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Initial Management of Radiation Injuries

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Abstract

The increasing utilization of radioactive isotopes in industry, medicine and research has raised the question, "How should hospitals deal with radiation injuries when they occur?" A system for initial management of radiation injuries has been developed by Radiation Management Corporation. Radiation injuries are classified and a treatment plan outlined for each at the emergency and short term medical care phase. This system includes clinical prognosis as well as a detailed plan for quick set up of a Radiation Emergency Area in any hospital. Procedures for patient admission, preparation of the facility, general decontamination, sample taking, and wound decontamination are included.

INTRODUCTION

Prior to 1895, the only way to study the internal aspect of the human body was through surgical procedures. When Wilhelm Konrad Roentgen discovered the ability of ionizing radiation to penetrate opaque objects including the human body, he ushered in a new medical era. Within five years of his discovery, excessive and unnecessary exposure to radiation led to the first diagnosis of adverse effects…radiodermatitis and cancer (REF 1). Since these first radiation injuries physicians and engineers have worked assiduously to develop the safest possible methods for dealing with radiation. As a result of this attention to safety, overexposure to radiation is relatively infrequent. In October 1979, at an International Conference on Radiation Injuries at Oak Ridge, Tennessee, the worldwide experience with radiation was reviewed (REF 2). The results (see Table I) are impressive. The question still remains, however, "How can we best manage these radiation injuries when they do occur?"

Ten years ago, Radiation Management Corporation (RMC) was established by the Hospital of the University of Pennsylvania and eight nuclear utilities in the Mid-Atlantic region of the United States. RMC's responsibility is to provide the facilities, expertise, and equipment to augment to the Hospital of the University of pennsylvania's capability to completely evaluate and treat radiation injury. RMC developed the Regional Approach to the Management of Radiation Injuries (REF 3). In this three part approach, the nuclear facility is equipped and and trained for handling the first aid of radiation injuries, and a nearby hospital

This article is based upon the system for initial management of radiation injuries developed by Radiation Management Corporation. The author, Roger E. Linnemann, M.D., is President of Radiation Management Corporation, Associate Professor of Clinical Radiology, University of Pennsylvania School of Medicine, Philadelphia, Pennsylvania, and Visiting Associate Professor of Radiology, Northwestern University Medical School, Chicago, Illinois.

is responsible for emergency care. RMC and the Hospital of the University of pennsylvania provide definitive evaluation and care. RMC coordinates this system by designing facilities, providing supplies and equipment, developing procedures, and conducting training at each level of care. A second definitive care center has been established at Northwestern University Medical School in Chicago, Illinois. In addition, RMC has prepared 25 hospitals near nuclear power sites to provide emergency care.

Past experience does not indicate a need for all hospitals to maintain facilities for definitive evaluation and care. What is required, however, is a system that can be adopted by any hospital for initial management of radiation injuries. This is the system developed by Radiation Management Corporation.

CLASSIFICATION OF RADIATION INJURIES

Radiation injuries can be classified medically according to the source relationship to the patient and the clinical picture evoked by this relationship (see Figure I).

External Exposure As indicated in Figure I, external exposure may be classified as whole or partial body exposure. Whole body exposure occurs when a large source of radiation, outside but not in contact with the body, irradiates the total body or a major portion of the body with penetrating radiation. This occurs in criticality accidents or when large gamma-emitting sources are involved, such as cobalt-60 or iridium-192. Such patients constitute no hazard to medical attendants as they are not themselves radioactive. The clinical picture is usually characterized by symptoms resulting from depression of the hematopoeitic system. With doses under about 100 rad symptoms will be minimal; with doses over about 1000 rad the clinical picture is determined by the extent of damage to the gastrointestinal tract. This can lead to a severe and practically irreversible disturbance of the electrolyte equilibrium. In the majority of cases, however, treatment is directed to combating secondary complications such as infections and bleeding.

On the other hand, partial body exposure occurs when only a part of the body, usually an extremity, receives a much higher dose then the rest of the body. For example, severe finger overexposure might occur during adjustments of X-ray defraction apparatus. In this case, local rather than systemic manifestations occur. The clinical picture of local radiation injury consists of erythema, edema, vesiculation and with high doses, tissue necrosis.

External Contamination The presence of radioactive materials on or in the body is referred to as radioactive contamination. This contamination is classified as external or internal. External contamination is the presence of radioactive materials on the body or clothes. In the absence of other external exposure to penetrating radiation, external contamination represents predomi-

Figure I. Classification of Radiation Injuries.

- *External Exposure
  - Whole Body
  - Partial Body
- *Radioactive Contamination
  - External
  - Internal
- *Combination Exposures
  - Contaminated Wounds
  - Combined Injuries

nantly a risk to the skin because the dose to superficial layers of the body is much higher than that to deep-lying organs. It is unlikely that hospital emergency rooms will receive patients with purely external contamination. In as a accident in which the patient is injured with incidental contamination as complication, prompt medical attention must be given in spite of the contamination, and special facilities for controlling possible spread of the radioactive substance required.

Internal Contamination Internal contamination is caused by inhalation, ingestion or absorption of radioactive materials. These materials will either be deposited throughout the entire body or concentration does not present a hazard to a ttendants or the medical facility. The radiation emitted by internally deposited isotopes is absorbed for the most part by body tissues. The amount excreted in feces and urine is too small to constitute a hazard. Usually the total body. dose will be too low to cause acute radiation sickness but the dose to specific organs may be appreciable. The diagnosis and treatment of internal contamination presents special problems to be discussed later.

Combination Exposurse and Injuries A combination of exposures or the existence of concomitant non-radiation iniuries requires complex measures to insure optimun medical care while protecting attending personnel. One example is a patient who, as a result of an explosion involving radioactive materials, receives whole body exposure, inhales radioactive materials and has a radioactive foreign body imbedded in a wound. This injured and contaminated patient requires special hospital facilities where attendants can administer emergency treatment while controlling the spread of contamination.

Treatment Priorities Exposure to ionizing radiation results in a physical insult to the body in which energy is deposited in a cell. This deposition of energy disrupts molecules, particularly DNA, in the cell. Depending upon the intensity of radiation and the duration of the exposure, the cell will repair the damage, be overwhelmed by the damage (death), or retain the damage with manifestations years later in carcinogenesis or genetic mutation. Since radiation injury is seldom, if ever, lifethreatening, any other traumatic injury or life-threatening disease takes precedence in emergency medical treatment. The order of priority for treatment is:

1) the injured and contaminated patient
2) treatment for certain types of internal contamination
3) the patient exposed only to external total body radiation
4) the patient exposed to external local body radiation

RADIATION EMERGENCY AREA

Special hospital facilities will allow emergency room personnel to treat traumatic injury while controlling the spread of contamination and reducing radiation hazards to themselves and the patient. The facility is referred to as a Radiation Emergency Area (REA). The plan described here

Table Ⅰ. The list is quite complete for total body exposure and underrecorded for serious local exposures.

	Accidents	Serious Exposure	Deaths
Total Body Exposure	129	354*	18
Local Exposure	46	72	—
Internal Contamination	16	23	2

*Excluding Atomic Testing

can be adopted by any hospital; and when backed up by a good support system, will provide effective short term and definitive care.

The REA must be an area that can be set up on short notice and in which traumatic iujury can be conveniently treated. In addition, the area must be one that can be temporarily denied hospital use. For this reason the emergency room itself is not usually the best choice. The most approoriate area is one that has direct access from the outside and where access can be easily controlled from the inside. The area must have an ample water supply with showers and sinks. The air-circulation system should be separated from the rest of the hospital. In this case, either turn the system off or have the outflow parts of the system filtered. Areas that might be appropriate to utilize as a Radiation Emergency Area are the physical therapy facility, the morgue, or any combination of rooms or hallways that meet the above specifications.

A suggested floor plan for the REA is indicated in Figure Ⅱ. The REA should consist of a holding area, a decontamination area, and a buffer zone between the main part of the hospital and the decontamination room. Two control points should be established. One located between the buffer zone and the main part of the hospital and the other at the outside entrance to the REA. All personnel and equipment must pass through these control points. As they enter, the names of all personnel are recored and each person is provided with personal dosimetry. As personnel leave, the dosimetry is collected and later analyzed. A guard should be posted at each control point. The holding area is utilized for triaging patients, or for detaing contaminated personnel who are not injured but require survey and decontamination at a more convenient time. The decontamination area is the area in which patients are actually treated and decontaminated. The floor of the holding area, the decontamintion area and the buffer zone should be covered with a non-skid material such as Herculite which can be either disposed of or decontaminated.

As soon as the decision has been made to utilize the REA, remove all personnel from the area except those who will actually attend the patient. On the other hand, any personnel in the REA after the patient has entered, or in any area through which the

Table Ⅱ. Health Physics Supplies & Equipment for. REA.

Description
Beta/Gamma Dosimeter
Radiation Survey Meter
O-1 R Dosimeters, self-reading
Dosimeter Charger for Self-Reading Dosimeter
Thermoluminescent Dosimeters, Badge type
Thermoluminescent Dosimeters, Ring type
Decontamination Table Top, w/splash guard, stretcher, hose
Plastic Receptacle for Contaminated Water, 30 gal.
Lead Container for High Activity Specimens
Decontamination Kit
Sample Taking Kit
Non-Skid, Water Resistant Floor Covering (to fit the REA)
5′ Roll of Non-Skid, Water Resistant Floor Covering
Radiation Signs and Rope
Aprons, plastic, disposable
Disposable Gowns, Masks, Caps, Shoe Covers, Gloves
Large Trash Cans
Plastic Trash Can Liners
Water Hose
Flexible (adjustable) Shower Head

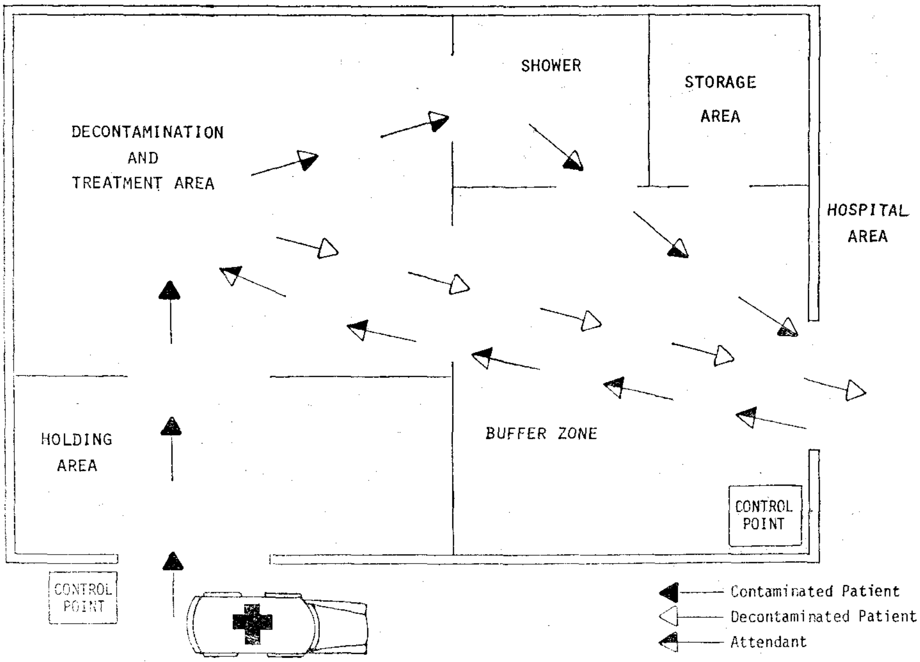


Figure Ⅱ. Radiation Emergency Area.

patient has passed, must remain until later surveyed, decontaminated if required, and released. All personnel must remain in the REA once they have entered. This applies to all equipment and supplies as well. The basic principle is that everything and everybody must remain in the area and traffic never moves in the reverse direction.

Equipment and supplies Remove all unnecessary equipment and supplies from the area during setup except those absolutely necessary for treatment and handling of the patient. Special equipment required for the REA is stored in the area (see Table Ⅱ). Other medical and surgical supplies necessary to treat and sustain a traumatic injury should be brought from the emergency room as required. Once any equipment is in the area it should remain there to avoid contamination of other areas in the hospital.

Since wash water should be contained and collected, a special container is used to treat and decontaminate the patient. A suggested decontamination table top is represented in Figure Ⅲ. Splash guards minimize cross-contamination of the attendants and floor. A 30 gallon plastic receptacle is used to collect contaminated water which should be assayed following the procedure. If the water meets regulatory guidelines, it may be disposed of in the hospital sewer; if activity is high, it must be disposed of with other nuclear medicine wastes.

Attendant Garb In addition to prepartion of the facility and equipment, at least three attendants should be properly clothed prior to patient arrival. These include a physician, a nurse in the decontamination room, and a nurse in the buffer zone. Other attendants should also be properly attired but waiting in the main part of the hospital, just beyond the control point. Suggested clothing for all attendants is indicated in Figure Ⅳ. Attendants should wear one surgical cap, one pair of surgical of preferably plastic or rubber shoe covers, two sets of surgical

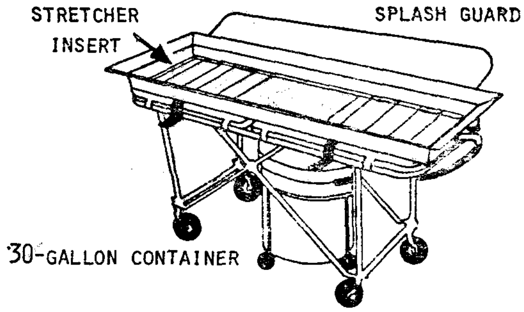


Figure Ⅲ. Decontamination Table Top.

gowns, two plastic aprons and two sets of surgical gloves. In addition, each attendant should be supplied with dosimetry. Dosimetry should a film badge or thermoluminescent dosimeter (TLD) badge worn at mid-chest under the inside surgical gown. A pencil dosimeter should be worn at the neckline attached to the inside surgical gown, and a ring dosimeter should be placed on either hand under the surgical gloves with detecting element at the palm.

INITIAL MANAGEMENT

Patient Arrival Under optimum conditions the hospital should be notified in advance

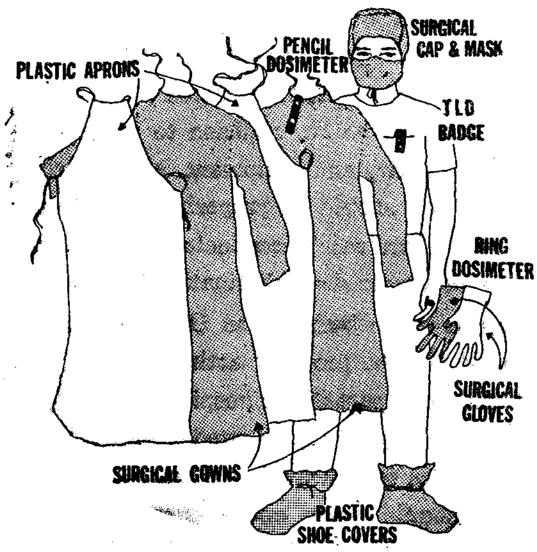


Figure Ⅳ. Attendant Garb.

of the impending arrival of a contaminated and injured patient. In this case, the REA can be prepared in advance; but it is entirely possible that a patient may arrive without prior notification. If radioactive contamination is not indicated until after the patient has entered the emergency room, immediately secure the entire area. Allow no person or eqipment to leave the area and establish a control point through which personnel and equipment may pass into the area. Admit other patients to uninvolved areas of the emergency room.

If radioactive contamination is discovered before the ambulance with a radiation survey meter to ascertain the presence and extent of contamination. Contaminated patients are admitted to the REA; if in doubt, assume that contamination exists and admit the patient to the REA as a precautionary measure.

The patient should be sustained in the ambulance if the clinical condition warrants it. If immediate life-saving measures are not necessary, the patient can be observed from a distance while the REA is prepared. Distance is an effective way to decrease exposure; therefore, an area of about eight feet should be cleared around the ambulance. Equipment and supplies other than those necessary for the treatment of the patient remain in the vicinity of the ambulance. Ambulance attendants place the patient on the special table provided. Before leaving the decontamination room, one of the ambulance attendants should give the physician a report on the medical condition of the patient, as well as any information about the radioactive contamination and exposure of the patient. Ambulance attendants are then instructed to remain near the ambulance until they can be surveyed for

Table Ⅲ. Radioactive Contamination: Emergency Room Procedures.

1. Prepare for Patient Arrival
   - Prepare Rea
   - Prepare Attendants
2. Admit Patient
   - Stabilize
   - Survey
3. Initial Decontamination
   - Remove Clothes
   - Obtain Samples
   - Survey
   - Scrub
4. Clean up Deconcamination Area
   - Remove Contaminated Articles
   - Remove outer Garment
5. Decontaminate Woud
   - Survey
   - Obtain Samples
   - Cleanse
6. Perform Final Decontamination
   - Survey
   - Cleanse
   - Attend to Fixed Contamination
7. Patient Transfer and Attendant Exit

contamination. If the attendants are contaminated, their clothes should be removed and retained in a plastic bag. They should shower and be monitored before leaving. If the ambulance is contaminated, it must not be released from the area until it has been properly decontaminated.

Resuscitation and Stabilization In the decontamination room, the first priority is resuscitation and stabilization. Contamination and radiation should be ignored at this point. A suggested procedure for handling of the contaminated and injured patient is indicated in Table Ⅲ. If the wound is unstable it should be undressed, stabilized and redressed with a plastic covering until it is decontaminated later. The wound is not usually decontaminated first unless transuranic elements such as plutonium or americium are involved.

Initial Decontamination As soon as the patient has been stabilized, begin the initial decontamination. The clothes and blankets brought in with the patient are carefully removed and placed in plastic bags in large containers. Any dosimetry and all metal objects such as belt buckles, rings, glasses, etc., should be removed and placed in a special container for later analysis. Before actual decontamination begins, the patient should be carefully surveyed with a radiation survey instrument and the results recorded. In addition, samples should be taken and labeled with the patient's name, the body location and the time of collectin. Obtain the following samples: Nasal, aural, oral, skin wipes, hair, nails, metallic objects, blood, urine, feces, wound exudate, tissue, vomitus, and irrigation fluids. The out-side of any container requiring immediate analysis must be rinsed with water, then monitored at the control point before it is taken to the lab. The contents of a suggested sample taking kit are indicated in Table Ⅳ.

The purpose of the initial decontamination is to remove as much of the external radioacive contamination as possible. Upon completion of this initial decontamination, levels should be no higher than the few millirad per hour or counts per minute range. Initial decontamination is basically a general showering or bathing of the patient with generous amounts of water and soap. This is most effective with patients who have widespread contamination. If contamination is localized uncontaminated areas of the patient can be isolated by plastic drapes taped to the patient, then proceed with local decontamination.

For the patient with widespread contam-

Table Ⅳ. Sample Taking Kit.

Sample Type	Sampling Instrument
Nasal	swabs
Aural	swabs
Oral	swabs
Skin Folds	swabs
Swipes	Nucon smear
Hair	Small container
Nails	Small container
Metallic Objects	Medium container/Plastic bags
Blood	10cc Vacutainers
Urine (24-hour)	2000cc Plastic container
Feces	Fecal Container
Wound Exudate	swabs eyedropper & bottle
Tissue	Containers
Vomitus	Fecal Container
Irrigation Fluids	100cc Plastic bottle
	Envelopes
	Labels
	Pens...(1) grease; (1) writing
	Scissors
	Tweezers
	Clippers

ination, begin by cleansing the areas of highest contamination. Use copious amounts of tepid water, a plain detergent, soft brushes, sponges and cotton balls. A list of decontamination supplies is provided in Table Ⅴ. Scrub the patient for about two or three minutes but avoid vigorous scrubbing as it may abrade the skin and cause the potential absorption of the radioactive substance. Frequent rinsing of the patient and changing of brushes and cotton balls will prevent recontamination. The table top must also be thoroughly rinsed or later surveys of the patient may be falsely high. In addition, attendants should frequently wash their gloved hands to prevent recontamination of the patient. After this initial decontamination, dry the patient thoroughly with turkish towels, clean the container and resurvey the patient. Experience indicates that about 90% of the contamination will be removed after first washing.

Table Ⅴ. Decontamination Kit.

Skin Decontamination
- Absorbent balls, extra large
- Sponge-holding forceps
- Plastic beaker, large
- Preop Sponges
- Surgical Scrub Brushes
- Wash Bottle (for localized contamination)

Decontaminants (Skin only)
- Plain Detergent, bottle (for first decon effort; general)
- Clorox, bottle (for second decon effort)
- Hydrogen peroxide (H_2O_2), bottle (for third decon effort)

Wound Cleansing
- Gauze Pads, sterile
- Sterile Surgical Gloves, assorted sizes
- Solution Bowl, plastic
- Syringe, 50cc
- Cotton-tipped Applicators
- Aperture Drape

Decontaminants (Wounds)
- Saline Solution, normal*, Sterile Bottle
- Surgical Scrub, Bottle

Treatment Agents
- Skin Cream, jar
- Collodian, bottle

Miscellaneous Materials
- Prep Kit
- Scissors, heavy duty
- Patient Radiation & Medical Status Anatomical Diagrams
- Plastic bags, assorted sizes (to hold decon materials after use)
- Tissue Paper, box
- Notebook
- Pencils
- Fingernail Clippers

*Shelf life=2-3 years

Room Cleanup The purpose of this cleanup effort is to reduce background radiation in the room so that low levels of radiation remaining on the patient may be accurately measured. All contaminated articles in the room are carefully placed in plastic bags. This includes instruments, brushes, blood pressure caffs, stethoscopes, etc. Those attendants in the room remove their outer plastic apron, surgical gown and gloves. These also are placed in plastic containers which are double-bagged, sealed, and placed outside the room. preferably they should be removed through the door to the outside through which the patient entered.

The decontamination procedure may take a few hours if repeated scrubbings and surveys are required. Attendants should, therefore, periodically check their pencil dosimeters to assess personal radiation exposure. As a guideline, attendants should receive no more than five rad (5000 millirad) during any decontamination procedure except to save a life or when other attendants are unavailable for rotation into the room.

Wound Decontamination After initial decontamination is completed, the wound should be undressed. Begin by removing all visible foreign particles. These foreign particles, blood, exudate and debrided tissue should be collected and retained for later analysis At this point, survey the wound and record the results. Next, clean and decontaminate the wound. Again, copious amounts of sterile water or saline may be required. After this cleansing, carefully dry and resurvey the wound. This process of cleansing, drying and surveying is repeated until readings are in the low millirad per hour or counts per minute range. At some point the removal of tissue, not because of necrotic process, but to remove retained radioactivity, may be required. If such tissue removal will compromise function, seek expert advice. A small amount of radiation left in the wound may represent less risk than interference with a major body function. The wound may be secondarily closed and decontamination completed later when expertise and instrumentation are available. for rare earths, plutonium or transplutonics, the wound may be cleansed with the chelating agent Calcium-diethylenetriaminepentacetic acid (Ca-DTPA) 1% solution. Once the wound has been completely decontaminated or decontaminated to levels that pose no serious threat to tissue in the area or to absorption and translocation of contamination, the wound should be closed, dressed and a plastic covering taped over it. At this point eyes, nose or other orifices should be decontaminated, if necessary, by irrigation with sterile water or saline.

Final Decontamination The purpose of this step is to remove any loose contamination still present on the body. Survey carefully to determine the location of residual contamination. Repeatedly scrub and survey until either background readings alone are achieved or continued efforts result in no further lowering of the readings. Pay special attention to fingernails, body folds and hair. In some cases, shaving of the hair may be required to remove contamination. On the other hand, if contamination is fixed, the area can be isolated with plastic drapes with taped edges or a fixing agent such as collodian may be utilized. A surgical glove may be used effectively when the fixed contamination is on the hand. The plastic covering may be removed 24 hours later, and frequently, the sweating mechanism will have removed the fixed contamination.

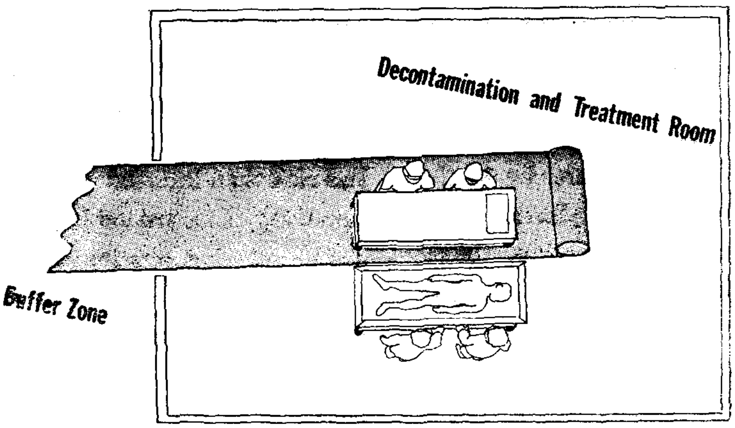


Figure Ⅴ. Clean Floor Covering as Utilized for Patient Transfer.

After the final decontamination, the patient is thoroughly dried and a sooting skin cream may be applied to abraded areas if necessary. The container should be cleaned out. Then any contaminated articles in the room are removed in plastic bags and a final survey is completed. If the patient is no longer contaminated or has fixed contamination that is properly sealed. remove the patient to the main part of the hospital.

Patient and Attendant Exit Removal of the decontaminated patient from the REA to the main hospital facility requires special precautions. A clean floor covering should be rolled in from the buffer zone to an area beside the table on which the patient has been treated. Attendants already in the decontamination room should avoid stepping on this floor covering. At the same time, attendants from the buffer zone should avoid stepping off this floor covering as they roll in a clean stretcher (see Figure Ⅴ). The new stretcher should remain on the clean floor covering as it is placed beside the table on which the patient is located. Attendant who are already in the room should thoroughly wash their gloved hands and remove their aprons. If, after surveying, they are free of radioactivity, they may assist in lifting the patient onto the clean stretcher. After the patient is removed to the buffer zone, both patient and stretcher are again surveyed. If all contamination has been removed the patient may be admitted to the hospital. If fixed contamination remains, the patient should be placed in a single room and treated as a patient who has been receiving radioisotopes as in nuclear medicine diagnostic or treatment procedues.

Upon removal of the patient, attendants who were in the decontamination room should proceed to the point between the decontamination room and the buffer zone. Here they remove the second set of surgical gowns, caps, gloves and their shoe covers and place them in a container inside the decontamination area as they would for a septic case. The attendant is then surveyed for residual contamination. If indications of contamination are noted the attendant should shower and be resurveyed. At this point, all dosimetry must be collected and recorded; then samples should be placed in a plastic bag and delivered to a laboratory for analysis. Before the area can be returned to normal use, experts in cleanup of radioactive contamination should survey the area and dispose of all contaminated articles.

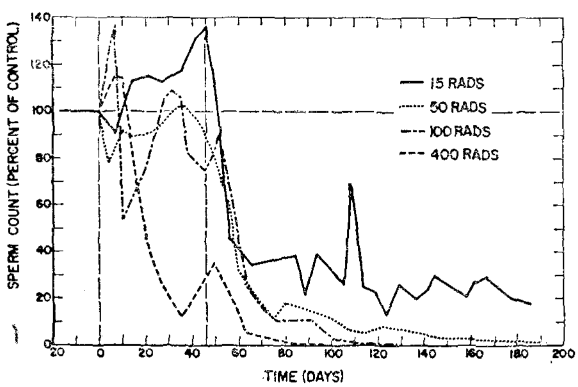
CLINICAL TREATMENT AND PROGNOSIS

The clinical course of a radiation injury is determined by the dose received and will evolve over a period of days and weeks. Usually definitive treatment and prognosis must be delayed until the type of radiation or radionuclide and dose received are determined. If appropriate laboratory facilities are not available in the hospital, samples may be assayed elsewhere and the results received upon within a few days. The

Table Ⅵ. Dose-Effect Relationships.

5 Rad	No Observable Effects
50 Rad	Blood Threshhold
100 Rad	Symptom Threshhold
350 Rad	50% Lethality
600 Rad	Approaching 100% Lethality

These relationships for midline depth doses of the total body are useful in the initial evaluation of a patient. These exposures are for pentrating gamma or x-ray radiation that occurs within a duration of a few hours.



Time-course of sperm counts of normal man following high-intensity exposure to various doses of 190-kVp x rays [Heller, 1966]. (Ref 5)

Figure Ⅳ. Dose/Response Relationship for Human Testes.

organs of major concern are total body, gonads, eyes, skin, thyroid, wounds and other internal organs. The dose to these organs should be calculated as soon as possible. Initial laboratory studies to assist in these calculations are I-131 uptake, hemogram, 24 hour urine, 72 hour feces, whole body count, and lymphocyte chromosome analysis.

External Irradiation-Whole Body When a major portion or the total body has been exposed to a penetrating dose of radiation for a short time (hours) acute radiation sickness syndrome occurs. The onset of symptoms in relation to the time of exposure is important in dose evaluation, as well as in predicting the future course of the disease. Nausea, vomiting and general malaise are the sine qua non of acute radiation syndrome. Usually it takes a minimum exposure of 75 rad to induce these symptoms; and most patients will experience nausea and vomiting with 150 rad or greater (REF 4). Nausea and vomiting that begin within two hours following exposure and persist over the next 24 houre indicate a serious exposure, greater than about 300 rad midline dose. Nausea and vomiting that begin after four hours indicate a midline dose of about 200 rad. If nausea and vomiting do occur within 24 hours, the patient has probably received a dose of less than about 75 rad midline exposure. Diarrhea within the first few hours indicates a grave prognosis with exposures greater than 400 rad. Central nervous symptoms that occur within the first few hours indicate a fatal prognosis of at least 2000-3000 rad exposure. If erythema occurs within 24 hours following total body exposure to penetrating radiation, the prognosis is grave.

A white cell count and differential should be obtained and analyzed manually as soon as possible and three or four times during the next few days. The rate at which peripheral blood elments drop are indicators of the dose received and the expected clinical course. Circulating lymphocytes are the most sensitive cell; in serious exposures these lymphocytes can completely disappear within 24 to 48 hours. If the level at 48 hours is 1200 count per cubic millimeter, prognosis is good; at 300-1200, prognosis is guarded; and at 300 or less, prognosis is poor. platelets and red cell element are less sensitive to radiation and therefore are not as valuable early indicators of the dose received. Table Ⅵ shows the dose/effect relationship that is useful in the initial evaluation of a patient. The Lethal Dose 50% (LD50/60) for human is between 250 and 350 rad (REF 4). Exposures of 600 rad without treatment will be fatal for most humans. With hematological care available today in most medical centers, a patient might be retrieved with doses as high as 800-1000 rad.

A heparinized 10-cc sample of peripheral blood should be obtained for chromosome analysis on circulating lymphocytes. Since the lymphocytes may disappear early with very high exposures this blood sample should be obtained immediately and arrangements made to send it to a laboratory experienced in interpreting chromosome aberrations due to radiation exposure. These aberrations are good indicators of uniform total body exposure and are quite linear with exposures above 15 rad. A control sample of heparinized blood should be obtained from an unexposed person. The purpose of the control sample is to check on any irradiation of the samples that may occur enroute to the laboratory. Sperm evaluation is also helpful in estimating radiation exposure. The spermatogonia type B are sensitive to doses as low as 15 rad. Figure Ⅵ (REF 5) shows the dose/response ralationship for human testes. Bone marrow examinations are also helpful in estimating dose and determining treament; as with sperm counts, these should be done at a center that will provide definitive care.

*Localized Irr*adiation Severe local damage is a result of serious radiation exposure to a small portion of the body (e.g., hands or feet). As with whole body irradiation, the extent of the damage is determined by the type of radiation, the energy involved and the geometrical relationship of the source to the skin. For example, sealed sources directly in contact with the skin produce a more superficial lesion that develops early. Sources removed from the skin but emitting penetrating radiation may produce a deeper lesion resulting in an obliterative endarteritis *with long-term necrosis* and even gangrene. In either case, the patient has few early symptoms. Feelings of warmth, tingling and hypersensitivity have been recorded with excessve exposures. The patient may show erythema and bullae formation within hours to days. The erythema in oher cases may come in waves, occurring in the *first few days; then in one to two weeks,* and again, as long as three weeks later. If erythema occurs within 24 huors, a severe clinical course of local damage can be expected. If early severe clinical course of local damage can be expected. If early erythema is complicated by blanched areas, then one can suspect a massive dose to the skin As the dose increases, the waves of erythema become almost continuous. In dark-skinned people, this initial erythema may be missed. Colored photographs should be obtained initially and frequently to follow the extent of the damage. If indications of skin exposure do not appear within a few days, the prognosis is good. Lesions can develop as late as two to three weeks; therefore, the first physician to see the patient should withhold prognosis. Epilation is an important sign in evaluation of local exposure. However, this is not helpful early, as epilation does not occur for approximately two to three weeks. An absorbed dose of about 300 rad to the hair follicles is necessary for epilation; if the exposure is not greater than about 700-800 rad, the hair will regrow in six to eight weeks. In evaluating epilation, two comparable areas of the body should be examined for unusual hair distribution. For example, the hair of manual laborers may wear off from parts of the hands.

Baseline and periodic slit lamp examinations of the eyes should be done with suspected eye exposures greater than 10 rad neutrons and 100 rad gamma or x-ray.

Generally local exposures require little treatment on an emergency basis. An antipruritic or astringent solution may relieve initial vague symptoms. Dose evaluation will be helpful not only in prognosis, but also in planning future treatment of the patient. Often these dose estimates are difficult to obtain and require expertise in mockup of accidents and dose calculations. Dose estimates are not required in the initial emergency treatment of the patient. Often initial dose estimates are somewhat higher than actual exposures. In any case, the patient is treated on the basis of symptoms rather than dose received.

Internal Contamination Since it is almost impossible for the body to internally incorpoate enough radioactive isotopes to result in acute radiation syndrome, the objective of treatment is to reduce the risk of long-term biological effects. There is little to offer in the way of specific treatment in the emergency phase in most cases. Often in this phase lack of detailed information about internally incorporated isotopes presents the physician with a conflict. In some cases, treatment is most effective if started early, but at the some time, complete evaluation may take days to complete. Since treatment for most isotopes carries little risk, therapy should be started immediately for its effect. At some point it can be interrupted or discontinued until the evaluation is completed. Specific treatment requires detailed and complex analyses, including bioassay of excreta and blood, as well as whole body counting. Immediately begin 24-hour urine collections and 72-hour fecal collections and arrange for analysis at a radiation laboratory. The most reliable method of determining what types of isotopes were incorporated, how much is present in the body, and where it is located is whole body counting. In addition, a thyroid uptake study for I-131 is required immediately, especially if the accident occurred in a nuclear reactor.

Frequently, decisions about required emergency treatment can be based on the isotopes involved. If iodine is a major contaminant, immediately administer stable potassium iodide. This will decrease the uptake of radioactive iodide in the thyroid gland by 50% if administered within fours, and more if administered earlier. When tritium is the major contaminant, forced fluids of at least five to eight liters of water per day should be administered. This enhances turnover of body water (and hence, tritium) from the normal 12-13 days to 3-4 days (REF 6). On the other hand, cardiac or renal disease may contraindicate this approach.

The major biological contaminants in fission product contamination (nuclear accidents) are iodines, cesium, cobalt and manganese. Emergency treatment for internal contamination is oral potassium iodide; inhalation of Ca-DTPA; oral phosphaljel to decrease absorption of cesium; and oral prussian Blue to decrease absorption of strontium (REF 7).

Although direct ingestion of radioactivity seldom occurs, inhaled material is removed by cilliary action of the lung and can enter the gastrointestinal tract. A cathartic, such as magnesium sulfate, will enhance elimination. In the case of uranium incorporation a profusion with bicarbonate physiological solution is indicated (REF 7). When plutonium or transplutonics are involved inhalation of a Ca-DTPA ampule in aerosol form is indicated.

Once initial treatment has been completed, a detailed evalua-tion of the patient is required. This is most effective if completed in a medical center equipped with instrumentation and expertise in evaluating the type, amount and location of incorporated isotopes, and therphy required.

PSYCHOLOGICAL STRESS

When radiation accidents do occur, the patient may be anxious and fearful. The patient should be handled immediately and properly by a physician who understands the problem and can convey an atmosphere of calm reassurance. A sedative or relaxation drug, such as Valium, might be administered. If necessary, anti-emetics might be administered for nausea and vomiting. Since there are no available drugs to interrupt the course of radiation injury, treatment is symptomatic and supportive. Except for massive doses, patients will respond to this systematic treatment and recover from the acute phase of radiation sickness.

SUMMARY

Experience indicates that major serious radiation injuries have been infrequent and should continue to be so. with the increasing use of radiation in medicine, industry and research, however, an increase in suspected or less serious exposures to radiation is anticipated. These require expert handling and require the same facilities and equipment that are necessary to treat actual overexposure. Radiation injury, itself, is seldom if ever life threatening. Therefore, all instances of combined injury…the traumatic injury or serious illness that accompanies radiation injury--take priority. Following resuscitation and stabilization of traumatic injury, the patient should be decontaminated. At this point, time is on the physician's side. Except for initial treatment which may be helpful in certain types of radiation injury, a complete evaluation of radiation exposure is necessary before more definitive care can be administered. Finally, hospitals accepting the responsibility for emergency treatment from a nuclear facility or for cases that appear at their emergency rooms should assure themselves of the availability of radiation expertise and a radiation laboratory to back up their own emergency capability. In this way, victims of radiation injury will receive the best possible care at each step of the way.

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