 1 gm over 15- 30mins daily and lung lavage	IV Nebulise
Radioactive phosphate	Potassium Phosphate	**Adult** 250-500mg p.o. QID, with full glass of water each time, with meals and at bedtime **Children** 4y, 250mg QID	Oral

Radioiodine (I-131)	Potassium Iodide Mixture 65mg/15mL (within first 4 hours)	Adult 130mg p.o OD. ASAP, repeat dose daily as long as the contamination lingers in the environment. Children 4 to18y, 65mg p.o. 1 mth to 3y, 32.5mg p.o. <1 mth, 16.25 mg mixed with a liquid such as low fat milk	Oral
	Propylthiouracil 50mg Tablet	100mg TDS for 8 days	
Strontium Sr - 90 Radium	Sodium Alginate	10 gm powder in a 30 cc vial, add water and drink	oral
	Calcium	IV 3.0gm in 500ml D5% over 4 hours	IV
	gluconate IV	for 6 consecutive days	
Cesium, Thallium, Rubidium	Prussian Blue	1g p.o. TDS for up to 3/52 or longer as required. Doses up to 10-12 g/day for significantly contaminated adults may be used	oral
Uranium	Sodium Bicarbonate 1.4% IV (available as 8.4% 10ml injection)	Slow IV infusion 250ml	IV

APPENDIX 5

Decorporation Therapy Recommendations in the USA for Radionuclides of Concern (NCRP Report 161, 2010).

Radionuclides	Alternate Treatment	Preferred Treatment
Actinium (Ac)	Consider DTPA	Consider DTPA
Americium (Am)	DTPA	DTPA
Antimony (Sb)	BAL, penicillamine	BAL
Arsenic (As)	BAL, DMSA	BAL
Barium (Ba)	Ba, Ca Therapy	See NCRP 161
Berkelium (Bk)	DTPA	DTPA
Bismuth (Bi)	BAL, penicillamine, DMSA	DMSA
Cadmium (Cd)	DMSA, DTPA, EDTA	DMSA
Californium (Cf)	DTPA	DTPA
Calcium (Ca)	Ba, Ca Therapy	See NCRP 161
Carbon	No treatment available	N/A
Cerium (Ce)	DTPA	DTPA
Cesium (Cs)	Prussian blue	Prussian blue
Chromium (Cr)	DTPA, EDTA (antacids are contraindicated)	DTPA
Cobalt (Co)	DMSA, DTPA, EDTA, NAC	DTPA
Copper (Cu)	EDTA, penicillamine, trientine	Penicillamine
Curium (Cm)	DTPA	DTPA
Einsteinium (Es)	DTPA	DTPA
Europium (Eu)	DTPA	DTPA
Fission Products (Mixed)	Management depends on predominant isotopes present at time. Early: iodine; Late: strontium, cesium, and others	
Fluorine (F)	Aluminum hydroxide	Aluminum hydroxide
Gallium (Ga)	Consider penicillamine	Penicillamine
Gold (Au)	BAL, penicillamine	BAL
Indium (In)	DTPA	DTPA
Iodine (I)	Potassium iodide (KI), propylthiouracil, methamizole	KI
Iridium (Ir)	Consider DTPA, EDTA	Consider DTPA
Iron (Fe)	Deferoxamine (DFOA), deferasirox, DTPA, DFOA and DTPA together	DFOA
Lanthanum (La)	DTPA	DTPA

Radionuclides	Alternate Treatment	Preferred Treatment
Lead (Pb)	DMSA, EDTA, EDTA with BAL	DMSA
Manganese (Mn)	DFOA, DTPA, EDTA	DTPA
Magnesium (Mg)	Consider strontium therapy	Consider strontium therapy
Mercury (Hg)	BAL; EDTA; penicillamine; DMSA	BAL
Molybdenum (Mo)	Limited clinical experience	
Neptunium (Np)	Consider DFOA and/or DTPA	Consider DFOA and/or DTPA
Nickel (Ni)	BAL, EDTA	BAL
Niobium (Nb)	DTPA	DTPA
Palladium (Pd)	Penicillamine, DTPA	Penicillamine
Phosphorus (P)	Phosphorus Therapy	Phosphorus therapy
Plutonium (Pu)	DTPA, DFOA, EDTA, DTPA and DFOA together	DTPA
Polonium (Po)	BAL, DMSA, penicillamine	BAL
Potassium (K)	Diuretics	Diuretics
Promethium (Pm)	DTPA	DTPA
Radium (Ra)	Ra, Sr therapy	
Rubidium (Rb)	Prussian Blue	Prussian Blue
Ruthenium (Ru)	DTPA, EDTA	DTPA
Scandium (Sc)	DTPA	DTPA
Silver (Ag)	No specific therapy. Consider gastric lavage and purgatives.	
Sodium (Na)	Diuretic and isotopic dilution with 0.9 % NaCl	Diuretic and isotopic dilution with 0.9 % NaCl
Strontium (Sr)	Ra, Sr therapy	
Sulfur (S)	Consider sodium thiosulfate	Consider thiosulfate
Lanthanum (La)	DTPA	DTPA

Radionuclides	Alternate Treatment	Preferred Treatment
Technetium	Potassium perchlorate	Potassium perchlorate
Thallium (Tl)	Prussian Blue	Prussian Blue
Thorium (Th)	Consider DTPA	Consider DTPA
Tritium (^{3}H)	Force fluids	Water diuresis
Uranium (U)	Bicarbonate to alkalinize the urine. Consider dialysis	Bicarbonate
Yttrium	DTPA, EDTA	DTPA
Zinc (Zn)	DTPA, EDTA, Zinc sulfate as a diluting agent	DTPA
Zirconium (Zr)	DTPA, EDTA	DTPA

APPENDIX 6

Dose Schedule for Drug or Treatment Modality

Drug	Treatment Modality
Acetylcystecine (NAC)	Age is not specified, IV 300 mg'kg in 5% dextrose in water over 24 hours for acetaminophen over dosage.
Deferoxamine (DFOA)	Age is not specified. Deferoxamine mesylate injectable (DFOA); IM is preferred. 1 g IIM or IV (2 ampules) slowly (15mg/kg/h) Repeat as indicated as 500 mg IM or IV every 4 h x2 doses, then 500 mg IM or IV every 12 h for 3 days.
Dimercaprol (BAL)	Age is not specified; IM: 300 mg per vial for deep IM use. 25 mg/kg or less every 4h for 2 days then twice daily for 1day then twice daily for 5-10 days.

APPENDIX 7

Radiation Contamination Survey Report

Date: ____________	Time: _____
Institute name: _____	Region:_____
Surveyed by :_____	Surveyor signature : _____

Full Name: _____ ID: _____

Date of birth: _____/_____/_____ Sex: ☐M ☐F

Location(s) during emergency:

_____

Time spent at each location:

_____

Date of exposure: _____________ Time of exposure:

_____

Intake pathway (if known): Inhalation Ingestion Skin absorption wound

Person externally decontaminated Y ☐ N ☐

Date of measurement: ____________ Time of measurement:

_____

Results of measurement

Instrument type: _____ Model: _____S/N:

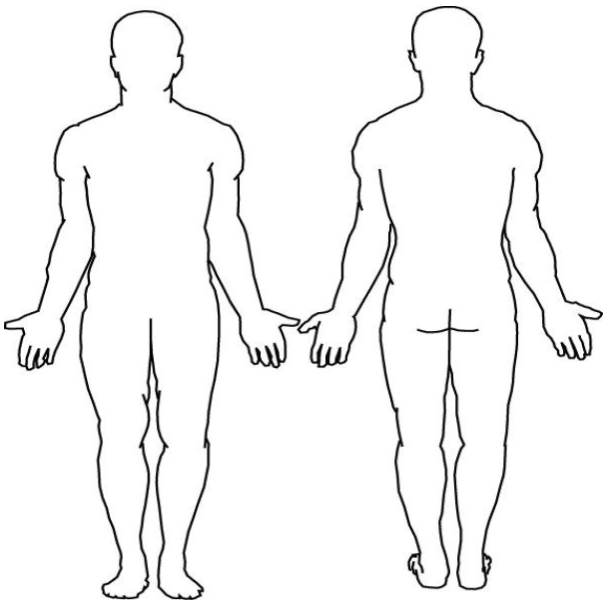
_____

Background reading: _____ [cps] Detector active Surface: _____[cm^2]

Date of calibration: ____________ Background reading: _____

[cps]

Mark location of contaminated areas on the charts below:



Levels following Decontamination:

Body Location Ex(arm, foot, head)	Decontamination Method	1st Attempt	2nd Attempt	3rd Attempt


وقاية
Weqaya
المركز الوطني للوقاية من الأمراض ومكافحتها
Saudi Center for Disease Prevention and Control