Abstract. Health care professionals must be prepared to efficiently and effectively treat injuries involving ionizing radiation. Although many regulatory and non-regulatory bodies provide guidelines for managing radiation incidents, individual establishments are responsible for developing their own response plan. The Radiation Safety Office of The Ottawa Hospital has developed an emergency response plan that assigns specific responsibilities to health care professionals during a radiation incident, to ensure proper medical treatment is provided during an emergency, in accordance with appropriate radiation safety principles. The Hospital’s response is intended to minimize the risk of contamination or exposure to staff members while providing the highest level of patient care. Part I of the plan targets the organization and management of radiation emergencies. It identifies members of the hospital’s response team and assigns responsibilities prior to the arrival of patients, during patient care and post incident cleanup. This section is also used during departmental training sessions to review personnel roles and responsibilities. Part II of the plan strictly targets the assessment and handling of radiation accident patients. A quick reference flow-chart allows for rapid radiological assessment of incoming patients and the proper triage and treatment of contaminated victims. At this time, the plan will successfully manage radiation victims of minor industrial accidents, transport accidents and medical incidents involving radiation emitting devices or nuclear substances. A major radiation event will require the coordinated efforts of many different community organizations; therefore, we propose to regionally standardize such a response plan so as to effectively coordinate radiation response with other emergency medical services.

1. Introduction

In response to Federal [1] and Provincial [2] mandates, The Ottawa Hospital (TOH) has developed an emergency response for the medical needs of patients who have or may have been exposed to a source of ionizing radiation. The Hospital’s response is intended to minimize the risk of secondary contamination to staff members while providing the highest level of patient care. The purpose of this policy is to assign responsibility and outline the Hospital’s response to a radiation incident involving internal or external exposure, while providing a basic guide in radiation safety principles in an emergency.

1.1. Radiological Terms and Definitions

(a) **Acute Radiation Syndrome (ARS):** An acute illness caused by irradiation of the entire body (or most of the body) by a high dose of penetrating radiation in a very short period of time (usually a matter of minutes) [3]. Sometimes known as radiation toxicity or radiation sickness. Manifested through cellular disruption of three major systems; hematopoietic, gastrointestinal and central nervous system.

(b) **Alpha Particle:** A specific type of particle ejected from an atom, which is unable to penetrate the thin layer of dead skin cells and has a very low range, consequently not posing an external radiation hazard. Alpha-emitting atoms can cause health hazards if introduced by inhalation or ingestion [4].

(c) **Background Radiation:** Radiation levels found in man’s environment consisting of both natural (radiation from naturally radioactive elements) and man-made sources of radioactivity.

(d) **Beta Particle:** A small type of particle ejected from an atom, which has moderate penetrating power and travels a few meters in air. At high levels, beta particles pose an external radiation hazard for the skin, but can easily be stopped by plastic or glass (NOTE: lead or metal are not suggested as shielding materials).
(e) **Contamination**: The deposition of radioactive material in the form of gases, liquids or solids in any place where its presence is undesirable [4]. Personal contamination can be internal or external.

(f) **Controlled Area**: A designated area where entry, activity and exit are controlled, to ensure radiation protection and prevent the spread of contamination [4].

(g) **Decontamination**: The reduction or removal of contaminating radioactive material from an area, object or person [4].

(h) **Detector**: A device that is sensitive to detect radiation and can produce a response signal [4].

(i) **Dose**: A general term for the quantity of radiation or energy absorbed [4].

(j) **Electronic Personal Dosimeter (EPD)**: A small, pocket-sized device used for measuring a person’s real time radiation dose.

(k) **Gamma Rays**: High energy electromagnetic radiation. Gamma rays (similar to X-rays) are the most penetrating type of radiation and represent a major external hazard. Shielding against gamma radiation requires thick layers of dense materials, such as lead.

(l) **Irradiation**: Exposure to ionizing radiation in the form of electromagnetic (X-ray and gamma) or particulate (alpha and beta) radiation.

(m) **Lethal Dose 50/30**: The dose of radiation expected to cause death within 30 days to 50% of those exposed without medical treatment.

### 1.2. Types of Radiation Exposure [5]

Regardless of where or how an accident involving radiation happens, radiation injury can occur from two major types of exposure: external and internal.

**1.2.1. External Exposure—Irradiation**

External irradiation occurs when all or part of the body is exposed to penetrating radiation from an external source. Externally irradiated patients **are not radioactive** and are **not at risk of spreading contamination**.

**1.2.2. External Exposure—Contamination**

External contamination occurs when radioactive material is deposited on body surfaces, generally the skin, hair and nails. This type of contamination requires physical decontamination.

**1.2.3. Internal Exposure—Contamination**

Internal contamination occurs when radioactive material is deposited internally by inhalation, ingestion, absorption or wound openings. Externally and internally contaminated patients are **at risk of spreading contamination**. Internal contamination requires immediate treatment to prevent further uptake or radioactive incorporation.

**1.2.4. Internal Exposure—Incorporation**

Incorporation refers to the uptake of radioactive materials by cells, tissues, and target organs such as bone, liver, thyroid, or kidney. Generally, radioactive materials are distributed throughout the body based upon their chemical properties. Patients with incorporated radioactivity are **at risk of spreading contamination only through body fluids**.
2. Organizing and Managing Radiation Emergencies

When casualties present themselves to the Emergency Department (ER), the ER is to activate the Emergency Procedure Manual, Code Brown Protocol and ensure the Radiation Incident Emergency Response Plan is followed. During an emergency response to a radiation incident, the normal patient entrance to the ER will be disrupted. To ensure continued efficient operation of the ER, the Admitting entrance door will be designated as the ER entrance for patient arrival either by ambulance or ambulatory. The Admitting and ER Team will work together during this time period.

2.1. Notification and Accident Verification

Upon notification that the ER is receiving radiation accident victim(s), the person taking the call will get as much information as possible [6], including:

— Name, telephone number and affiliation of the caller
— Number of victims
— Victim’s medical status and type of accident (e.g. transportation, laboratory, explosion…)
— Identity of contaminant and amount involved, if known
— Radiological status of victims (exposed vs. contaminated)
— If victims have been surveyed for contamination
— Estimated time of arrival

If any doubt about contamination exists, assume the victim is contaminated until proven otherwise. Advise ambulance personnel that all radiation accident victims are to be brought to the ER entrance doors.

2.2. Radiation Incident Response Team

The magnitude of the incident will dictate the number of personnel required from each department; nevertheless, the Hospital’s response team will be comprised of at least the following key personnel.

<table>
<thead>
<tr>
<th>Table I. Radiation Incident Response Team</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Personnel Responsible</strong></td>
</tr>
</tbody>
</table>
| ER Nurse Team Leader | • Informs ER physicians of in-coming patients  
• Notifies ER Central Desk Clerk who will notify Radiation Safety Officer (RSO)  
• Notifies Housekeeping of situation and requests their immediate presence  
• Notifies Security of situation and their immediate assistance  
• Advises ER staff of preparation measures  
• Designates a Treatment Area Registered Nurse (RN) and a Circulating RN  
• Ensures staff are in proper Personal Protective Equipment (PPE) |
| ER physician or Nuclear Medicine physician | • Treats, diagnoses and provides emergency medical care of patient  
• Directs decontamination procedure of patient |
| Housekeeping | • Covers floor of Treatment Area with plastic lined paper  
• Covers floor from Treatment Area to ambulance entrance with plastic lined paper and tapes down all edges  
• Clears all non-essential equipment from area |
• Prepares treatment room as outlined below
• Cleans up spills according to radiation “Spills Response Guide”
• Wraps stretchers with plastic, then covers with sheets

<table>
<thead>
<tr>
<th>Triage officer</th>
<th>Performs triage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fills out radiation incident response form</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Circulating RN or Nuclear Medicine Technologist</th>
<th>Obtains needed supplies from personnel outside Treatment Area</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Assists team as situation merits</td>
</tr>
<tr>
<td></td>
<td>Monitors patient with detector during decontamination procedures</td>
</tr>
<tr>
<td></td>
<td>Places waste in appropriately labeled containers</td>
</tr>
<tr>
<td></td>
<td>Monitors Emergency Personnel before they leave area</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Treatment Area RN</th>
<th>Assists physician in decontamination efforts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Collects specimens as requested</td>
</tr>
<tr>
<td></td>
<td>Monitors vital signs and records data</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Supply personnel</th>
<th>Remains ‘clean’ to access and transfer any needed equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Relays communication between team members</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Security</th>
<th>Cordons-off area with rope, placards and barriers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Provides security and limit access to area</td>
</tr>
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</table>

| Typist            | Registers patient while outside Treatment Area |

<table>
<thead>
<tr>
<th>RSO</th>
<th>Supervises contamination control</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Makes recommendations regarding staff safety</td>
</tr>
<tr>
<td></td>
<td>Supervises/Aids in decontamination process</td>
</tr>
<tr>
<td></td>
<td>Provides final monitoring of Treatment Area and declares the area free of contamination</td>
</tr>
<tr>
<td></td>
<td>Maintains survey equipment</td>
</tr>
</tbody>
</table>

| Laboratory Technician | Provides routine clinical analysis of possible contaminated biological samples |

**NOTE:** Pregnant staff are **NOT** to be assigned to care for any patients involved in a radiation incident. Staff with open cuts or scratches are **NOT** to be part of the decontamination team or to handle contaminated patients.

**2.3. Response Team PPE**

The purpose of protective clothing is to keep bare skin and personal clothing free of contaminants. Members of the radiation incident response team will dress as follows:

— Remove street clothes and all jewelry
— Keep under garments and shoes on
— Put on OR scrubs and surgical gown as outer cover
— Put on waterproof foot covers over shoes
— Ensure pant top goes over the foot cover
— Tape pant top to foot cover (3 turns) ensuring slack
— Put on two layers of blue neoprene gloves
— Tape surgical gown to gloves (3 turns) ensuring slack
— Place paper bonnet over head covering all hair
— Put on full-face shield to ensure face and eyes are covered
— Attach the assigned EPD to the outside of the surgical gown at the shoulder area
— Place tape with your name and role in response team on the surgical gown
— Ensure the RSO receives the EPD after use
2.4. Treatment Area Preparation

The designated treatment area must be cleared of visitors and patients. Equipment that will not be needed during emergency care of a radiation accident patient should be removed or covered with plastic.

Two large plastic lined garbage containers should be in the area. The treatment table(s) should be covered with several layers of plastic lined paper and plastic bags of all sizes should be readily available.

Survey instruments should be checked prior to the arrival of victims and background radiation levels should be documented.

Additional equipment (ie. signage, boundary cones, decontamination kits, PPE and detectors) is available through the RSO (Old Service Building room 221A) and the departments of Nuclear Medicine (C1 – Civic Campus or Module T – General Campus).

The path from the ambulance entrance to the treatment room as well as the floor of the treatment area should be covered using plastic lined paper or butcher paper. **It should be taped securely to the floor.**

A wide strip of tape on the floor at the entrance to the treatment room should differentiate clearly the controlled (contaminated) from the non-controlled (uncontaminated) side.

2.5. General Precautions and Contamination Control

It is the responsibility of personnel involved in the care of patients with radioactive contamination to observe precautions that will achieve the following goals:

— Prevent the spread of radioactive contamination to the surroundings, to other persons or to equipment not directly involved in the decontamination procedure.
— Carry out decontamination procedures on accident victims as quickly as possible.
— Observe radiation safety precautions (reduce your **TIME**; increase your **DISTANCE**; use appropriate **SHIELDING**; and wear your **PPE**) to reduce total radiation exposure As Low As Reasonably Achievable.

The actual circumstances will dictate potential levels of exposure and contamination, but the following techniques of contamination control will help to realize goals:

Potential radiation damage to tissues is a function of the exposure time, therefore it is important to move efficiently in an organized way in evaluating and treating patients.

— All personnel involved in handling radioactive contaminated patients must wear disposable PPE and should wear an EPD, which will be monitored by a RSO.
— Tracking of contaminants is prevented by covering floor areas, monitoring exits and entrances to the controlled area, and restricting access to the controlled area.
— Ambulances, first responder personnel and their equipment must be monitored before leaving the controlled area.
— Instruments, outer gloves and gown must be changed when contaminated.
— Contaminated waste must be clearly identified from non-contaminated waste.
— All areas used in the examination, treatment and decontamination of radioactive contaminated patients must be surveyed by RSO and decontaminated if necessary, before being used for any other purpose.
— When treatment is complete, staff will remove outer gowns in the treatment room and be checked for possible personal contamination by RSO before leaving.

If radioactive contamination is discovered **AFTER** a patient has been admitted to a non-controlled area, the following procedures are to be followed [6]:

— Continue attending to the patient’s medical needs as required.
— Secure entire area where the patient and attending staff are located by establishing control lines.
— Monitor **anyone** and **anything** leaving the area to ensure radioactive contamination is not spread.
Assess patient’s radiological status (amount and location of contamination, exposure hazard) and begin decontamination efforts.

Once patient is stable, staff should remove contaminated clothing and they should be surveyed, decontaminated, dressed and resurveyed before leaving area.

3. Hospital Emergency Care of Radiation Accident Patients

Radioactive contamination (internal or external) is never immediately life threatening. Serious medical treatment always takes precedence over radiological assessment or decontamination of the patient [7].

3.1. Patient Arrival and Triage

Meet the radiation accident victim at the ambulance with a covered clean stretcher. EMS personnel are to transfer patient onto stretcher. Instruct EMS personnel to stay with their vehicle until they, their vehicle and equipment are surveyed and released by RSO [8].

Triage patient depending on associated bodily injury. If life threatening or serious medical injury is present, the patient is immediately taken to the treatment room where surgical and/or medical procedures are performed. After the patient’s physical condition is stabilized, they are to be surveyed for contamination. Location of wounds and/or contamination must be clearly identified on appendix C of the radiation incident form. Decontamination procedures are undertaken and clearly documented.

If minor or no bodily injury is present, the problem may be one of decontamination. The patient is surveyed for contamination. Non-contaminated patients are admitted to the usual treatment areas in other places in the hospital. Contaminated patients are taken to the decontamination room(s) for more definitive decontamination procedures. Contaminated areas must be clearly identified on the radiation incident form.

3.2. Assessment and Treatment of Non-Contaminated Patients

Non-contaminated individuals can be cared for like any other emergency case. They pose no radiological hazard to anyone. After the patient’s medical needs are addressed, question the patient to determine the possibility of radiation exposure from an external source. If exposure is known or suspected, a Complete Blood Count (CBC) should be ordered with particular attention given to determining the absolute lymphocyte count [8].

3.3. Assessment and Treatment of Contaminated Patients

Contaminated patients can have radioactive material deposited on skin, in wounds or internally.

1- Foremost, treat and stabilize life-threatening injuries.

2- Prevent and minimize internal contamination by cleaning and covering wounds.

3- Assess external contamination by monitoring and decontaminate as required.

4- Contain contamination to treatment and decontamination rooms.

5- Minimize external contamination to medical personnel by ensuring all staff attending contaminated patients wear proper PPE.

6- Assess internal contamination by ordering radiological and clinical laboratory tests.

3.3.1. Radiological and Clinical Laboratory Assessments

Certain clinical and radiological laboratory analyses are essential to the care of the radiation accident patient [8]. All samples must be placed in separate labeled containers specifying: name of patient, date, time of sampling and type of sample [8]. Samples are to be sent to laboratories with individuals trained in handling radioactive specimens. Storage and waste procedures of collected samples should be coordinated through the RSO. Selected clinical and physiological tests are outlined below:
### Table II. Clinical and Radiological Laboratory Analyses

<table>
<thead>
<tr>
<th>Sample Type</th>
<th>Reason for Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>In all cases of radiation injury:</td>
<td></td>
</tr>
<tr>
<td>• CBC (follow with lymphocyte counts every 6 hours for 48 hours)</td>
<td>• To assess radiation dose. Initial counts establish a baseline then subsequent counts reflect degree of injury</td>
</tr>
<tr>
<td>• Urinalysis</td>
<td>• To determine if kidneys are functioning normally and establish a baseline of urinary constituents.</td>
</tr>
<tr>
<td>Cases of external contamination:</td>
<td></td>
</tr>
<tr>
<td>• Survey of swabs from body orifices</td>
<td>• To assess possibility of internal contamination</td>
</tr>
<tr>
<td>• Survey of wound dressing or swabs from wounds</td>
<td>• To determine if wounds are contaminated</td>
</tr>
<tr>
<td>Cases of internal contamination:</td>
<td></td>
</tr>
<tr>
<td>• Counts of urine (24hr specimen x4 days); Counts of feces (x4 days)</td>
<td>• To determine the presence of radioactivity in body excreta due to incorporation.</td>
</tr>
</tbody>
</table>

#### 3.3.2. Guidelines for Decontamination of Patients

Contaminated wounds and body orifices are decontaminated first, followed by areas of the skin with highest contamination levels. **Frequent glove changes will be necessary.**

**WOUNDS** – Visibly embedded radioactive material are removed with forceps and surveyed for level of contamination. Drape the wound with a plastic covering then surround with absorbent material. Gently irrigate with saline or water for 10 minutes. Monitor wound and absorbent material. Replace with clean absorbent material and repeat irrigation and monitoring as necessary. After decontamination efforts, the wound is covered with waterproof dressing and the area around the wound is decontaminated thoroughly as outlined under skin [9].

**EYES** – Perform on one eye at a time. Irrigate with sterile water for 10-15 minutes from the inner corner to the outer corner of the eye. Collect irrigated fluid in an absorbent towel. Monitor eyes, towel and repeat as necessary.

**MOUTH** – Advise the patient not to swallow and rinse out mouth with sterile water. Mild detergent or toothpaste may be used. Collect discharge, monitor mouth and fluid. Repeat as necessary.

**NOSE** – Advise the patient to blow down into a tissue and spit into a cup. Monitor nasal cavity and discharge. A moistened Q-tip swab may be used to remove radioactivity.

**EARS** – Using an ear syringe irrigate the auditory canal with sterile water, providing the tympanic membrane is intact. A moistened Q-tip swab may be used to remove radioactivity from exterior surroundings. Monitor and repeat as necessary.

**SKIN** – Begin with least aggressive agents and progress to more aggressive ones. Swab the area gently with warm water and monitor swabs. Continue process, avoiding aggressive rubbing, which can break, inflame or irritate the skin. If water is ineffective, a mild soap or surgical scrub can be used. The area should be scrubbed for 3-4 minutes, then rinsed for 2-3 minutes, dried and repeated as necessary. Between scrub and rinse, monitor the area to see if radiation levels are decreasing. **The decontamination procedure stops when the radioactivity level cannot be reduced any further.**

**HAIR and NAILS** – Hair must be cut or washed. This is at the discretion of the RSO or a designated responder.

A final complete body survey is performed after decontamination procedures. Clean floor coverings are laid from the door to the patient. A clean stretcher is brought and the patient is transferred to it, by clean attendants. At the door, the RSO makes a final check of the patient and the stretcher before the patient is taken from the room.
3.3.3. Treatment for Incorporated Contamination

Incorporation is a time-dependant, physiological occurrence related to both the physical and chemical nature of the radioactive contaminant. Incorporation can be rapid (in minutes) or slow (over days or months) [7]. Time can be critical in the prevention of further radioactive uptake.

If internal contamination has occurred or is suspected, the physician should request samples of urine and feces over a four day period. Treatment for selected internal contaminants are outlined below [7]:

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Medication</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iodine</td>
<td>Potassium iodide</td>
<td>Blocks thyroid deposition</td>
</tr>
<tr>
<td>Plutonium</td>
<td>Zn-DTPA</td>
<td>Chelates</td>
</tr>
<tr>
<td>Yttrium</td>
<td>Ca-DTPA</td>
<td></td>
</tr>
<tr>
<td>Uranium</td>
<td>Bicarbonates</td>
<td>Alkalizes urine and reduces chance of tubular necrosis</td>
</tr>
<tr>
<td>Cesium</td>
<td>Ferrihexacyano-Ferrate (Prussian Blue)</td>
<td>Blocks absorption from GI tract and prevents recycling</td>
</tr>
<tr>
<td>Rubidium</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thallium</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tritium</td>
<td>Water</td>
<td>Dilutes</td>
</tr>
</tbody>
</table>

3.3.4. Staff Exit from Controlled Area

Each member of the decontamination and treatment teams goes to the control line where PPE is removed and final surveying is performed [8].
- Remove outer gloves turning them inside out as they are pulled off and place them in plastic bag held open by RSO.
- Give EPD to RSO.
- Remove all tape at pant leg and sleeves and place them in plastic bag.
- Remove outer surgical gown, turning it inside-out and place it in plastic bag.
- Pull surgical pants off over shoe covers and place them in plastic bag.
- Remove head covering and mask.
- Remove one shoe cover and let RSO monitor shoe; if clean step over control line. Repeat for the other side.
- Remove inner gloves turning them inside-out as they are removed.
- RSO to do total body survey.

After staff exits, the decontamination and treatment rooms remain secure until they are checked and cleared by the RSO. A sign bearing “RADIATION---DANGER---RAYONNEMENT” should be posted [8].

References
2. Emergency Response Act, http://www.canlii.org/on/sta/cson/20030205/r.s.o.1990c.e.9/whole.html
5. Niven, E., Education Session: Radiological and Nuclear Incidents, Radiation Safety Office, The Ottawa Hospital, Canada (2002).