

REGULATORY GUIDE

**GUIDELINES FOR MEDICAL PRACTITIONERS ON HANDLING,
TRANSPORT AND TREATMENT OF CONTAMINATED AND
EXPOSED PATIENTS**

PAKISTAN NUCLEAR REGULATORY AUTHORITY
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Regulatory Guide

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I – INTRODUCTION:

This guideline is prepared in support to “Regulations on Radiation Protection” PAK/904 and “Regulations on Management of a Nuclear or Radiological Emergency” PAK/914* (Rev.0).

This guide addresses only the clinical aspects and laboratory information which are required for establishing a diagnosis of radiation exposure in case of a radiological accident. For more details, PNRA handbook on the management and treatment of exposed/contaminated patients can be consulted.

II – OBJECTIVE:

The objective of this guide is to offer general guidance for medical practitioners in handling of patients with typical injuries complicated by the presence of radioactive contamination, and patients suspected of having being exposed to elevated levels of radiation. Dealing effectively with known or suspected contamination, and accurately assessing the potential exposure, can avoid not only long-term health problems for the patient but also saves the general practitioner from administrative problems associated with a radiological accident.

III – SCOPE:

The scope of the guide is to explain the practical aspects of handling a patient contaminated and/or exposed to radiation in an emergency. It addresses issues that EMS (Emergency Medical Service) personnel and rescue teams should consider when confronted with a situation involving radiologically contaminated or exposed victims. It also addresses issues that are encountered while transporting the patients from an accident site.

*=These regulations are presently in draft form.

1 – RADIATION ACCIDENTS: ⁽²⁾

1.1 – ACCIDENT TYPES:

Potential accident types include the following:

- a. A radioactive source e.g., gamma radiography source may be misplaced, lost or stolen. It will cause unwanted exposure to individuals.
- b. A radioactive source may become unshielded as a result of equipment failure. As in industrial radiography, after making an exposure an operator may find it impossible to retract the source into its container.
- c. A radioactive material may also get dispersed. For example, a vial containing a radioactive solution might develop a leak during storage or there is a possibility of a violent release of radioactive wastes from a radiochemical facility e.g., results from the detonation of a nuclear device.

1.2 – EXPOSURE ROUTES: The most important exposure routes are:

- Direct radiation from the source or from any radioactive material released;
- Inhalation of airborne material (volatiles, aerosols, particulates);
- Direct radiation from ground or surface deposition;
- Contamination of skin and clothing.

2 – CLASSIFICATION OF ACCIDENTS: ⁽¹⁾ & ⁽⁶⁾

For clinical purposes accidents are classified according to their severity, the number of individuals injured (e.g., more than five is considered a major accident), and their radiological consequences reference Tables 1 & 2.

2.1 – ACUTE RADIATION ACCIDENT: This is an extremely rare incident characterized by a sudden burst of radiation. It is more likely to occur in nuclear war, nuclear power plants, research reactors, radiotherapy and industrial irradiators.

2.2 – CHRONIC RADIATION EXPOSURE: A patient may present with chronic ill health which owing to his profession (e.g., a radiographer) may indicate the possibility of radiation exposure.

2.3 – CHRONIC ILL HEALTH: Sometime a patient may present with history of chronic ill health which may be the only clue available to the treating doctor.

2.4 – RADIOPHOBIA: The patient may present with a bizarre set of symptoms which they attribute to their living near a nuclear establishment.

3 – CLINICAL EVALUATION OF RADIATION ACCIDENT VICTIMS:

Exposure to radiation may be:

- i. Local i.e., extremity or other portions of the body. It is rarely lethal though considerable local injury may occur;
- ii. Generalized, referred to as whole-body exposure involves Whole-body or nearly whole-body and can be lethal.

3.1 – ACUTE RADIATION SYNDROME: ^{(1) & (6)}

Acute Radiation Syndrome (ARS) is induced by exposure of the whole body to a very high penetrating external radiation field or to gross contamination, both external and internal.

The clinical picture depends upon:

1. Time during which the exposure took place and dose rate;
2. Total accumulated dose;
3. The route of radiation.

3.1.1 – CLINICAL ASPECTS OF ARS:

The ARS is the clinical expression of damage to many important organs.

3.1.2 – STAGES OF ARS:

a – PRODROMAL PHASE: A prodromal illness onsets within few hours of the accident and manifest itself as general malaise, anorexia, vomiting and possibly diarrhea. Table 3 illustrates the prodromal phase.

b – LATENT PHASE: The prodromal phase is usually followed by a latent period of relative well-being which may last upto few weeks depending upon the initial dose. Table 4 summarizes the latent phase.

c – CRITICAL PHASE: There is diarrhea, vomiting, severe fluid & electrolyte loss followed by intestinal ulceration and haemorrhage. The haemopoietic syndrome soon follows and is associated with haemorrhages from serous surfaces and bacterial infection due to severe bone marrow deficit (Table 5).

d – NEUROVASCULAR PHASE: The neurovascular phase onsets at doses in excess of about 50Gy (5000rads). The predominant system affected is central nervous system. The patient complains of a generalized severe burning sensation associated with parasthaesias, rapidly followed by excitement and then coma. Death occurs within 72 hours. At autopsy, there is cerebral edema and superficial vessels are dilated, the picture being of fulminating encephalitis (Table 5).

3.2 – LOCAL RADIATION INJURY – RADIATION BURNS: ^(1 & 2)

LRI may appear as an independent entity or as a part of ARS. LRI caused by high doses of radiation (>8 – 10Gy) produces signs and symptoms similar to that of a thermal burn except for the striking delay in the onset of clinical changes, from several days to a week or longer. The severity of LRI depends on:

- i. the dose;
- ii. type of radiation involved,
- iii. location of the burn and
- iv. the size of the area exposed. Although not usually life threatening, its delayed effects can result in serious impairment.

3.2.1 – CLASSIFICATION OF RADIATION BURNS: ⁽²⁾

Radiation burns are classified into four types:

Type I – (Local exposure 6.0-8.0Gy; 600-800rads): Local prodromal symptoms of warmth, itching or mild erythema are followed by a latent phase of several

weeks. When the symptoms appear, the skin becomes red and dry desquamation may occur. The healing will occur without impairment of function.

Type II – (Local exposure 8.0-20.0Gy; 800-2000rads): The prodromal phase consists of itching, pain and erythema. A latent phase of one to two weeks follows. The clinical picture resembles a second degree thermal burn with blistering. The burns are painful, slow to heal and prone to infections.

Type III – (Local exposure in excess of 20.0Gy; 2000rads): Erythema appears quickly and intense pain accompanies it. The prodromal phase is very short or nonexistent, followed rapidly by blistering and desquamation.

Type IV – (Chronic exposure): Burns in this category result from chronic exposure at low doses. The result is a chronic radiation dermatitis, which may ulcerate. The healing of the ulcer is poor and the area is prone to formation of cancer over the long term.

3.2.2 – CLINICAL SYMPTOM: ⁽¹⁾

A gradual incremental development of skin reaction with underlying tissue involvement is a typical feature of LRI. In general, the higher the dose received, the more rapid the development of pathological symptoms and the more severe the prognosis. Intractable pain of increasing intensity is a typical symptom. Table 6 illustrates the time of onset of clinical signs of skin injury depending on the dose received. Table 7 illustrates LRI to the hand following low energy exposure.

3.2.2.1 – Transient erythema: This appears within 2 – 3 hours of the accident. The patient may give the history of a sensation of warmth in the affected area during the exposure. At doses in excess of 50Gy (5000rads), the symptoms appear very rapidly with the onset of severe pain and burning sensation.

3.2.2.2 – Fixed erythema: In moderate exposures, the transient reddening of the skin lasts for only a short time but returns in 2 – 3 weeks.

3.2.2.3 – Subcutaneous injury: All the important organs in the subcutaneous tissue (nerve endings, hair follicles, sweat glands). The endothelium of the blood vessels is damaged resulting in obliterating endarteritis causing necrosis. The severity and rapidity with which the radiation burns develop is dose and dose rate dependent. Other internal structures are also damaged. In the long term, radiation necrosis of bone, muscle and other internal organs may take place.

3.2.2.4 – Epilation: Loss of hair may occur after exposure in excess of about 3 – 4Gy (300-400rads), 2 – 3 weeks post accident. With doses of up to 7Gy (700rads), the hair may in time regrow but above this dose, the hair follicles are destroyed and epilation is likely to be permanent.

4 – REQUIRED LABORATORY INVESTIGATIONS ^{(1), (2), (5) & (6)};

The following test should be performed as early as possible:

4.1 – ABSOLUTE LYMPHOCYTE COUNT (ALC): Changes in the absolute lymphocyte reach their peak in three to five days. Table 8 illustrates changes in lymphocyte counts with respect to dose incurred. Lymphocyte levels remain depressed for four to six weeks before starting to return to normal. Six months later they return to normal values.

4.2 – NEUTROPHIL COUNT (NC): Exposures of 1.0Gy (100rads) result in mild neutropenia. Exposures up to 2.0Gy (200rads) will results in a 50% decrease in the neutrophil count. The decrease in neutrophils is gradual, reaching its peak at four to six weeks post exposure. At higher levels, the neutrophil count may actually rise in the first several days followed by a fall dropping to 50% or less of normal values within one week post exposure. If the patient survives, recovery of neutrophils is noted between the sixth and eighth weeks post exposure.

4.3 – PLATELET COUNT: Larger exposures will result in a decrease in the platelet count beginning within the first week or two post exposure. Lower levels of exposure will manifest changes at four weeks. Platelet counts in the 20000 – 30000 range will commonly result from whole-body exposure of 2.0 – 5.0Gy (200 – 500rads).

4.4 – RED CELL COUNT: It is uncommon to see anemia as a result of acute radiation exposure. Red cell depression may begin at six to eight weeks after exposure.

4.5 – SPERM COUNT: Changes may be seen with doses as low as 0.15Gy (15rads). A sperm sample should be obtained as soon as possible with additional samples taken at one month and then at two months. A dose of 0.15Gy (15rads) will produce mild oligospermia. A dose of 2.0 – 3.0Gy (200 – 300rads) will produce azoospermia for one to two years. Doses above 5.0Gy (500rads) may result in permanent sterility.

4.6 – CHROMOSOMAL STUDIES: Chromosomal studies are performed on lymphocytes. Anomalies may be detected at exposure below 0.05Gy (5rads).

5 – DIAGNOSIS OF RADIATION ACCIDENTS

5.1 – DIAGNOSIS OF ACUTE RADIATION SYNDROME:

Diagnosis of ARS is based on clinical and laboratory data. Blood samples should be taken daily for ALC, neutrophil counts and chromosomal studies.

Blood biochemistry should be carried out as a routine investigation.

Bacteriological screening of the eyes, nose, scalp, hands, axillae, feet (fungi), perineum, vagina, faeces, urine, sputum and any other septic spots should be carried out.

5.2 – DIAGNOSIS OF LOCAL RADIATION INJURY:

A detailed history of the accident should be taken. Skin reaction should be observed daily with the aid of serial color photo documentation.

In the case of LRI:

- i. Use electron spin resonance methods to estimate the dose.
- ii. During the first week, daily blood counts are to be taken. In LRI there is mild leucocytosis or raised erythrocyte sedimentation rate.
- iii. Chromosomal aberrations can be found in only a small number of cultured lymphocytes at a dose range of 5 – 10Gy.
- iv. Both contact thermography and infrared telethermvision are useful. A radioisotopic method can be used to record the vascular circulation in an organ or part of the body when ^{99m}Tc pertechnate is injected intravenously, the distribution being monitored with a scintillation camera. New techniques, such as hair cortical cell counting, are being studied, as indicators of radiation exposure.

6 – MANAGEMENT AND TREATMENT

6.1 – TRIAGE (SORTING) OF INJURED PERSONS: (1) & (6)

Triage refers to the sorting of patients into classes on the basis of their injury and/or disease. Table 9 gives management of radiation injuries based on early symptoms. The first task is to divide the persons exposed (or suspected of having been exposed) into groups:

6.1.1 – CATEGORY 1: It includes those individuals, whether overexposed or suspected of overexposure that displays signs of conventional injuries. These individuals should be managed as in any medical emergency.

6.1.1 – CATEGORY 2: The second category includes:

- individuals who are likely to have been exposed externally or
- who have external or internal contamination, or
- who are suspected of having been exposed at such dose levels that they may require a certain degree of medical management.

For this category, preplanned actions are required. These victims should be regrouped in a treatment centre into three subcategories:

- persons with whole body exposure;
- those with local exposure; and
- those who have been contaminated with radionuclides.

6.1.3 – CATEGORY 3: The last category comprises of individuals who are likely to have received only low doses and are free from any other injury. These individuals should be registered and treated as outpatients.

The severity of the injury depends on:

- the dose level incurred,
- the dose rate,
- the radiosensitivity of the tissue involved,
- the area of the body exposed and the extent of exposure suffered by the organ system.

6.2 – MANAGEMENT & TREATMENT OF ARS: ⁽¹⁾ & ⁽⁶⁾

6.2.1 – HISTORY: A careful history of the patient which also includes his occupational history should be taken.

6.2.2 – CLINICAL EXAMINATION: Clinical examination should be thorough and comprehensive. Samples of blood, urine, faeces and vomitus should be collected immediately for analysis.

6.2.3 – COMPLICATING FACTORS: The presence of severe injuries or illness may necessitate emergency medical intervention and such actions must take precedence over other considerations.

6.2.4 – TREATMENT OF ARS:

6.2.4.1 – General: Patients may suffer from nausea and vomiting. It should be treated symptomatically. Give:

- i. 4mg of Dexamethasone or
- ii. 100mg of Hydrocortisone Hemisuccinate should be given intravenously at 4 hours intervals
- iii. with Chlorpromazine 25mg or Metaclopramide 10 mg given intramuscularly.
- iv. Supportive treatment by use of tranquilizers and drugs to relieve pain, supportive fluids and adequate nutrition and adequate rest.
- v. Patients who have received external doses of less than 1Gy may be followed up as outpatients.
- vi. Patients exposed to radiation doses exceeding 1Gy should be observed. Those cases which have been subjected to doses in excess of 10Gy (1000rads) are likely to require terminal care only and this should be directed to alleviate pain and anxiety and to make the patient as comfortable as possible. The principal therapeutic measures corresponding to different degrees of ARS severity are summarized in Table 10.

6.2.4.2 – Haemopoiesis:

- i. The fluid & electrolyte balance of the patient should be maintained
- ii. Platelet and erythrocyte transfusions are used prophylactically when the platelet count is less than 20G/L ($1\text{G/L}=10^9$ cells/L) and haemoglobin is less than 100g/L.
- iii. Isolate the patient in aseptic condition and
- iv. Carefully monitor for symptoms of fever, bleeding, oropharyngeal ulceration, neurological and vascular changes.

6.2.4.3 – Control of Infection:

- i. Blood culture should be performed;
- ii. Prophylactic antibiotics should be administered;
- iii. Appropriate steps should be taken to avoid the possibility of opportunistic fungal infection of GIT and other parts of the body;
- iv. Control of the patient's environment is of paramount importance. Barrier nursing is highly recommended in patients with moderate to severe immunosuppression.

6.2.4.4 – Nursing Care: The nursing care of the irradiated patients must be of the highest order as their immune system is moderate to severely compromised.

6.2.4.5 – Bone Marrow Transplantation: Bone marrow transplantation (BMT) is the treatment of choice for the victims when the dose is sufficiently high. Early bone marrow transplantation, within the first week after exposure is recommended. The availability of a compatible transplant is often the major problem for a BMT which can be avoided by foetal cord blood transplants.

6.2.4.6 – Use of Haematopoietic Growth Factors:

- i. For haematopoietic recovery use Granulocyte-Colony Stimulating Factors (G-CSF) and Granulocyte Macrophage-Colony Stimulating Factors (GM-CSF)
- ii. Interleukins (IL-1 & IL-3) act in synergy with GM-CSF.
- iii. Other haematopoietic growth factors include: Erythropoietin (EPO), Thrombopoietin (TPO), IL-6, IL-11. PIX-321 (fusion protein consisting of GM-CSF & IL-3).

6.3 – MANAGEMENT AND TREATMENT OF LOCAL RADIATION INJURY: ⁽¹⁾

6.3.1 – A bland lotion is all that is required for mild erythema, together with advice to the patient not to wear tight or irritating clothing overlying the area.

6.3.2 – The indications for the treatment of radiation burns are summarized in Table 11.

- i. Irritating applications to the skin are not allowed and only bland lotions are used.
- ii. Erythema and dry desquamation can be treated symptomatically by applying 1% aqueous solution of Gention Violet.
- iii. Lotions or sprays containing Hydrocortisone can be used to relieve the symptoms associated with severe erythema accompanied by oedema.
- iv. For moist desquamation, daily dressings and bathing of the affected skin in antiseptic solution is helpful.
- v. Antibiotic creams can also be used.

6.3.3 – For ulceration:

- i. isolation of the limb in a sterile environment or
- ii. daily dressings and bathing of the ulcer in antiseptic solutions.

6.3.4 – Severe & intractable pain should be controlled by use of analgesics. Opiates may be used only when other analgesics fail to relieve pain. Drugs causing bone marrow depression should not be used.

6.3.5 – The burns may progress to blistering, leading to skin loss and superficial or deep tissue necrosis with superimposed infection. Administer systemic or topical antibiotics/antifungals.

6.3.6 – For necrosis, surgical excision is followed by skin grafts. The extent, timing and type of surgical intervention should be assessed on case to case basis. Skin grafting is possible only when the underlying vasculature is stable, otherwise a myocutaneous flap or pedicle flap should be made. Surgery is justified whenever irreversible alterations appear which require ulcerectomy, necrectomy and amputation.

With a local dose in excess of 20 – 25Gy, surgical treatment might be justified, since spontaneous recovery may not be possible. Healing is not expected, even after superficial epithelialization, as a secondary ulcer may appear in the higher dose range. When irreversible alterations are clinically evident, the operation should be undertaken as soon as possible. Indications for amputation include very severe lesions with destruction of underlying tissues, including vascular damage, intractable pain and lack of infection control. Table 12 A & B illustrates the clinical aspects and the diagnostic and therapeutic options available for acute LRI and their chronic evolution.

7 – CONTAMINATION WITH RADIONUCLIDES

Radioactive contamination can be external or internal.

7.1 – EXTERNAL CONTAMINATION BY RADIOACTIVE MATERIALS: ⁽¹⁾

Radioactive dusts, liquids or gases may be released to the environment, and contamination may occur externally on the skin or internally by inhalation, ingestion or absorption through breaks in the skin.

Treatment of a contaminated wound should be started by following procedure:

- i. Irrigate the area with sterile water or saline;
- ii. Encourage free bleeding by occluding the venous return to the area with a tourniquet.
- iii. Treatment of the skin should be as gentle as possible in order not to cause further breakdown of the skin surface.
- iv. It may become necessary to enlarge the wound in order to allow more effective irrigation.
- v. If such treatment fails, a block of tissue containing as much of the contaminant as possible should be removed. Pain can be alleviated by using surface anaesthetic agents.

7.2 – INTERNAL CONTAMINATION WITH RADIOACTIVE MATERIALS: ⁽¹⁾

7.2.1 – GENERAL:

The mode of intake may be through ingestion, inhalation or through breaks in the skin. Internal contamination may be seen to consist of four stages:

- i. **Deposition along the route of entry:** Possible pathways of contamination are the skin, mucosa, GI tract, respiratory system or wounds.
- ii. **Translocation:** The contaminant may move from the site of deposition to the blood or lymph.
- iii. **Deposition in the target organ.**

- iv. **Clearance:** It occurs directly by filtration of the radionuclide or indirectly in which uptake by the tissues is reversed, with recirculation in the blood.

7.2.2 – DIAGNOSIS:

In the case of internal contamination, physical measurements include thyroid monitoring, whole body counting, gamma camera measurement and blood and excreta analysis.

7.2.3 – TREATMENT OF INTERNAL CONTAMINATION: (3) & (6)

7.2.3.1 – SPECIFIC DECORPORATION PROCEDURES:

For radioiodine, block thyroid with potassium iodide tablets. Table 13 shows the dose of potassium iodide tablets. Administration of the KI tablets four hours after the radioiodine intake will result in only a 50% decrease of the thyroid dose. Thyroid blocking on the day following radioiodine inhalations is ineffective. If radioactive iodine has already been deposited in the thyroid, treatment with KI is ineffective. Antithyroid drugs such as Propylthiouracil and Methimazole might be considered if the dose is sufficiently high.

7.2.3.2 – GASTROINTESTINAL TRACT: (1), (3)

Treatment should be instituted as soon as possible:

i – **Reduction of GI Absorption:** GI absorption can be reduced either by doing lavage or by using medications which reduce absorption (Appendix A):

- i. Perform stomach lavage when ingestion has occurred recently.
- ii. If it is not successful, mild emetics are prescribed. The use of emetics is contraindicated if the consciousness is impaired or if a corrosive agent has been ingested. Apomorphine Hydrochloride or Ipecac are the drugs of choice.
- iii. Purgatives: Magnesium Sulphate is a saline cathartic that produces relatively insoluble sulphates with some radionuclides (e.g., Radium) and thus reduces absorption. Oral Purgatives take a longer time to act (e.g., Bisacodyl, Castor Oil etc). Use of enemas will empty the colon in a few minutes and can be used in some cases.
- iv. For Caesium, Thallium & Rubidium use Ferric Ferrocyanide (Prussian Blue) 1gm with 100-200ml water orally three times a day for several days.
- v. Aluminium containing antacids are effective in reducing intestinal absorption of radioactive Strontium.
- vi. Barium Sulphate acts as an immediate antidote for ingested Strontium and Radium.

ii – **Diluting and Displacement Agents:**

- i. Oral Phosphates are given in inorganic (Sodium or Potassium Phosphate) and organic forms (Sodium Glycerophosphate) for misadministration of ³²P. Vomiting, diarrhea, or both, may occur from Phosphate administration if doses exceed 2g per day.

- ii. In cases of Tritium intake, large amounts of fluids (water, tea) should be administered as a dilutant over a period of one week. At the same time, diuretics may be given to enhance excretion.

iii – Mobilizing Agents:

- i. Calcium is administered orally or intravenously as a displacing (mobilizing) agent for enhancing the urinary excretion of radioactive Strontium and Calcium from the body.
- ii. Ammonium Chloride, given orally, is effective in mobilizing Strontium deposited in the body. Its effectiveness can be enhanced by simultaneous use of intravenous Calcium Gluconate.

iv – Diuretics: Diuretics are untested for the treatment of internal radionuclide deposition with the exception of Tritium.

v – Chelating Agents: Therapy with a chelating agent is most effective when given immediately after exposure while the metallic ions are still in the circulation and are not incorporated within the tissues or have not found time for deposition in the bone.

- i. The calcium salt of Ethylenediaminetetraacetic Acid (Calcium Edentate, CaNaEDTA or CaEDTA) is the most common chelating agent used for Plutonium and Americium. The Edetates are nephrotoxic and must be used with extreme caution in patients with preexisting renal disease.
- ii. Diethylenetriaminepentaacetic Acid (Pentathamil, DTPA) is generally more effective than CaEDTA. It is effective for the transuranium metals (Plutonium, Americium, Californium, Curium and Neptunium), the rare earths (Cerium, Yttrium, Lanthanum, Promethium and Scandium) and some transition metals (Zirconium and Niobium). Ca- and ZnDTPA are primarily used for the treatment of Plutonium and Americium exposures. The zinc salt of DTPA is less toxic and is, therefore, more advantageous for long term treatments. However, CaDTPA is more effective than ZnDTPA if given promptly after exposure.
- iii. CaDTPA should be used during the first 24 to 48 hours after exposure and then ZnDTPA should be given for long-term use. Both CaDTPA and ZnDTPA can be given intravenously and through aerosol inhalations.
- iv. Chelating agents should not be given in cases of Uranium as the kidneys are then subjected to Uranium overload. Treatment to remove Uranium intake is not particularly successful, but Sodium Bicarbonate in saline may be given by slow intravenous infusion.
- v. DMPS (Dimercaptopropansulphonate, available as “Dimaval”) is more effective and less toxic than Dimercaprol. Its use is recommended for treatment of Polonium incorporation.
- vi. Penicillamine is more effective than Dimercaprol and CaDTPA for the removal of Copper.

- vii. Deferoxamine (DFOA) enhances the excretion of Plutonium compounds provided it is given promptly. Its effectiveness declines rapidly, which makes its clinical use for this purpose questionable. The combination therapy using both DFOA and CaDTPA yields better results than either drug separately.

7.2.3.3 – RESPIRATORY TRACT:

The lungs constitute the most important portal of entry. Ciliary action removes the majority of the inhaled contaminant to the pharynx from where it is subsequently swallowed. The treatment is then directed according to the GI tract.

Where insoluble radioactive material is deposited in the small bronchi and the lung parenchyma use of expectorants and specific agents through aerosol are recommended. Lavage of the tracheobronchial tree has proved to be effective in a very limited number of high exposure cases where a reduction of the dose could be expected to prevent acute or subacute effects, such as radiation pneumonitis or fibrosis.

7.2.3.4 – ELIMINATION BY EXTRACORPORAL TREATMENT TECHNIQUES:

This method is used for the removal of radionuclides or labeled compounds while they are circulating in the blood stream through haemodialysis or haemoperfusion.

8 – MEDICAL CARE AT THE ACCIDENT SITE AND IN HOSPITALS

8.1 – ON-SCENE EMERGENCY TREATMENT AND TRANSPORT PROTOCOLS FOR CONTAMINATED OR EXPOSED PATIENTS ⁽²⁾

The first priority of Emergency Medical Service (EMS) personnel is to save life. Annexure A provides a sample of the form which needs to be filled-in by the EMS.

The medical/health physicist or Radiation Protection/Safety Officer should perform contamination surveys of the patient and perform decontamination procedures. He should then inform EMS for delivering medical services.

8.2 – HANDLING AND TRANSPORT OF THE CONTAMINATED PATIENT:

- i. If contamination is there, use double-glove before touching the patient.
- ii. Complete the necessary evaluation of the patient's medical condition and provide immediate medical treatment e.g., treatment of the wounds, splinting, CPR (cardiopulmonary resuscitation), avoiding unnecessary contact with the contaminated area.
- iii. If a female patient is involved, EMS personnel should enquire about any possibility of pregnancy.
- iv. If the patient is pregnant, expert advice should immediately be sought regarding:
 - Evaluation of radiation hazard from external and internal sources;
 - Techniques that will help to minimize exposure to the foetus;

- Foetal monitoring badges, if appropriate
 - Termination of pregnancy, if the probability of foetal damage is high.
- v. If the clothing of the patient needs to be removed, it should be left at the scene.
 - vi. RPO/RSO will collect the clothing or other personal articles of the patient.
 - vii. Before moving an injured contaminated or potentially contaminated patient, drape the stretcher, backboard or any other device with a blanket, sheet or other material that can then be wrapped around the patient, a process known as “cocooning”. Once the process is complete, remove the outer set of gloves, place them in a plastic bag or other secure container and re-glove. If, however, cocooning interferes with the delivery of necessary medical assistance to the patient, it should not be attempted. Non-porous wraps such as plastic or rubber sheeting are preferable materials for cocooning a patient, but a blanket or sheet of cloth may be used. If it becomes necessary to remove a portion of the wrap during transport to deliver a treatment to the patient, it should be done carefully and only to the extent necessary. It is advised to turn the exterior side of the wrap inside itself so that any contamination clinging to the interior surface is not spread.
 - viii. During transport, the receiving hospital should be informed.
 - ix. Upon arrival, EMS personnel should move the patient immediately to the designated treatment area.
 - x. EMS personnel must not leave the isolation area until they have been surveyed for contamination and, if necessary, decontaminated.
 - xi. Likewise, any equipment, including the vehicle in which the patient was transported, uniforms, stretchers, etc, that is found to be contaminated should be isolated until it can be properly decontaminated.
 - xii. All materials used to handle and treat the patient or that may have come in contact with the patient during transport, including gloves, pads, bandages, splints, oxygen masks, blood pressure apparatus, stethoscope, etc, and any waste left in the vehicle/ambulance should be disposed of as radioactive waste.
 - xiii. All the actions and steps taken by the EMS personnel should be fully documented. In particular, the time taken to reach the accident site and the time elapsed to transfer the patient to the hospital and the name of the individuals of EMS team, who contacted the patient, should be noted.
 - xiv. If exposure has occurred, it should be within regulatory limits.
 - xv. If the interior of the transport vehicle/ambulance is contaminated, the vehicle/ambulance should be removed from service, locked and isolated.
 - xvi. Decontamination of the vehicle/ambulance should not be attempted by the hospital administration without assistance and advice from experts.
 - xvii. If the removal of the vehicle/ambulance due to contamination would compromise the ability of the hospital to respond to life-threatening situations, the regulatory authority should be consulted.
 - xviii. Government authorities may be notified about the accident.

8.3 – EMERGENCY ROOM PROTOCOLS:

EMS personnel on arrival at ER should consider the following guideline:

- i. Notify other staff physicians, nurses, nuclear medicine department etc;
- ii. Notify the hospital administration;
- iii. Obtain the emergency kit, if available (Appendix B).
- iv. The patient should be considered contaminated until proved otherwise.
- v. A separate room or a cubicle should be isolated. Disposable drapes should be used to cover treatment areas.
- vi. The treatment area must be restricted from unauthorized personnel. Rope or portable screens may be used to restrict access to the area.
- vii. Security personnel should be posted to control the access.
- viii. If possible, background radiation level of ER must be recorded and displayed in the treatment area & on the patient's chart.

8.4 – RESPONSIBILITY OF THE HOSPITAL PHYSICIAN UPON THE ARRIVAL OF THE AMBULANCE:

- i. Assess the patient quickly and treat the acute emergency conditions.
- ii. Seek advice from medical/health physicist for radiation monitoring of the patient, EMS personnel and the equipment.
- iii. As soon as the medical condition of the patient is stabilized, medical/health physicist should be asked for decontamination.
- iv. If a wound is involved, cover the wound with self-adhering disposable surgical drapes. Ask the medical physicist to decontaminate the surrounding area, and then seal off the cleansed area with disposable drapes. Remove the wound covering and irrigate the wound with sterile solution. Re-monitor the area for any reduction in contamination.
- v. Perform simple debridement for grossly contaminated wounds.
- vi. Make sure that all personnel are monitored before leaving the restricted area.
- vii. Retain all protective clothing, instruments and supplies used in treating the contaminated patient in properly labeled containers.
- viii. Once the patient's condition has been stabilized, the patient may be moved from the treatment area. Isolate the treatment area and restrict entry until a thorough radiation survey is conducted by a qualified individual.
- ix. If a patient dies before decontamination is attempted or successfully completed, do not release the body or remove it from the facility. Seek advice from medical/health physicist and the regulatory authority.

9 – ROLES & RESPONSIBILITIES OF THE HOSPITAL ADMINISTRATION:

Every country should have well defined emergency response centres either located within or near a well equipped hospital. The hospital designated to deal with radiation emergency should have a specified department which need to be supported by an appropriate infrastructure (Appendix B) to ensure an effective & adequate programme for the management of radiological accidents.

The responsibility of the hospital administration is:

- i. Formally documenting its commitment in a corporate policy;
- ii. Record radiological emergencies on specified forms (Annexure A);
- iii. Emergency plans should be drawn, regularly exercised & updated;

- iv. To ensure the availability of internal resources in case of an emergency;
- v. Appropriate staff should be designated as Emergency Medical Service (EMS) providers. Table 14 enlists the EMS personnel and their respective responsibilities.
- vi. Allocation of appropriate space for the reception/treatment of the casualties, if not inbuilt in the facility;
- vii. Allocation of parking place separate from the general parking;
- viii. Immediate availability of appropriate warning signs/alarms;
- ix. Deal with government agencies and seek their help, if required;
 - x. Designate a person to deal with the media to alleviate public anxiety;
- xi. Notify the regulatory authority well in time;
- xii. Maintain an appropriate record of all the events and steps taken.

TABLE 1: ACCIDENT CLASSIFICATION ⁽¹⁾

TYPES OF ACCIDENTS	POSSIBLE LOCATION	RADIATION
Whole-body exposure	Nuclear facilities	Neutron, γ
	Hospitals <ul style="list-style-type: none"> • Radiotherapy • Radiodiagnosis • In Radiotherapy when LINAC operates above 10MV in x-rays mode 	γ or χ -rays Neutron
	Industry <ul style="list-style-type: none"> • Radiography • Sources 	α , β , γ or χ n
Local exposure	As above	χ , γ , β
Contamination	Nuclear facilities Hospitals, isotope or research labs Industry, Research labs	α β γ
External <ul style="list-style-type: none"> - Skin - Wounds 	Educational – establishments & laboratories	
Internal <ul style="list-style-type: none"> - Ingestion - Inhalation - Injection 	As above	
		α & β α & β γ

TABLE 2: CLASSIFICATION OF ACCIDENTS ACCORDING TO THE RADIOISOTOPES INVOLVED ⁽⁶⁾

AREA OF APPLICATION	SOURCE, RADIONUCLIDE	PART OF BODY EXPOSED	APPROXIMATE NUMBER OF PERSONS EXPOSED
Industry <ul style="list-style-type: none"> - Sterilization - Radiography - Gauging 	Co-60, Cs-137 Ir-192, Cs-137 Ir-192, Cs-137	Whole body, hands Hands, other parts Hands, other parts	1 – 4 1 – 10 1 – 4
Medicine <ul style="list-style-type: none"> - Diagnostics - Therapy 	χ -ray generators Co-60, Cs-137 & accelerators	Hands, face Whole body, hands & other parts	1 – 10 1 – 10 (more in extremely rare cases)
Research	Broad spectrum of sources, including reactors	Hands, face and other parts	1 – 3 (more at research reactors)
Spent sources	Co-60, Cs-137 and others	Hands and other parts	1 – 20 (more in extremely rare cases)
Nuclear reactors	Cs-137, Sr-90 I-131 Pu-210	Whole body Thyroid gland Lungs	1 – 500 (usually much less than the number of persons affected)

TABLE 3: PRODROMAL PHASE OF ARS ⁽⁶⁾

Symptoms and medical response	ARS DEGREE AND THE APPROXIMATE DOSE OF ACUTE WBE* (Gy)				
	MILD (1-2Gy)	MODERATE (2-4Gy)	SEVERE (4-6Gy)	VERY SEVERE (6-8Gy)	LETHAL (>8Gy)
Vomiting Onset	2h after exposure or later	1-2h after exposure	Earlier than 1h after exposure	Earlier than 30 min after exposure	Earlier than 10 min after exposure
% of incidence	10 – 50	70 – 90	100	100	100
Diarrhea Onset	None	None	Mild 3 – 8h	Heavy 1 – 3h	Heavy Within minutes or 1h
% of incidence	--	--	<10	>10	Almost 100
Headache Onset	Slight	Mild	Moderate 4 – 24h	Severe 3 – 4h	Severe 1 – 2h
% of incidence	--	--	50	80	80 – 90
Consciousness	Unaffected	Unaffected	Unaffected	May be altered	Unconsciousness (may last seconds/minutes)
Onset	--	--	--	--	Seconds/minutes
% of incidence	--	--	--	--	100(at>50Gy)
Body temperature	Normal	Increased	Fever	High fever	High fever
Onset	--	1-3 h	1 – 2h	<1h	<1h
% of incidence	--	10 -80	80 – 100	100	100
Medical response	Outpatient observation	Observation in general hospital, treatment in specialized hospital, if needed	Treatment in specialized unit	Treatment in specialized unit	Palliative treatment (symptomatic only)

*WBE = Whole Body Exposure

TABLE 4: LATENT PHASE OF ARS ⁽⁶⁾

	DEGREE OF ARS AND APPROXIMATE DOSE OF ACUTE WBE(Gy)				
	MILD (1 – 2Gy)	MODERATE (2 – 4Gy)	SEVERE (4 – 6Gy)	VERY SEVERE (6 – 8Gy)	LETHAL (>8Gy)
Lymphocytes (G/L) (days 3 – 6)	0.8 – 1.5	0.5 – 0.8	0.3 – 0.5	0.1 – 0.3	0.0 – 0.1
Granulocytes (G/L)	>2.0	1.5 – 2.0	1.0 – 1.5	≤0.5	≤0.1
Diarrhea	None	None	Rare	Appears on days 6 – 9	Appears on days 4 – 5
Epilation	None	Moderate, beginning on day 15 or later	Moderate or complete on days 11 – 21	Complete earlier than day 11	Complete earlier than 10 days
Latency period (d)	21 – 35	18 – 28	8 – 18	7 or less	None
Medical response	Hospitalization not necessary	Hospitalization recommended	Hospitalization necessary	Hospitalization urgently necessary	Symptomatic treatment only

TABLE 5: CRITICAL PHASE OF ARS ⁽⁶⁾

	DEGREE OF ARS AND APPROXIMATE DOSE OF ACUTE WBE (Gy)				
	MILD (1 – 2Gy)	MODERATE (2 – 4 Gy)	SEVERE (4 – 6Gy)	VERY SEVERE (6 – 8Gy)	LETHAL (>8Gy)
Onset of symptoms	>30d	18 – 28d	8 – 18d	<7d	<3d
Lymphocytes (G/L)	0.8 – 1.5	0.5 – 0.8	0.3 – 0.5	0.1 – 0.3	0 – 0.1
Platelets (G/L)	60 – 100 10 – 25%	30 – 60 25 – 40%	25 – 35 40 – 80%	15 – 25 60 – 80%	<20 80 – 100% ^{a*}
Clinical manifestations	Fatigue, weakness	Fever, infections, bleeding, weakness, epilation	High fever, infections, bleeding, epilation	High fever, diarrhea, vomiting, dizziness & disorientation, hypotension	High fever, diarrhea, unconsciousness
Lethality (%)	0	0 – 50 Onset 6 – 8 weeks	20 – 70 Onset 4 – 8 weeks	50 – 100 Onset 1 – 2 weeks	100 1 – 2 weeks
Medical response	Prophylactic	Special prophylactic treatment from days 14-20; isolation from days 10-20	Special prophylactic treatment from days 7 – 10; isolation from the beginning	Special treatment from the first day; isolation from the beginning	Symptomatic only

a* = In very severe cases, with a dose >50Gy, death precedes cytopenia.

TABLE 6: TIME OF ONSET OF CLINICAL SIGNS OF SKIN INJURY DEPENDING ON THE DOSE RECEIVED ⁽⁶⁾

STAGE/SYMPTOMS	DOSE RANGE (Gy)	TIME OF ONSET(d)
Erythema	3 – 10	14 – 21
Epilation	>3	14 – 18
Dry desquamation	8 – 12	25 – 30
Moist desquamation	15 – 20	20 – 28
Blister formation	15 – 25	15 – 25
Ulceration (within skin)	>20	14 – 21
Necrosis (deeper penetration)	>25	>21

TABLE 7: CLINICAL SIGNS OF LRI TO THE HAND FOLLOWING LOW ENERGY RADIATION EXPOSURE ⁽⁶⁾

PERIOD OF ONSET OF CLINICAL SIGNS IN THE ACUTE PHASE					Time & evolution of late phase effects (d)	Delayed effects	Estimated dose range (Gy)
Primary erythema	Secondary erythema	Blisters	Erosion Ulceration	Necrosis			
None or 12 – 24h	12 – 20d	---	---	---	30 – 35 Dry desquamation	None	12 – 18 ^a 10 – 15 ^b
6 – 12h	6 – 14d	8 – 15d	---	---	40 – 50 Moist desquamation, Epithelialization	None or slight atrophy	20 – 30 ^a 18 – 25 ^b
4 – 6h	3 – 7d	5 – 10d	10 – 18d	---	50 – 70 Epithelialization	Atrophy, depigmentation, telangiectasia	35 – 80 ^a 30 – 70 ^b
1 – 2h	0 – 4d	3 – 5d	6 – 7d	6 – 10d	60 – 80 Scar formation, no healing without surgery	Atrophy, depigmentation, telangiectasia, possible functional incapacity	>80

a = Fingers only; b = Whole hand

TABLE 8: CHANGE OF LYMPHOCYTE COUNTS IN THE INITIAL DAYS OF ARS DEPENDING ON THE DOSE OF ACUTE WHOLE BODY EXPOSURE ⁽⁶⁾

DEGREE OF ARS	DOSE (Gy)	LYMPHOCYTE COUNTS (G/L) ^{a*} AFTER 6 DAYS SINCE FIRST EXPOSURE
Pre-clinical phase	0.1 – 1.0	1.5 – 2.5
Mild	1.0 – 2.0	0.7 – 1.5
Moderate	2.0 – 4.0	0.5 – 0.8
Severe	4.0 – 6.0	0.3 – 0.5
Very severe	6.0 – 8.0	0.1 – 0.3
Lethal	>8.0	0.0 – 0.05

a* = Expressed as 10⁹ cells/L

TABLE 9: GUIDE FOR THE MANAGEMENT OF RADIATION INJURIES BASED ON EARLY SYMPTOMS ⁽⁶⁾

CLINICAL SIGNS		CORRESPONDING DOSE (Gy)		DECISION
WBE*	LE**	WBE	LE	
No vomiting	No early erythema	<1	<10	Outpatient with five week surveillance period (blood, skin)
Vomiting 2 – 3h after exposure	Early erythema or abnormal sensation 12 – 24h after exposure	1 – 2	8 – 15	Surveillance in a general hospital (or outpatient for 3 weeks followed by hospitalization if necessary)
Vomiting 1 – 2h after exposure	Early erythema or abnormal sensation 8 – 15h after exposure	2 – 4	15 – 30	Hospitalization in a haematological or surgical (burns) department
Vomiting earlier than 1h after exposure and/or other severe symptoms, e.g., hypotension	Early erythema, within the first 3 – 6h (or less) after exposure, of skin and/or mucosa with edema	>4	>30	Hospitalization in a well equipped haematological or surgical department with transfer to a specialized center for radiopathology

*WBE: Whole body exposure;

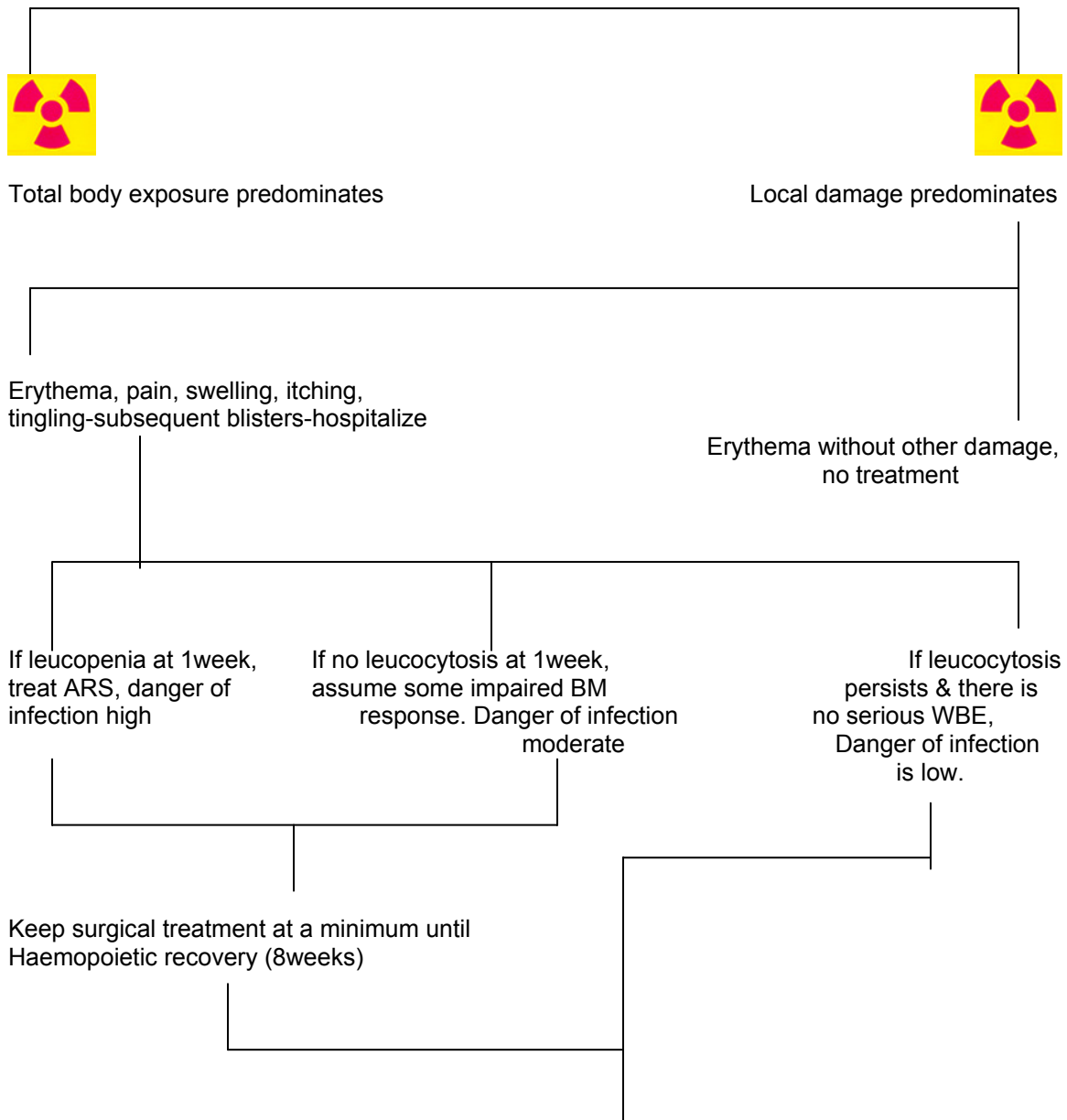
**LE: Local exposure

TABLE 10 – PRINCIPAL THERAPEUTIC MEASURES FOR ACUTE RADIATION SYNDROME ACCORDING TO DEGREE OF SEVERITY ⁽⁶⁾

Whole body dose(Gy)	1 – 2	2 – 4	4 – 6	6 – 8	>8
Degree of severity of ARS	Mild	Moderate	Severe	Very severe	Lethal
Medical management & treatment	OPD observation for maximum of one month	Hospitalization			
		Isolation, as early as possible			
		G-CSF or GM-CSF As early as possible (or within the first week)		IL-3 and GM-CSF	
		Broad spectrum antibiotics (from the end of latent period) Antifungal and Antivirals, if necessary			
		Blood components transfusion: platelets, erythrocytes (when necessary)			
		Complete parenteral nutrition (first week) Metabolism correction, detoxication (when necessary)			
		Plasmapheresis (second or third week) Prophylaxis of disseminated intravascular coagulation (second week)			
			HLA-identical allogene BMT (first week)	Symptomatic therapy only	

BMT: Bone Marrow Transplantation;
 G-CSF: Granulocyte-Colony Stimulating Factor;
 GM-CSF: Granulocyte Macrophage-Colony Stimulating Factor;
 IL-3: Interleukin.

**TABLE 11: INDICATIONS FOR THE TREATMENT OF RADIATION BURNS
INJURY FROM EXTERNAL RADIATION ⁽¹⁾**



Time of amputation, reconstructive surgery determinants:

1. Intractable pain
2. Size & location of lesion
3. Value of part
4. Degree of control of secondary infection
5. Degree to which vascular damage can be estimated.

BM: Bone Marrow;
ARS: Acute Radiation Syndrome;
WBE: Whole Body Exposure

TABLE 12-A: CLINICAL AND DIAGNOSTIC ASPECTS AND THERAPEUTIC OPTIONS FOR LRI: ACUTE PHASE ⁽⁶⁾

		Irradiation ↓	End of 1 st day ↓	End of 1 st week ↓	End of 1 st month ↓
		Dose Estimation	History Physical dosimetry Accident reconstruction Biological dosimetry		Vascular thermography
		R/E	Peripheral blood counts Sperm counts Slit lamp exam of eye Serial color photographs		
		Specialized Studies	Vascular scintigraphy CAT scan Thermography		
		PRODROMAL PHASE	LATENT PHASE	ACUTE PHASE	
CLINICAL PICTURE	SYMP-TOMS	Heat sensation Itching Tenderness	Minor (itching, pain), if any	Pain Itching Paresthesia Hyperalgia	
	SIGNS	Transient erythema	Minor epilation, if any	Erythema Oedema Blistering Moist desquamation	
TREATMENT		Symptomatic	Avoidance of trauma Analgesics Hydration emulsion (sweet almond oil)	Pain relief NSAIDs Local antibiotics Vasodilators Healing drugs Anti-adherent platelet drugs Epidermal growth factors Debridement	

NSAIDs= Non-steroidal anti inflammatory drugs;

TABLE 12-B: CLINICAL AND DIAGNOSTIC ASPECTS AND THERAPEUTIC OPTIONS FOR LRI: CHRONIC PHASE ⁽⁶⁾

Vascular scintigraphy Thermography Biopsy (histo- & Immunocytochemical Studies)	Vascular scintigraphy Bone scan Thermography	Vascular scintigraphy Bone scan Thermography
First Year		Second Year
HEALING OR CHRONIC EVOLUTION (SCLEROSIS & FIBROSIS) (SECONDARY INFECTION POSSIBLE)		
PAIN	Injury Reopening Vasculitis (possible) Pain Late erythema Oedema Ulcer Necrosis (spontaneous healing impossible)	Pain Altered tactile and thermal sensitivities Paresthesia Skin dryness
Ulceration Necrosis		Atrophy, telangiectasia, pigmentry changes, keratoses, epilation or problems with hair, deformity (ankylosis), functional incapacity
Surgery (necrectomy, skin grafts, amputation)	Conservative Analgesics NSAIDs Surgery (necrectomy)	Avoidance of trauma Rehabilitation Superoxide dismutase (liposomal & topical) Surgery

TABLE 13– DOSE OF POTASSIUM IODIDE TABLETS TO BE ADMINISTERED FOR THYROID BLOCKING

AGE OF PERSONS	RECOMMENDED DOSAGE (mg)
Infants (not breast fed)	10 – 20
1 – 10 years	20 – 50
11 – 18 years	50 – 100
Adults	100 – 300

TABLE NO: 14 EMERGENCY MEDICAL SERVICE TEAM ⁽⁷⁾

TEAM MEMBER	RESPONSIBILITY
Team leader	Leads the team, takes immediate decisions, advise and coordination
Emergency physician	Diagnosis, treatment and provision of emergency medical care (can also function as team coordinator or triage officer)
Triage officer	Qualified medical officer to perform triage for emergency management of the casualties
Nurse	Assistance to physician with medical/surgical procedures, collection of specimens & decontamination of the patient; assessment of patient's needs & intervenes appropriately.
Technical recorder	Recording and documentation of medical and radiological data
Medical/Health physicist	Radiation monitoring of patient, staff & areas, ambulance etc; advice on contamination & exposure control; maintenance of monitors; management of contaminated waste & other contamination control mechanisms.
Media officer	Release of accident information to the public media
Administrator	Coordination of hospital responses; assures normal hospital operations and all administrative problems
Security personnel	Secure the controlled and ambulance areas; control access to and exit from areas.
Maintenance personnel	Aid in preparation of the controlled areas for contamination control; provide various supplies.
Laboratory technician	Provision of routine clinical analysis of biological samples.
Counselor	Counseling of the patients and relatives

APPENDIX A

TREATMENT FOR SPECIFIC RADIONUCLIDES ⁽¹⁾

RADIOIODINE

Accidents may take place where there is a release of radioiodine to the environment and intake may occur either by ingestion or inhalation. In the normal euthyroid individual, about 25% of an orally administered dose of radioiodine will be present in the thyroid at about 6 hours after intake if no treatment is undertaken, but this can be greatly reduced by the administration of non-radioactive iodine. The treatment consists of oral administration of stable iodine, usually as Potassium Iodate in tablet form. Foil wrapped tablets of 170 mg of Potassium Iodate are commercially available for this purpose. Treatment should be given as soon as possible, but even if instituted within 5 hours after the intake, it may still be highly effective.

STRONTIUM AND RADIUM

These elements are absorbed from the intestine in competition with calcium, although to a rather lesser extent. It has been found that the administration of Calcium Alginate shortly after the ingestion of Strontium will partially prevent its absorption. Calcium Alginate is very unpalatable and it is best given as a single dose of 10-20 g dissolved in a large amount of sugared water. Although alginates also prevent the absorption of Radium from the gut, they are much less effective than in the case of Strontium. In the case of wounds contaminated by these elements, it is suggested to sprinkle the wound with 1 g of Calcium Rhodizonate which precipitates Strontium and Radium, making them insoluble. To be effective, treatment needs to be instituted making them insoluble. To be effective, treatment needs to be instituted within 15 minutes of the accident.

CAESIUM AND OTHER ALKALINE METALS

These are rapidly absorbed from the gut and the respiratory system and are concentrated mainly in the muscles and the other soft tissue. There is a continual turnover of absorbed Caesium and related elements, secretion taking place into the gut; treatment is therefore directed to preventing absorption and re-absorption. This may be achieved by the administration of Prussian Blue in doses of 1 g dissolved in water and taken three times daily until no further substantial excretion of Caesium occurs.

TRITIUM

This is a special case because, as it is easily oxidized to tritiated water, it is rapidly absorbed following both ingestion and inhalation. It can also be absorbed through the intact skin. As might be expected, it is distributed through the intact skin. As might be expected, it is distributed evenly throughout the body,

its metabolic pattern being largely that of the body water. This fact makes its elimination simple, the treatment being forced fluid intake together with the administration of a diuretics. Because of its rapid absorption and uniform distribution, it effectively produces whole body irradiation.

PLUTONIUM AND OTHER TRANSURANIC ELEMENTS

Plutonium is primarily an alpha emitting radioisotope, and after mixing with the intestinal contents, irradiation of the gut wall is minimal since the alpha particles have a range of only about 40 μm and will not therefore reach the radiosensitive intestinal epithelium. Furthermore, the ingestion of Plutonium is unlikely to prove hazardous from the point of view of absorption since its absorption factor is extremely small. If the material has been swallowed, then a mild cathartic, such as Magnesium Sulphate, is all that is needed.

Plutonium contaminated wounds and intakes by inhalation pose much greater problems, and action needs to be taken as soon as possible following the accident. The metabolic pathway of Plutonium is related very closely to the solubility or otherwise of the compounds involved. Soluble materials tend to translocate from the lungs to the blood, with deposition taking place mainly in the bones and the liver. In the case of insoluble materials, however, some is removed by the ciliary escalator to the pharynx and then swallowed. The Plutonium remaining in the lung is subsequently engulfed by macrophages and deposited in the regional lymphnodes. The management of Plutonium intake by inhalation is therefore determined by the physical nature of the material involved. The immediate intravenous administration of DTPA (Diethylenetriaminepentaacetic Acid) is the choice prescription for soluble uptakes. This forms a complex with the circulating Plutonium which is then excreted via the kidney. DTPA may be given as an initial bolus of 0.25 g in 20 ml of saline or 1 g may be given in 250 ml of saline by intravenous infusion. Following this initial treatment, 0.25 g should be given intravenously daily until the urinary Plutonium output falls to a negligible level.

When the inhaled contaminant consists of insoluble material, intravenous DTPA is of little or no value since translocation to the blood stream is minimal and chelation cannot therefore take place. In such cases the administration of DTPA as an aerosol is recommended, the object being to solubilize the deposited Plutonium, thus allowing its absorption and subsequent elimination through the kidney. Finally if the intake has been very large (in excess of about 3.7×10^{10} Bq = 1.5 Ci), consideration needs to be given to carrying out lung lavage. However, as stated earlier, this procedure is not without risk and should only be undertaken on specialist advice in a specialist unit.

In the management of wounds contaminated by Plutonium intravenous DTPA should be given as soon as possible, irrespective of whether the deposited material is soluble or insoluble. Following chelation therapy, consideration must be given as to whether the wound needs to be excised.

URANIUM

The danger from natural Uranium (U-238) is its chemical toxicity to the kidney. Intake may occur by ingestion, inhalation or via wounds, and spread takes place throughout the body. Chelating agents (DTPA) should not be given since the kidney may then be subjected to Uranium overload. Treatment to remove Uranium intakes is not particularly successful, but 250 ml of 1.4% Sodium Bicarbonate in saline may be given by slow intravenous infusion. Other Uranium isotopes are radio-toxic rather chemo-toxic but the treatment schedule in cases of intake should follow the same pattern.

APPENDIX B

LIST OF RECOMMENDED EQUIPMENT AND MEDICATIONS ⁽¹⁾

HOSPITAL EMERGENCY ROOM

All major hospitals should make some provision for the accommodation of acute radiation exposed or contaminated individuals, sufficient to allow first aid treatment to be undertaken.

The facilities should comprise a room at the periphery of the hospital with direct access from outside the building. The room should have impervious, easily washable and strippable paint work, and washable floor together with floor drains. An easily cleanable, simple table should be provided to treat the exposed/contaminated person. Showering facility should be included as an integral part of the room and there should also be a large sink with elbow-operated taps set at a height which will allow decontamination of the arms, face and hair. Air movement through the room via air conditioning and heating systems should be capable of isolation in order to minimize the spread of contamination.

It is not necessary for such facilities to be purpose-built and accommodation which is ordinarily used for other purposes may be identified for use in emergency situation as part of the hospital emergency plan.

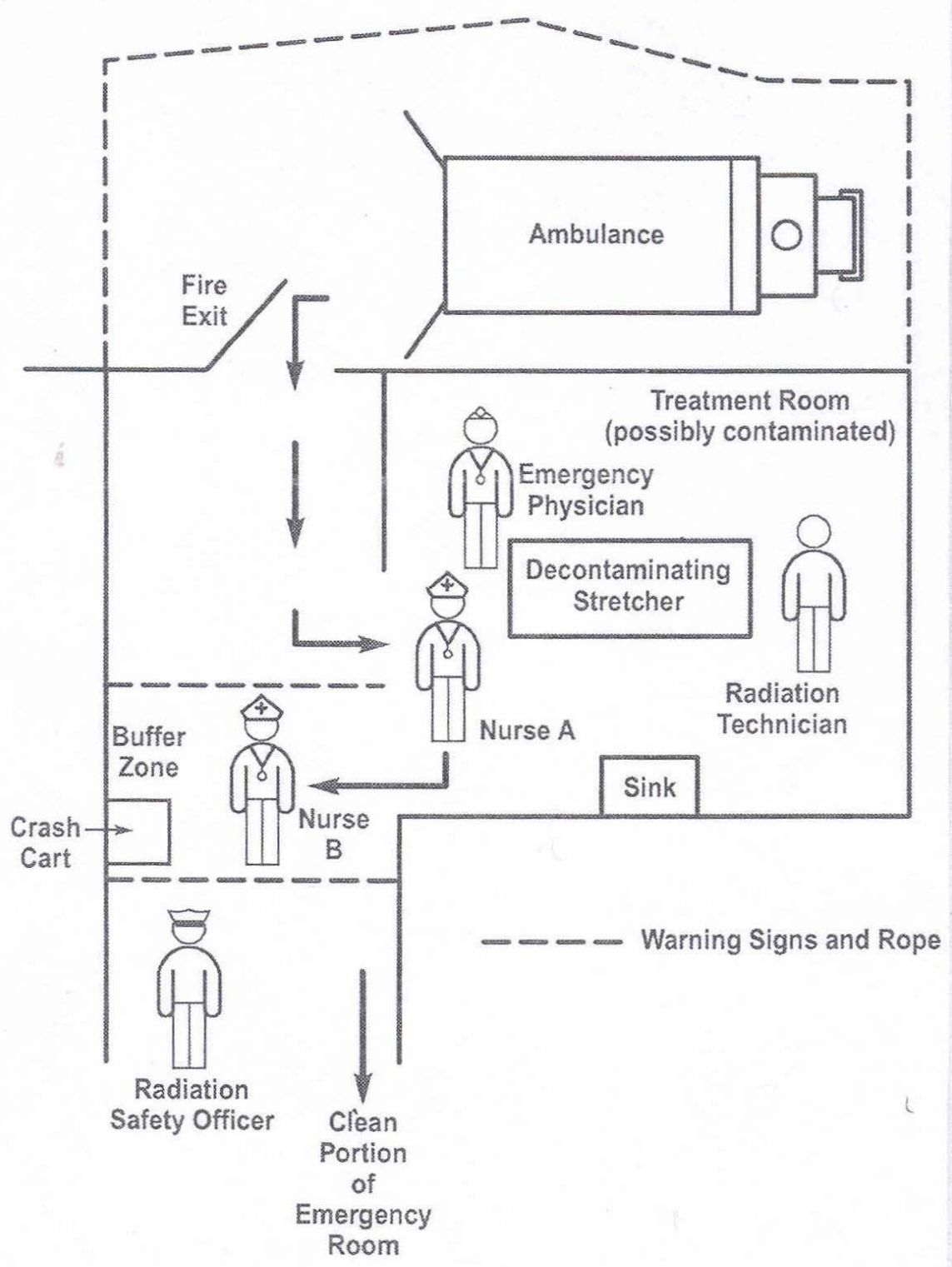
The hospital management may build its emergency room for receiving radiation victims according to the drawn plan on the next page.

CLOTHING

Complete protective clothing for each staff member (surgical scrub suits, overalls, plastic shoe covers, surgical caps, sterile and non-sterile masking tape, plastic or rubber gloves (short and long), pre-fitted respirators) should be available. Clean, long patient gowns or coveralls, shoes, shoe covers, socks and blankets should be available for patients.

DETECTION EQUIPMENT

Portable radiation detection equipment should be available which must be simple and easily operated, and need only be concerned with the detection of beta-gamma emissions. It is only in very unlikely circumstances outside a nuclear establishment that alpha contamination could occur. The most commonly available ones are whole body counter, lungs counter, gross alpha beta counter etc.



ANCILLARY EQUIPMENT

Cotton applicators for nasal swabs.

Sterile suture sets with additional sterile scissors (2), forceps (10), clamps, retractors.

Ca-DTPA – group medical kit

Topical antiseptic (benzalkonium chloride).

Local anaesthetic (lignocaine 2%).

Sterile irrigation set.

Sterile applicators – miscellaneous dressings and bandages.

Plastic airways.

Intravenous sets with cannulae.

Six bottles of sterile physiological saline and six bottles of 5% dextrose in distilled water.

Emergency medication tray.

Suction apparatus.

Clippers, razor with extra blades and aerosol shaving soap.

Sterile sheets, towels, drapes.

Adhesive labels and tags.

Large plastic bags for collection of clothing.

Large towels.

Soft scrub brushes.

Plastic sheets.

Large fibreboard waste baskets lined with plastic bags.

Detergent.

Acid soap.

Sodium hypochlorite 25%.

Potassium permanganate and sodium metabisulfite 10%.

Paraffin with heater.

Adhesive tape.

Disposable syringes and needles.

Complete surgical first-aid, splints.

MISCELLANEOUS

Tape recorder

Felt pens, note books, paper and pencils.

Specimen bottles for collecting urine and faecal specimens, with complete instructions for collecting and labelling specimens.

Appropriate specimen containers for blood counts, blood biochemistry and cytogenetics.

Specimen bottles for tissue specimens (Formalin may be used if freezing facilities are not available).

ANNEXURE A

IDENTIFICATION MEDICAL FORM ⁽³⁾

IDENTIFICATION OF THE VICTIM

Name:
Sex:
Date of birth:
Identity of the patient:

IDENTIFICATION OF THE INDIVIDUAL WHO FILLS THE FORM

Name:
Sex:
Organization:
Designation:
Date of filling the form:
Time of filling:

ACCIDENT SITE

Date of occurrence:
Time of occurrence:

EXPOSURE CONDITIONS

Date & time of exposure:
Duration of exposure:
Position of the victim:
Occupation of the victim:

DOSIMETRY HISTORY

The victim had a dosimeter: YES / NO
Dosimeter recovered: YES / NO
Number (If Recovered): -----

CONTAMINATION HISTORY

Contamination of clothes – Detected
Contamination of clothes – Not detected

FIRST SYMPTOMS

CLINICAL STATE OF THE VICTIM

Nausea:
- Time of appearance
- Duration & number
Vomiting:
- Time of appearance
- Duration & number

Wound/trauma description:	
Associated burns:	YES/NO
If yes, then describe the burn:	

MEDICAL FINDINGS	
(To be filled by the physician)	
Name of the physician:	
PMDC Registration Number:	
Name of the patient:	
Date & Time of examination:	
SYMPTOMS:	YES / NO
Asthenia:	
Headaches:	
Nausea:	
Vomiting:	
Diarrhea:	
Temperature:	
Pulse:	
Blood pressure:	
Level of consciousness:	Normal Abnormal – (agitation, delirium, sleepiness & coma)
Equilibrium:	
Coordination:	
Skin & Mucosae: Edema:	
Erythema:	
Others:	

LABORATORY TESTS	
BLOOD SAMPLES:	
FIRST SAMPLE (if possible, before the third hour))	Date & time
- CBC	
- Platelets	
- Cytogenetics (10ml)	
- Sample for spectrometry	
SECOND SAMPLE (If possible, 2hours after the first one)	Date & time
- CBC	
- Platelets	
- HLA typing	
URINE SAMPLES:	
(If possible for gamma spectrometry):	
Is it the first urine passed after the accident?	YES / NO
24 hour urine sample collection for depleted uranium:	YES / NO

MEASURES TAKEN

Undressing:	YES / NO
Decontamination:	YES / NO
Any medication given (e.g., DTPA etc):	
Route of administration:	
<ul style="list-style-type: none"> - aerosol - bathing - intravenous - intramuscular 	
Stable Iodine:	
Dose given:	

PHYSICIANS CONCLUSIONS

DESTINATION OF THE VICTIM

SAMPLE ACCIDENT INFORMATION FORM

(To be filled in by physician/In charge)

IDENTIFICATION INFORMATION	
Name	
Sex	
Organization	
Designation	
Date & time of accident	

NUMBER OF VICTIMS	
Number & Condition of uncontaminated patients	
Number & condition of contaminated patient	

DESCRIPTION AND EXTENT OF ACCIDENT	
A – Irradiation conditions: <ul style="list-style-type: none"> • Source • Distance • Time • Estimated dose 	

B – External contamination: <ul style="list-style-type: none"> • Radionuclides involved • Activity involved • Body area involved 	
C – Internal contamination: <ul style="list-style-type: none"> • Ingestion • Inhalation 	
D – Contaminated wound	
E – Whether initial decontamination done	

ARRIVAL OF THE CASUALTIES	
Arrival time of the casualties	

DATE: _____

SIGNATURES: _____

SAMPLE IDENTITY TAG FOR ACCIDENTAL EXPOSURE

IDENTITY TAG (FIRST AID POST)	
NAME	
DEPARTMENT/ORGANIZATION	
CONTAMINATION	YES / NO
SITE OF CONTAMINATION	
INJURY	YES / NO
SITE OF INJURY	
OVEREXPOSURE	YES / NO
PRILIMINARY ACTIONS TAKEN	
TREATMENT	
FIRST AID	
DECONTAMINATION	
TO: PERSONNEL DECONTAMINATION CENTRE / SITE HOSPITAL	

GLOSSARY

Accident: Any unintended event, including operating errors, equipment failures or other mishaps, the consequences of which are not negligible from the point of view of protection or safety.

Contamination: The presence of radioactive material in or on any place or equipment or on the human body where they are undesirable or could be harmful

Controlled area: A controlled area is any area in which specific protection measures and safety provisions are or could be required for:

a)-controlling normal exposures or preventing the spread of contamination during normal working conditions; and

b)-preventing or limiting the extent of potential exposures.

Synonymous to "Restricted Area".

Decontamination: The removal or reduction of contamination in or on materials, persons, equipment or environment.

Exposure: It means the act or condition of being subject to irradiation. Exposure can be either external exposure (irradiation by source outside the body) or internal exposure (irradiation by source inside the body). Exposure can be classified as either normal exposure or potential exposure; occupational, medical or public exposure; and, in intervention situations, either emergency exposure or chronic exposure. The term exposure is also used in radiodosimetry to express the amount of ionization produced in air by ionizing radiation.

Medical Exposure: Exposure incurred by patients as part of their own medical or dental diagnosis or treatment; by persons, other than those occupationally exposed, knowingly while voluntarily helping in the support or comfort of patients; and by volunteers in a programme of biomedical research involving their exposure.

Medical Professional: It means an individual who: (a) has been accredited through Pakistan Medical and Dental Council (PMDC) as a registered medical practitioner or registered dental surgeon; and (b) fulfills the national requirements of training and experience for prescribing procedures involving medical exposure.

Monitoring: The measurement of dose or contamination for reasons related to the assessment or control of exposure to radiation or radioactive substances, and the interpretation of results.

Normal Exposure: An exposure which is expected to be received under normal operating conditions of an installation or a source, including possible minor mishaps that can be kept under control.

Occupational Exposure: All exposure of workers incurred in the course of their work with the exception of exposures excluded from the BSS and exposures from practices or sources exempted by the standards.

Potential Exposure: Exposure that is not expected to be delivered with certainty but may result from an accident at a source or owing to an event or sequence of events of a probabilistic nature, including equipment failures & operating errors.

Public Exposure: Exposure incurred by members of the public from radiation sources, excluding any occupational or medical exposure and the normal local background radiation but including exposure from authorized sources & practices and from intervention situations.

Radiation Protection Officer: An individual technically competent in radiation protection matters relevant for a given type of practice who is designated by the registrant or licensee to oversee the application of the requirements of the standards.

Radiation Worker: An individual who has received the required training necessary to work with radiation and is authorized to do so by the Radiation Protection Officer.

Radioactive Waste: Those radioactive materials arising from a source within a practice that are retained with the intention of restricting the rates of release to the biosphere, regardless of the physical state of those materials. For legal and regulatory purposes, radioactive waste is material that contains or is contaminated with radionuclides at concentrations or activity greater than the clearance levels and for which no use is foreseen.

Radioactivity: The property of radionuclides of spontaneously emitting ionizing radiation; the transformation of unstable atomic nuclei by the emission of radiation.

Regulatory Authority: Here Regulatory Authority means Pakistan Nuclear Regulatory Authority (PNRA).

Sealed Source: Radioactive material that is (a) permanently sealed in a capsule or (b) closely bounded and in a solid form. The capsule or material of a sealed source shall be strong enough to maintain leak tightness under the conditions of use and wear for which the source was designed, also under foreseeable mishaps.

Source: Anything that may cause radiation exposure, such as by emitting ionizing radiation or releasing radioactive substances or materials and can be treated as a single entity for protection and safety purposes.

Storage Room: Facility designated for lodging, preparation, control and sterilization of radioactive sources.

Supervised Area: Any area not designated as a controlled area but for which occupational exposure conditions are kept under review even though specific protective measures and safety provisions are not normally needed.

Uncontrolled Area (Unrestricted Area): An area to which access is neither limited nor controlled for purposes of radiation protection.

Unsealed Sources: A source that does not meet the definition of a sealed source.

Worker: Any person who works, whether full time, part time or temporarily, for an employer and who has recognized rights and duties in relation to occupational radiation protection. (A self-employed person is regarded as having the duties of both an employer and a worker).

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