

EMERGENCY RESPONSE TO RADIATION INCIDENTS AT HOSPITALS AND MEDICAL FACILITIES

Hospitals and medical facilities house a variety of radiation-emitting technologies used for diagnostics, treatment, and research. While these tools provide immense medical benefits, they also present potential hazards if mishandled, damaged, or improperly secured. Emergencies such as spills, source breaches, equipment malfunctions, or fires in radiological areas require specialised response strategies to protect patients, staff, and first responders. Unlike radiation emergencies in industrial or nuclear power plant settings, incidents in hospitals require careful consideration of vulnerable patients, controlled medical environments, and high-security radioactive materials.

The complexity of hospital-based radiation emergencies requires a coordinated response involving fire departments, hazmat teams, hospital radiation safety officers (RSOs), and regulatory agencies. Understanding the risks associated with these radiation sources, combined with proper training and mitigation strategies, ensures an effective and safe response.

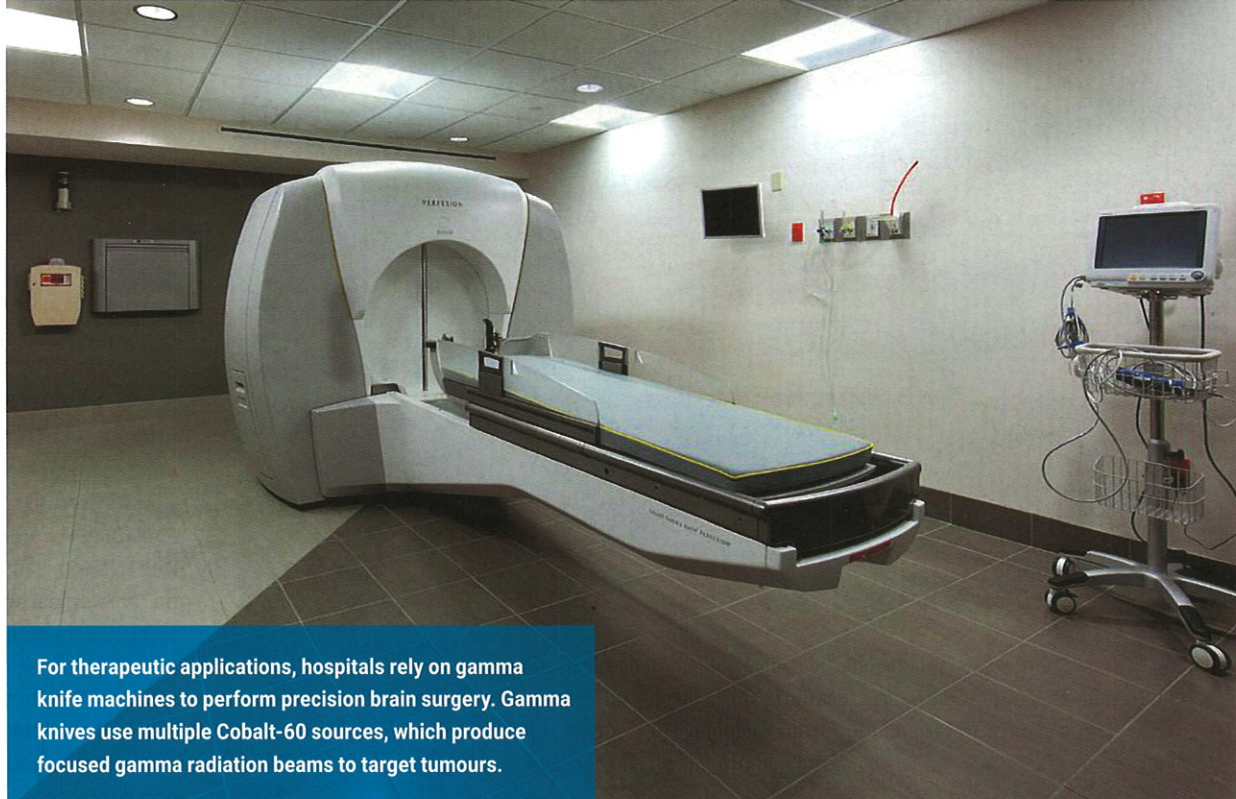
BACKGROUND ON RADIATION IN MEDICAL FACILITIES

Medical facilities house various radiation-emitting equipment and materials, categorised into three primary types: diagnostic imaging devices, therapeutic radiation machines, and radiopharmaceuticals used in nuclear medicine. Each has unique hazards that responders must understand when approaching an emergency.

One of the hospital's most radioactive devices is the blood irradiator, commonly used in transfusion medicine. Blood irradiators contain Cesium-137 or Cobalt-60 sources that emit intense gamma radiation to prevent transfusion-associated graft-versus-host disease (TA-GVHD). Cesium-137 is particularly hazardous because it emits penetrating gamma rays and is water-soluble, meaning it can spread quickly if containment is breached. While blood irradiators are designed with heavy shielding to prevent accidental exposure, fires, natural disasters, or security breaches could lead to contamination risks if the sealed source is damaged or dispersed.

'THE COMPLEXITY OF HOSPITAL-BASED RADIATION EMERGENCIES REQUIRES A COORDINATED RESPONSE INVOLVING FIRE DEPARTMENTS, HAZMAT TEAMS, HOSPITAL RADIATION SAFETY OFFICERS (RSOs), AND REGULATORY AGENCIES'





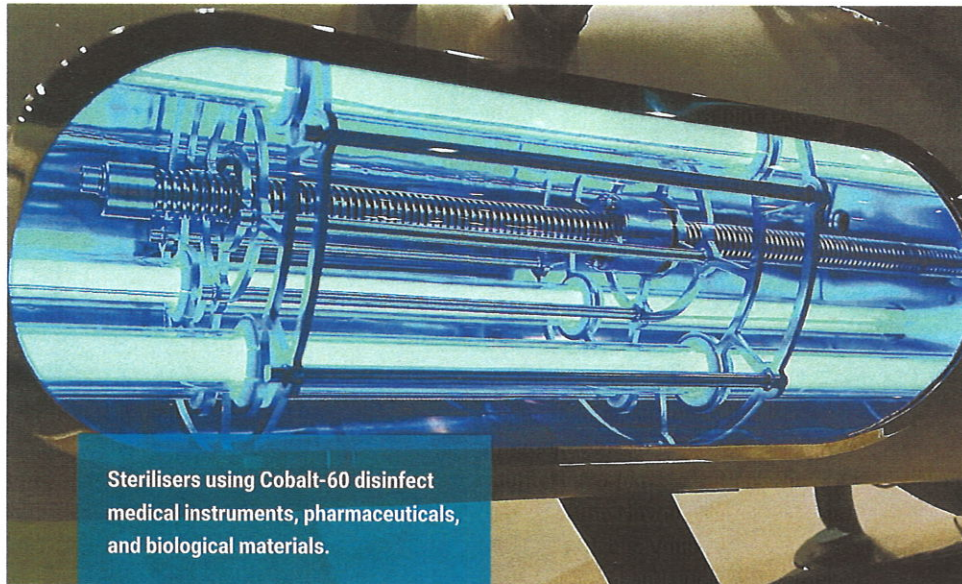
For therapeutic applications, hospitals rely on gamma knife machines to perform precision brain surgery. Gamma knives use multiple Cobalt-60 sources, which produce focused gamma radiation beams to target tumours.



Another critical application of radiation in hospitals is medical sterilisation. Sterilisers using Cobalt-60 disinfect medical instruments, pharmaceuticals, and biological materials. These sterilisation units generate extremely high radiation fields, requiring substantial lead or concrete shielding. In the event of a fire or mechanical failure, responders must be cautious, as exposure to an unshielded source could be lethal within minutes.

For therapeutic applications, hospitals rely on gamma knife machines to perform precision brain surgery. Gamma knives use multiple Cobalt-60 sources, which produce focused gamma radiation beams to target tumours. While these machines provide life-saving treatments, their radioactive sources remain active indefinitely. If a gamma knife machine is damaged or experiences shielding failure, responders must limit time in the exposure area, use remote detection methods, and coordinate with hospital physicists for safe containment.

In nuclear medicine, unsealed radiopharmaceuticals like Technetium-99m ($Tc-99m$), Iodine-131, Fluorine-18, and Lutetium-177 are commonly used for imaging and treatment. Technetium-99m, the most frequently used isotope in medical diagnostics, has a short half-life of six hours, meaning its radioactivity diminishes quickly, but a spill can still cause contamination hazards. Iodine-131, used for thyroid cancer treatment, emits both beta and gamma radiation, posing risks of internal and external exposure if not appropriately handled. The potential



Sterilisers using Cobalt-60 disinfect medical instruments, pharmaceuticals, and biological materials.

for a spill, theft, or misadministration of these materials requires responders to understand decontamination techniques, proper shielding, and containment procedures.

RADIATION KNOWLEDGE AND TRAINING FOR RESPONDERS

Radiation emergencies require specialised knowledge and training to ensure adequate response and minimal exposure. Unlike chemical or biological incidents, radiation is invisible and odourless and cannot be detected without proper instrumentation. Responders must be trained to identify radiation sources, understand exposure risks, and implement protective measures based on the type of radiation involved.

Radiation in medical facilities is typically emitted as alpha, beta, gamma, or neutron radiation. Each type presents different hazards, requiring specific response techniques:

- **Alpha radiation** (e.g. Polonium-210, Radium-226) consists of large, slow-moving particles that cannot penetrate the skin but pose severe internal hazards if inhaled or ingested.
- **Beta radiation** (e.g. Iodine-131, Technetium-99m, Strontium-89) consists of fast-moving electrons that can penetrate the skin but are stopped by plastic or protective clothing. Internal contamination from beta emitters is a significant concern, as they can cause severe damage to tissues and organs.
- **Gamma radiation** (e.g. Cobalt-60, Cesium-137) is highly penetrating, capable of passing through the body, and requiring dense materials like lead or concrete for shielding. Gamma sources are commonly found in blood irradiators, medical sterilisers, and gamma knife machines.

- **Neutron radiation** (rare in medical settings, except in certain research reactors) is highly penetrating and challenging to shield.

Since radiation cannot be seen, responders must rely on specialised detection equipment to assess radiation levels, locate sources, and determine contamination risks.

Training programmes focus on the use of:

- Geiger-Müller (GM) counters to detect beta and gamma radiation, which is common in nuclear medicine spills.
- Scintillation detectors which are highly sensitive instruments for detecting low-energy gamma emissions, such as Technetium-99m in diagnostic imaging.
- Ion chambers which measure high radiation fields and are particularly useful for monitoring exposure around gamma knife machines or blood irradiators.
- Personal dosimeters (TLDs, EPDs) worn by responders to track cumulative radiation exposure and ensure they do not exceed safe dose limits.

In high-risk radiation environments, responders should limit time in the area, maximise distance from the source, and use appropriate shielding materials. Training exercises reinforce these principles through real-world scenarios, such as containing a nuclear medicine spill or responding to a blood irradiator breach.

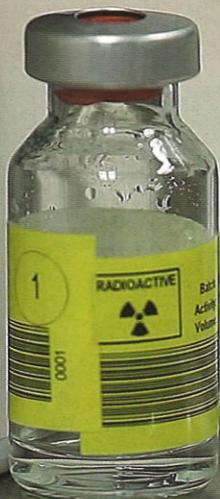
Given the complexities of radiation incidents, responders benefit from attending specialised radiation training courses. Some of the most recognised programmes include:

- **Advanced Radiation Training (ART) at Oak Ridge National Laboratory (ORNL), Tennessee** – This programme provides hands-on experience with live radioactive sources, teaching responders how to use detection instruments, establish contamination zones, and conduct patient decontamination. ART courses are tailored for fire departments, hazmat teams, and hospital emergency personnel.
- **Counterterrorism Operations Support (CTOS) at the Nevada National Security Site (NNSS), Las Vegas** – This focuses on radiological and nuclear emergency response training, including terrorist threats involving medical radiation sources. Responders learn to handle scenarios involving stolen radiological materials, hospital sabotage, or dirty bomb threats.
- **National Fire Academy (NFA) – Radiological Response Training** – This offers courses for fire departments and hazmat teams, emphasising emergency procedures for radiation incidents including those in hospitals and medical research facilities.
- **Department of Energy (DOE) National Training Centre (NTC)** – This provides radiation safety courses for hazmat teams responding to radiological contamination events, including nuclear medicine spills and equipment malfunctions.

These programmes emphasise radiation detection, emergency response coordination, patient decontamination, and regulatory compliance, ensuring responders are well-equipped for any radiological incident.

Radiation emergencies in hospitals often require coordination with multiple agencies. Fire departments, hazmat teams, RSOs, and medical physicists must work together to ensure effective incident containment and safety. In large-scale incidents, agencies such as the Environmental Protection Agency (EPA), the Nuclear Regulatory Commission (NRC), and the Department of Homeland Security (DHS) may be involved in assessing contamination levels and determining decontamination protocols.

Pre-planned joint exercises and hospital radiation drills improve coordination and readiness for real-world incidents. Hospitals should ensure that all personnel – including security, nurses, and physicians – know emergency radiation protocols and proper reporting procedures in case of an incident. ▶



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THE ROLE OF RADIATION MONITORING SYSTEMS (RMS) IN TRAINING & RESPONSE

Radiation Monitoring Systems (RMS) provide real-time radiation level tracking in hospitals, aiding responders in identifying hazard zones and determining exposure risks. These systems are particularly valuable in high-radiation areas like gamma knife suites, blood irradiator rooms, and nuclear medicine storage. Regular training should incorporate RMS data interpretation, allowing responders to assess radiation threats before entering a hot zone.

EMERGENCY RESPONSE PROCEDURES

A structured response is essential when managing radiation emergencies in medical facilities. Incident commanders must quickly assess the situation upon arrival using available RMS data and consultation with hospital personnel. Establishing hot, warm, and cold zones prevents unnecessary exposure and limits contamination spread. The hot zone encompasses the highest radiation levels and is restricted to trained hazmat personnel using specialised PPE and detection equipment. The warm zone serves as a decontamination area, while the cold zone remains contamination-free and functions as a staging area for support personnel.

Each type of radiation emergency requires specific response actions. A gamma knife failure or shielding breach necessitates limiting time in the affected area and coordinating with hospital physicists to determine if the source is still contained. Irradiation machine malfunctions require remote handling and lead shielding to reduce exposure. Spills

involving radiopharmaceuticals such as Iodine-131 or Fluorine-18 demand immediate containment using absorbent materials and controlled access to prevent further spread. Fires in radiological areas introduce additional risks, requiring air system shutdowns and structural assessments to determine if radiation sources remain secured.

Patient and personnel decontamination are critical aspects of the response. Removing contaminated clothing eliminates up to 90% of surface radiation, with further decontamination performed using mild soap and water. Radiation monitoring ensures individuals are cleared adequately before leaving the scene. In large-scale incidents, hospitals may need to establish temporary decontamination areas for affected patients before transferring them to clean treatment zones.

MITIGATION AND LONG-TERM MANAGEMENT

Once immediate hazards are controlled, mitigation efforts focus on dose reduction, contamination clean-up, and long-term recovery. Time, distance, and shielding principles guide responder actions, ensuring exposure remains within safe limits. If iodine-based radioactive materials were involved, potassium iodide (KI) may be administered to reduce thyroid absorption in cases of internal exposure.

Hospitals must integrate RMS data into post-incident analysis to assess residual contamination and determine when affected areas can be safely reopened. Radiation surveys help identify remaining hazards, while decontamination teams use specialised cleaning methods to remove contamination from surfaces and medical

equipment. Personnel exposure monitoring through bioassays and dosimetry ensures that responders and hospital staff receive appropriate medical follow-up.

Regulatory compliance is a crucial component of long-term management. Incident reports detailing radiation exposure levels, contamination spread, and mitigation efforts must be submitted to agencies such as the NRC and EPA. Hospitals should review their radiation emergency plans, and update protocols based on lessons learned. Conducting post-incident training exercises reinforces response effectiveness and identifies areas for improvement.

Hospitals and emergency responders can enhance their preparedness for future incidents by continuously improving radiation safety measures. Strengthening partnerships between fire departments, hazmat teams, and medical institutions ensures a swift and coordinated response to any radiological emergency, protecting the public and those on the front lines.

CONCLUSION

Hospital-based radiation emergencies require a specialised response that balances rapid intervention with patient safety and contamination control. Understanding radiation hazards, maintaining proper training, and implementing coordinated response procedures allow emergency personnel to manage these complex incidents effectively. By leveraging advanced training programmes, integrating RMS data, and enforcing mitigation strategies, responders can minimise exposure risks and ensure a safe return to normal hospital operations. Continuous education and interagency collaboration are essential in maintaining readiness for future radiological emergencies, reinforcing that preparedness saves lives. 🔥



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