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MCRP 4-11.1B
NTRP 4-02.21
AFMAN 44-161(I)

MULTISERVICE TACTICS, TECHNIQUES, AND PROCEDURES FOR TREATMENT OF NUCLEAR AND RADIOLOGICAL CASUALTIES

May 2014

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FOREWORD

This publication has been prepared under our direction for use by our respective commands and other commands as appropriate.

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Multiservice Tactics, Techniques, and Procedures for Treatment of Nuclear and Radiological Casualties

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Preface

PURPOSE

This multiservice publication serves as a guide and a reference on the recognition and treatment of nuclear and radiological casualties.

SCOPE

This publication classifies and describes potential nuclear and radiological threats and hazards.

Further, this publication describes—

- The biological aspects of blast, thermal radiation, and ionizing radiation and its effects on organs and systems of the body.
- Procedures for first aid, medical diagnosis, personnel treatment, and management of nuclear and radiological casualties.
- Effective communication when *concerns are high and/or trust is low* during a major radiation event.

The material in this publication is applicable to both the nuclear environment and to other operations where high- or low-level radiation hazard exists; this includes Defense Support of Civil Authorities during weapons of mass destruction consequence management operations.

The treatment modalities contained in this manual are based upon those described in the most recent North Atlantic Treaty Organization (NATO) Handbook on the Medical Aspects of Nuclear, Biological, and Chemical (NBC) Defensive Operations–AMedP-6(C) Volume I (Nuclear) and Volume II (Biological); Armed Forces Radiobiology Research Institute, Medical Management of Radiological Casualties Handbook; and the Defense Medical Materiel Program Office Treatment Briefs.

APPLICABILITY

The principal audience for this publication is the trained members of the Armed Forces Medical Services and other medically qualified personnel.

Commanders, staffs, and subordinates ensure their decisions and actions comply with applicable United States (U.S.), international, and, in some cases, host-nation laws and regulations. Commanders at all levels ensure their Service members operate in accordance with the law of war and the rules of engagement. (See Field Manual [FM] 27-10.)

This publication uses joint terms where applicable. Selected joint and Army terms and definitions appear in both the glossary and the text.

This publication applies to the Active Army, Army National Guard/Army National Guard of the United States, and United States Army Reserve unless otherwise stated.

The proponent of this publication is the United States Army Medical Department Center and School (USAMEDDC&S). The preparing agency is the Doctrine Literature Division, USAMEDDC&S. Send comments and recommendations on a Department of the Army Form 2028 (Recommended Changes to Publications and Blank Forms) to **Commander, U.S. Army Medical Department Center and School, ATTN: MCCS-FC-DL, 2377 Greeley Road, Suite D, JBSA Fort Sam Houston, Texas 78234-7731**; by e-mail to usarmy.jbsa.medcom-ameddcs.mbx.ameddcs-medical-doctrine@mail.mil; or submit an electronic Department of the Army Form 2028.

This publication is in consonance with the following NATO multinational force compatibility agreements (Standardization Agreements [STANAGs]):

TITLE	NATO STANAG
Commanders' Guide on the Effects from Nuclear Radiation Exposure During War	2083
NATO Handbook on the Medical Aspects of NBC Defensive Operations (Nuclear)—AMedP-6(C) Volume I	2461
NATO Handbook on the Medical Aspects of NBC Defensive Operations (Biological)—AMedP-6(C) Volume II	2462
Commander's Guide to Radiation Exposures in Non-Article 5 Crisis Response Operations	2473
Determination and Recording of Ionising Radiation and Exposure for Medical Purposes	2474
Medical Support Planning for Nuclear, Biological and Chemical Environments	2478
Materials Handling in the Field	2827
Concept of Operations of Medical Support in Chemical Biological, Radiological, and Nuclear (CBRN) Environments—AMedP-7(D)	2873
Principles of Medical Policy in the Management of a Mass Casualty Situation	2879
Training of Medical Personnel for NBC Defence Operations	2954
Aeromedical Evacuation	3204

IMPLEMENTATION PLAN

Participating Service command offices of primary responsibility will review this publication, validate the information and, where appropriate, reference and incorporate it in Service manuals, regulations, and curricula as follows:

UNITED STATES ARMY

The U.S. Army will incorporate this publication in U.S. Army training and doctrinal publications as directed by the Commander, U.S. Army Training and Doctrine Command. Distribution is according to initial distribution number 115861 requirements for FM 4-02.283.

UNITED STATES MARINE CORPS*

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UNITED STATES NAVY

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USER INFORMATION

THE UNITED STATES ARMY MEDICAL DEPARTMENT CENTER AND SCHOOL

The U.S. Army Medical Department Center and School developed this publication with the joint participation of the approving Service commands.

SERVICE AND JOINT DOCTRINE

This publication reflects current Service and joint doctrine on prevention, protection, and medical management of nuclear and radiological agent casualties.

RECOMMENDED CHANGES

We encourage recommended changes for improving this publication. Key your comments to the specific page and paragraph and provide a rationale for each comment or recommendation. Send comments and recommendations directly to—

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Introduction

Army Techniques Publication 4-02.83 remains generally consistent with FM 4-02.283 on key topics while adopting updated terminology and concepts as necessary. Key topics include global and regional threats; types of ionizing radiation; diagnosis, severity, and triage of radiation casualties; treatment of radiation subsydromes; combined injury—blast, thermal, and radiological injuries; psychological effects; treatment briefs; and medication table.

The material presented in this publication reflects enduring practices and multiservice tactics, techniques, and procedures for the treatment of nuclear and radiological casualties. Implementation of these tactics, techniques, and procedures enable commanders, members of the Armed Forces Medical Services, and other medically qualified personnel to preserve the health of their Service members in order for them to accomplish their mission.

Summary of changes include—

- Designating this publication as an Army techniques publication in compliance with the Army's Doctrine 2015 initiative. This publication supersedes FM 4-02.283 dated 20 December 2001.
- Adding biodosimetry information.
- Removing the appendix that discusses depleted uranium.
- Adding an appendix that discusses the new four levels of identification.
- Updating the treatment briefs from 28 to the current eight treatment briefs.
- Adding an appendix that discusses radiation and risk communication.

Army Techniques Publication 4-02.83 consists of six chapters—

- Chapter 1 provides introduction information on recognition and treatment of nuclear warfare casualties and medical management of persons exposed to high- and low-level radiation. This chapter also discusses radiation accidents, nuclear weapons incidents, terrorism and radiological dispersal/explosive devices, terrorism and a single nuclear detonation, nuclear warfare, and global and regional threats.
- Chapter 2 discusses basic biophysical and biological effects of ionizing radiation, and blast and thermal effects in order to form a foundation for understanding the clinical aspects of radiation injury and combined injury covered later in the publication.
- Chapter 3 describes the treatment of casualties who have suffered high-dose radiological injuries and/or combined injuries. This chapter also discusses ionizing radiation effects on cells and tissues, diagnosis, severity, triage of radiation casualties, and treatment of radiation subsyndromes.
- Chapter 4 discusses levels of contamination measurement, external irradiation, decontamination, local tissue irradiation, and internal contamination and irradiation.
- Chapter 5 describes low-level radiation characteristics and hazards, low-level radiation exposure, delayed/late health effects to include types of long-term effects, embryonic and fetal effects, reproductive cell kinetics and sterility, carcinogenesis, and cataract formation. This chapter also discusses prevention, initial actions, medical care, medical follow-up, and documentation of radiation exposure records.
- Chapter 6 provides information on psychological effects of radiological dispersal devices (RDDs) and nuclear incidents, psychosocial sequelae of radiation exposure, treatment, and prevention and risk mitigation.

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Chapter 1

Nuclear and Radiological Threat

NUCLEAR AND RADIOLOGICAL WEAPONS

1-1. The proliferation of nuclear material and technology has made the acquisition and adversarial use of nuclear and radiological weapons more probable. Additionally, military personnel may be deployed to areas that could be radiologically contaminated because of the presence of radioactive materials and nuclear facilities. Treatment protocols for radiation casualties are preliminary but constantly improving and must be part of U.S. Armed Forces medical contingency planning efforts. In order to understand potential nuclear and radiological hazards, the entire spectrum of threat events, with examples, is discussed starting with paragraph 1-2. Currently, radiation accidents involving industrial or medical radiological material and nuclear weapons incidents are the most likely threat to U.S. forces and civilians. The least likely threats are theater and strategic nuclear war (see Figure 1-1).

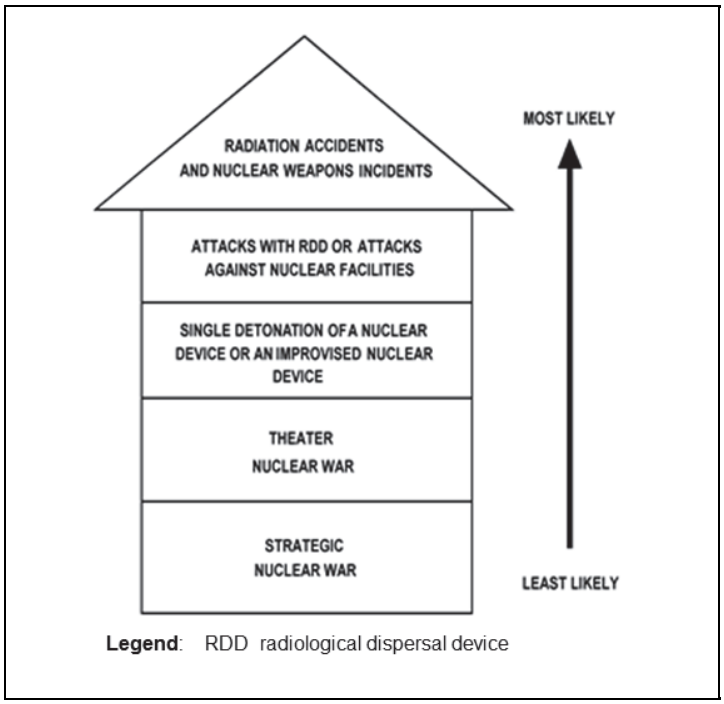

Figure 1-1. Likelihood of radiation accidents and terrorist actions

1-2. Throughout this publication, both U.S. conventional units and the International System of Units (*Systeme International d'Unites*, abbreviated internationally as SI) are used to annotate ionizing radiation. The U.S. conventional units and SI units are discussed in detail in Chapter 2. Refer to Table 1-1 on page 1-2 for more information regarding radiation measurement unit conversion table.

Table 1-1. Radiation measurement unit conversion table

U.S. conventional units to SI	*SI to U.S. conventional units*
curie (Ci) to becquerel (Bq)*	***becquerel (Bq)* to curie (Ci)***
1 kilocurie (kCi) = 37 terabecquerel (TBq)	1 terabecquerel (TBq) ~ 27 curie (Ci)
1 curie (Ci) = 37 gigabecquerel (GBq)	1 gigabecquerel (GBq) ~ 27 millicurie (mCi)
1 millicurie (mCi) = 37 megabecquerel (MBq)	1 megabecquerel (MBq) ~ 27 microcurie (µCi)
1 microcurie (µCi) = 37 kilobecquerel (kBq)	1 kilobecquerel (kBq) ~ 27 nanocurie (nCi)
1 nanocurie (nCi) = 37 becquerel (Bq)	1 becquerel (Bq) ~ 27 picocurie (pCi)
1 picocurie (pCi) = 37 millibecquerel (mBq)	
rad (rad) to gray (Gy)	***gray (Gy) to rad (rad)***
1 kilorad (krad) = 10 gray (Gy)	1 gray (Gy) = 100 radiation absorbed dose (rad)
1 rad (rad) = 10 milligray (mGy)	1 milligray (mGy) = 100 millirad (mrad)
1 millirad (mrad) = 10 microgray (µGy)	1 microgray (µGy) = 100 microrad (µrad)
1 microrad (µrad) = 10 nanogray (nGy)	1 nanogray (nGy) = 100 nanorad (nrad)
roentgen (R) to coulomb/kg (C/kg)	***coulomb/kg(C/kg) to roentgen (R)***
1 kiloroentgen (kR) ~ 258 millicoulomb//kg (mC/kg)	1 coulomb/kg (C/kg) ~ 3876 roentgen (R)
1 roentgen (R) ~ 258 microcoulomb/kg (µC/kg)	1 millicoulomb/kg (mC/kg) ~ 3876 milliroentgen (mR)
1 milliroentgen (mR) ~ 258 nanocoulomb/kg (nC/kg)	1 microcoulomb/kg (µC/kg) ~ 3876 microroentgen (µR)
1 microroentgen (µR) ~ 258 picocoulomb/kg (pC/kg)	1 nanocoulomb/kg (nC/kg) ~ 3876 nanoroentgen (nR)
rem (rem) to sievert (Sv)	***sievert (Sv) to rem (rem)***
1 kilorem (krem) = 10 sievert (Sv)	1 sievert (Sv) = 100 roentgen equivalent in man (rem)
1 rem (rem) = 10 millisievert (mSv)	1 millisievert (mSv) = 100 millirem (mrem)
1 millirem (mrem) = 10 mirosievert (µSv)	1 microsievert (µSv) = 100 microrem (µrem)
1 microrem (µrem) = 10 nanosievert (nSv)	1 nanosievert (nSv) = 100 nanorem (nrem)
gray (Gy) to centigray (cGy)	***centigray (cGy) to gray (Gy)***
1 gray (Gy) = 100 centigray (cGy)	100 centigray (cGy) = 1 gray (Gy)
Legend: * 1 Bq = 1 disintegration/second	

RADIATION ACCIDENTS

1-3. Radiation accidents are the most likely events that threaten U.S. forces and the civilian population. A radiation accident is a situation in which there is a real or suspected intentional or unintentional exposure to ionizing radiation or radioactive contamination. Radiation accidents may involve radiation devices, radioisotopes, and criticality incidents. It must be emphasized that radiation accidents could involve either high- or low-level radiation exposures. These exposures can result in varying levels of injuries including acute radiation syndrome, acute local radiation injury, combined injuries (radiation, thermal, or blast injuries), psychological consequences, and long-term deterministic and stochastic effects. For more information on emergency health powers on an installation during a CBRN incident, refer to AFI 10-2603.

1-4. Intentional exposures may result when individuals purposely administer radioactive materials to personnel, the effects of which may result in a broad spectrum of medical effects, from no obvious deterministic effect to symptoms of acute radiation sickness and onset of associated syndromes, to death.

One of the better known cases occurred in 2006, with the Polonium-210 poisoning of a former KGB officer, Alexander Litvenenko. Estimates of less than 10 micrograms of Po-210 were used, with the final result being the death of Litvenenko 22 days following ingestion.

INDUSTRIAL RADIATION SOURCES AND ACCIDENTS

1-5. Radiation devices and radioactive materials are used in many industrial processes (such as agricultural practices, scientific research, manufacturing, sterilization, and radiography). In fact, radiation accidents have involved industrial gamma and x-ray radiography (nondestructive inspection) devices and sources. For more information on industrial sources of radiation, see Table 1-2. Under normal operating conditions, most industrial sources of radiation present minimal exposure risks when used safely, but accidental exposures can result in serious consequences. All personnel must always be aware of the possible dangers from these sources especially when conducting missions in areas previously subjected to ground and/or air combat operations.

Table 1-2. Industrial sources of radiation

Locations and materials	***Examples of radiation sources (including but not limited to)***	***Strength/exposure potential***
Gauges, sources, static eliminators.	Iridium-192, cesium-137, cobalt-60, radium-226, neutrons, americium-241, polonium-210, californium-252.	Greater than about 4 TBq. Sealed sources, and if leaking, presents surface contamination.
X-ray machine sterilizers, processors, and particle accelerators.	X rays, protons, neutrons, deuterons, electrons, gammas, cesium-137, cobalt-60.	~4 TBq to ~40 PBq. Anywhere in an industrial area. Be aware of possible activation products.
Mineral extraction and processing, including phosphate fertilizers, oil, natural gas, and coal.	Naturally occurring radio-active materials-uranium, thorium, and their progeny.	Generally low level with external exposures from background level to about 0.01 mSv (1 mrem). Dispersed low-level material and scale build-up in piping. Also, in gauges as noted above. Radon is a possible concern.
Radiothermal generators.	Plutonium-238, strontium-90.	Plutonium-238: up to 4 GBq; strontium-90: Up to 1 TBq. In equipment in isolated areas.
Radioluminescent materials.	Promethium-147, tritium, radium-226.	Up to tens of TBq. Various applications, and if leaking, surface contami-nation.

Legend:
TBq terabecquerel — mSv millisievert
GBq gigabecquerel — mrem millirem
PBq petabecquerel

MEDICAL SOURCES

1-6. Medical sources of ionizing radiation are those devices or materials that are readily available at hospitals and some laboratories. They include x-ray machines, fluoroscopy devices, linear accelerators, radiopharmaceuticals, and radiation from nuclear medicine and cancer therapy sources. These nuclear medicine and therapy sources could present a hazard if individuals are accidentally exposed directly to the materials within these devices, or are exposed indirectly by dispersion of these materials into the surrounding environment. For more information on ionizing radiation protection, refer to AFI 48-148. For example, an explosion near a cancer treatment facility's cobalt-60 source could spread radioactive material throughout the rubble of the target structure and possibly spread material outside of the building. Responding firefighters, rescuers, and the casualties themselves could be at high risk of encountering the dispersed radioactive material. Examples of medical sources of radiation are shown in Table 1-3. The strengths and exposure potential are measured in gray (Gy) (an absorbed radiation dose of one joule per kilogram) and becquerel (Bq) (the quantity of radioactive material in which one atom disintegrates [undergoes radioactive decay] per second).

Table 1-3. Medical sources of radiation

Locations and materials	***Radiation sources (not encompassing)***	***Strength/exposure potential***
Radiation oncology departments	Iridium-192, cobalt-60 and cesium-137.	~1 to 10 Gy over several hours at about 1 meter if the source is exposed. Found in therapy rooms.
Sources and applicators	Cesium-137, iridium-192, radium-226, phosphorus-32, strontium-90, iodine-125.	Tens of MBq. Therapy and nuclear medicine areas.
Radiopharmaceuticals	Iodine-123, phosphorus-32, technetium-99^m, thallium-201, iodine-131, strontium-89.	Tens of MBq. Hundreds of MBq. Storage, nuclear medicine areas, and transportation.
X-ray machines and accelerators	X rays and electrons.	~0.01 Gy per minute at the source. Radiology or therapy rooms. Hazard is only present when the device is energized.
Legend: Gy gray MBq megabecquerel		

THE NUCLEAR FUEL CYCLE AND NUCLEAR REACTORS (POWER PLANTS)

1-7. The nuclear fuel cycle includes all the activities associated with the production of electricity from nuclear reactions. This includes mining, milling, conversion, enrichment, and fabrication of the fuel as well as the reaction triggered by the fuel, and the disposal of the spent fuel and other wastes. If released, high-level waste from the nuclear fuel cycle poses serious environmental and health concerns. United States forces may be operating in a theater that has nuclear fuel processing facilities and nuclear reactors with varying degrees of safety and containment. Tactical considerations may require units to maneuver

near these reactors, or to occupy areas in the vicinity of these facilities. Exposure of U.S. Forces could occur if an accident in one of these facilities dispersed radiation into the surrounding environment. Intentional exposure could occur if terrorists chose to destroy one of these nuclear reactors and its containment facility. This would result in both the disruption of electrical power and the potential for radiological contamination. Examples of wastes from the nuclear fuel cycle are shown in Table 1-4.

Table 1-4. Examples of nuclear fuel cycle wastes

Cycle process	*Physical state of waste*	*Principal radionuclides*
Mining and milling	Gaseous	Bismuth-214; polonium-210, 214, 218; radon-222.
	Liquid and solid	Lead-210; radium-226; thorium-230; uranium-235, 238.
Conversion and enrichment fuel fabrication	Liquid	Protactinium-234; radium-226; thorium-234; uranium-235, 238.
	Liquid and solid	Plutonium-239; thorium-232; uranium-235, 238.
Reactor operations	Gaseous	Argon-41; cesium-134, 137; iodine-131, 133; krypton-87, 89; nitrogen-13; xenon-138.
	Liquid and solid	Cobalt-58, 60; chromium-51; iron-59; tritiated water.
Waste reprocessing	Gaseous	Hydrogen-3 (tritium); iodine-129, 131; krypton-85; xenon-133.
	Liquid and solid	Americium-241, cesium-137, curium-244, plutonium-239, strontium-90, uranium-235, 238.

Nuclear Fuel Processing

1-8. There are several steps in the processing of the fuel that result in radioactive wastes. For example, milling waste contains long-lived radioactive materials and progeny in low concentrations and toxic materials such as heavy metals. The chemical conversion process of turning uranium hexafluoride to dioxide produces liquid waste that contains chemical impurities, including fluorides. The fuel enrichment process leads to the production of depleted uranium. This is uranium in which the concentration of uranium-235 (radioactive isotope) is significantly less than the 0.7 percent found in nature. The remaining material which is primarily uranium-238 is used in applications where a high-density material is required.

1-9. An example of an exposure related to the nuclear fuel process is the large-scale radioactive waste problem at the Mayak military complex in the Ural Mountains of Russia. The contamination began in 1948, when the Mayak complex provided the Soviet Union with the material for its first atomic bomb. For over a decade, the facility was responsible for pumping 1.2 billion curies of cesium and strontium-laced nuclear waste into the bottom of Lake Karachai. This resulted in nearly 24 times the radioactive content released by the Chernobyl reactor failure. During the summer of 1967, a portion of the lake evaporated due to hot and dry weather conditions. Radioactive dust resuspended from the lake, affecting a large number of people in an area of more than 40,000 square kilometers. By 1990, radiation levels near the lakeshore were still high enough to provide a lethal dose (LD) within 60 minutes of exposure. Today, Lake Karachai is one of the most contaminated spots on the earth's surface.

Nuclear Reactors (Power Plants)

1-10. Pressurized water reactors are the most common type of nuclear power plants in the world and constitute the majority of the western nuclear power plants. Waste from this type of a reactor is generated as liquid, solid, and gaseous effluents. Nuclear reactors produce several potentially dangerous radioactive materials such as iodine-131 and iodine-133 which can be absorbed by the thyroid. The fission process also produces significant amounts of cesium-134 and cesium-137 that becomes uniformly distributed

throughout the body and becomes a beta-gamma source irradiating all organs. Tritium may also present an exposure risk if allowed to accumulate in the liquid and gaseous effluents and in the surrounding environment. Reactor accidents are rare, but if an accident occurs there are several exposure pathways including—

- External exposure from a plume overhead (cloud shine) or radioactive material on the ground (ground shine).
- Internal exposure due to inhaling materials directly from the plume or from stirred up dust.
- Ingestion of radioactive material deposited in or on food or water.

SOURCES FROM UNITED STATES FORCES COMMODITIES AND FOREIGN MATERIAL

1-11. United States forces use many radioactive sources in equipment, vehicles, ships, aircraft, and weapons systems. Some of the common radioactive sources in U.S. material are—

- Hydrogen-3 (tritium). This radionuclide is the heaviest isotope of hydrogen and is a low energy beta emitter. Tritium is generally used in devices requiring a light source, such as watches, compasses, and fire control devices for tanks, mortars, and howitzers. Only a release of a large amount in a closed space can cause an exposure of clinical importance.
- Nickel-63. This radionuclide is a pure beta emitter and is used in some chemical agent monitor and many commercial mass spectrometers. The beta energy of nickel-63 is too low to penetrate the dead layer of skin; however, efforts should be taken to prevent internalization.
- Cesium-137. This radionuclide is used in the soil density and moisture tester. Cesium-137 emits a beta particle as it decays to barium-137, which in turn decays by emitting gamma rays. The beta hazard is minimal due to the source being doubly encapsulated in steel. However, the gamma emission presents an external exposure hazard. Extended exposures may lead to clinical injury. This source is of concern for potential use as RDDs and is the agent responsible for the casualties at a recycling center in Goiania and had widespread release from nuclear testing and the reactor accidents at Chernobyl and Fukushima.
- Thorium-232. This radionuclide is a naturally occurring radioisotope of thorium and is an alpha emitter. When thorium is heated in air, it glows with a white light. For this reason, one of the major uses of thorium has been the *Welsback lantern mantle* used in portable gas lanterns. Thorium-232 is also used in Radiation Detection, Indication, and Computation (RADIAC) sets for use as calibration check sources. Thorium-coated optics are found on many night vision devices and thermal optic fire control systems. Also, heat resistant thorium alloys are used in the combustor liner for the Abrams tank turbine engine and on various military aircraft engines. In general, thorium-232 presents a minimal hazard, but care should be taken to avoid internalization of any particles from damaged components or during metal working activities.
- Americium-241. This radionuclide is used as a sealed source in the M43A1 Chemical Agent Detector that is a component of the M8A1 alarm and is found in most commercial smoke detection systems. Americium-241 is also found in the soil density and moisture tester. Americium-241 is primarily an alpha emitter and a very low energy gamma emitter. External exposure is not a concern unless large amounts of the substance are located in one area and personnel are in close contact for an extended period of time.
- Cobalt-60. This radionuclide is a gamma emitter widely used in industry for radiography of machined and welded parts, measurement devices, food and medical sterilization, and medical radiotherapy. Cobalt-60 represents an external hazard to the body and is high on the RDD threat list.
- Strontium-90. This radionuclide is used in aviation for ice detection systems and in radio-thermal generators. It is sometimes used in foreign radioluminous dials and gauges. It decays to yttrium-90. Both strontium- and yttrium-90 are beta emitters; the strontium-90 being of mid-energy, while the yttrium-90 is of high energy. An external exposure to this source could present a hazard to the skin and eyes, if damage has occurred to the device and the individual handles the material. It would also be a hazard if it were internalized.
- Uranium-238 (depleted uranium). It is primarily an alpha emitter that also has low-level beta and gamma emissions associated with its decay products (progeny). Depleted uranium is 40

percent less radioactive than uranium. The U.S. Armed Forces have used depleted uranium in the manufacture of munitions, armor, and armor-piercing projectiles (kinetic energy penetrators). Depleted uranium projectiles are capable of readily penetrating armor. Armor constructed with depleted uranium provides a high degree of shielding and resistance to penetration from other munitions. During the 1991 Gulf War, depleted uranium-containing munitions were used on a large scale for the first time. In the manufacture of projectiles and armor, depleted uranium is alloyed with small amounts of other metals. Depleted uranium is generally not an external hazard; however, there are two potential hazards when large amounts of depleted uranium are taken into the body. The first concern is related to the chemical effects associated with heavy metal toxicity on the kidneys, much like that seen with tungsten, lead, and cadmium. The second is related to the possible long-term effects related to depleted uranium's low-level radioactivity.

NUCLEAR WEAPONS INCIDENTS

1-12. All nuclear weapons contain a conventional high explosive component, and in any accident involving this type of weapon, there is a risk of either an explosion of this material, or a fire. Either may occur during an accident with the weapon, resulting in the device's radioactive material being dispersed into the environment. The principal fissionable materials in nuclear weapons (uranium-235 and plutonium-239) are alpha particle emitters, and therefore, internalizing these particles is the principal hazard. However, there are weak X and gamma ray emissions associated with alpha particle decay. These weak X and gamma radiations from unfissioned bomb material are not very penetrating. Actual nuclear detonations due to accidents and/or mishandling are considered to be highly unlikely.

1-13. A few very serious incidents involving nuclear weapons have occurred throughout the world. However, the Palomares incident remains the most severe accident in U.S. nuclear weapons history. In January 1966, a B-52 bomber carrying four hydrogen bombs collided in midair with a KC-135 tanker during high altitude refueling operations near Palomares, Spain. The KC-135's 40,000 gallons of jet fuel ignited, killing all four tanker crew members and three bomber crewmen. Four of the bomber's crew parachuted to safety. Wreckage from the accident fell across approximately 100 square miles of land and water. Of the four H-bombs aboard, two of the weapons containing high explosive material exploded on ground impact, releasing radioactive materials, including plutonium, over the fields of Palomares. A third nuclear weapon fell to earth but remained relatively intact. The last one fell into the Mediterranean Sea and was not recovered until 7 April 1966. Land areas contaminated with nuclear material were remediated within weeks of the accident. Contaminated soil was removed and shipped in metal drums to the Savannah River Site in South Carolina, and buried there (1,600 tons). Arable soil contaminated at lower levels of radiation was watered down and plowed to 30 centimeters deep in order to dilute the contaminated soil and reduce surface contamination of radionuclides. The exteriors of homes were hosed down with water to remove surface contamination.

TERRORISM AND RADIOLOGICAL DISPERSAL DEVICES

1-14. Another threat facing U.S. Armed Forces and civilians today is terrorists and organized crime groups who could potentially use RDD. Radiological dispersal devices are designed to scatter radioactive material to cause destruction, damage, area denial, or injury without producing a nuclear explosion. One design, popularly called a dirty bomb, uses conventional explosives to disperse radioactive material. A dirty bomb typically generates its immediate casualties from the direct effects of the conventional explosion (that is, blast injuries and trauma). However, one of the primary purposes of a dirty bomb is to inflict combat and operational stress reaction on troops as well as the civilian population by contaminating their environment with radioactive materials. Environmental radiological problems are of special concern since at very low levels of radiation there will not be any immediate outward signs of exposure. For more information on CBRN incident survivability, refer to AFI 10-2607.

1-15. Radiological dispersal devices are low-technology devices that may use medical sources, industrial radioactive material, and/or radioactive waste as the core element in the device. Potential radioactive material for RDDs include medical sources from radiation oncology departments (such as iridium-192, cobalt-60), and radiopharmaceuticals (such as iodine-123, phosphorus-32). Potential radioactive material

for RDDs may also include industrial radiation sources such as cobalt-60 and cesium-137, nuclear reactor fuel rods (uranium-235, plutonium-239), and radiography/gauging material (cobalt-60, cesium-137, iridium-192, radium-226). Any radioactive material will present safety risks to the terrorists themselves, and would present serious difficulties for any adversary attempting to store, handle, and disseminate it effectively.

1-16. Another type of terrorist radiological weapon would be the malicious distribution of sealed radioactive sources. This is simply abandoning the material in a populated or sensitive area. This is referred to as a radiological exposure device (RED). According to Joint Publication (JP) 1-02, a RED is a radioactive source placed to cause injury or death while a *radiological dispersal device* is an improvised assembly or process, other than a nuclear explosive device, designed to disseminate radioactive material in order to cause destruction, damage, or injury (JP 3-11).

TERRORISM AND A SINGLE NUCLEAR DETONATION

1-17. Acquiring or processing sensitive nuclear material, that is, either highly enriched uranium or plutonium is extremely difficult. Although much of the information about nuclear weapons design and production has become public knowledge during the past years, it is still extraordinary for nonstate entities to attempt to embark on a nuclear weapons research and development program. A successful program hinges on obtaining enough fissile material to form a supercritical mass for the nuclear weapon to permit a chain reaction.

NUCLEAR WARFARE

1-18. In the Cold War environment, there were two basic scenarios for an exchange of nuclear weapons: either a general strategic exchange of large-yield thermonuclear weapons, or the limited use of nonstrategic nuclear weapons in the theater of operations.

1-19. Strategic nuclear war would use weapons that generally range in yield from hundreds of kilotons (KTs) to multiple megatons. They are designed to destroy large population centers, destroy or disrupt the armed forces, and to destroy or disrupt national infrastructure and logistics capabilities. The exchange of multiple strategic nuclear weapons would result in catastrophic casualty numbers, which would overwhelm surviving local medical resources. Military personnel who are nominally capable of returning to short-term duty would be utilized despite significant radiation injury. Casualties would receive medical care and evacuation as soon as conditions permit according to mass casualty contingency plans. The only examples of this type of nuclear strike were the destruction of Hiroshima and Nagasaki in August of 1945. Even though the 1945 weapons were of a relatively low yield as compared to today's weapons, their employment was to accomplish strategic objectives. This event is now considered the least likely threat.

1-20. Nuclear weapons include gravity bombs, air-launched cruise missiles, and Tomahawk land attack missile/nuclear. These larger yield (up to 400 KT) theater weapons would normally be used at the operational level against theater targets such as enemy long-range nuclear weapons systems, ports, airfields, theater-level logistic bases. They would also provide a deterrence and response to either the enemy's use, or threat of use, of any weapons of mass destruction. While large numbers of casualties would likely be generated within a given area, medical care would be available outside the area of immediate destruction. For a given nuclear detonation, casualties would depend on population density, terrain, weapon yield, weapon employment technique, and other factors. Casualties could also be produced at a later time due to fallout. The primary patient management concept would be to evacuate and distribute casualties to all available medical treatment facilities.

Chapter 2

Hazards of Nuclear and Radiological Events

TYPES OF IONIZING RADIATION

2-1. *Ionizing radiation* is particulate (alpha, beta, and neutron) and electromagnetic (x ray and gamma) radiation of sufficient energy to displace electrons from atoms, producing ions (JP 3-11). In living tissues, these electrically charged ions produced by radiation may affect normal biological processes. There are five types of ionizing radiation of biological significance. These five types of radiation are classified into two categories—particulate and nonparticulate or electromagnetic.

PARTICULATE IONIZING RADIATION

2-2. Particulate ionizing radiation types are alpha particles, beta particles, and neutrons.

Alpha Radiation

2-3. An alpha particle is a helium nucleus consisting of two protons and two neutrons all strongly bound together by nuclear forces. Although highly ionizing, alpha particles are only slightly penetrating. They are generally emitted by high atomic number elements such as polonium, uranium, plutonium, and americium. If the source of the radiation is external to the body, all of the alpha radiation is absorbed in the superficial layers of dead cells within the stratum corneum, or any outer clothing or covering. Because of this, alpha radiation is not an external hazard. If alpha-emitting material is internally deposited, all the radiation energy will be absorbed in a very small volume of tissue immediately surrounding each particle. Beyond a radius of about 0.02 millimeters, the deposition of energy is very small. The high radiation doses within this critical radius are lethal to the cells immediately adjacent to the source. Thus, while extremely high radiation doses may be deposited in the few cells immediately surrounding a source of alpha radiation, regions outside this irradiated volume are not affected. However, internal deposition of alpha emitting radionuclides is important in terms of causing radiation injury. Some alpha emissions are accompanied by a gamma photon emission and many alpha sources are accompanied by beta-emitting progeny both of which will irradiate tissues far from the areas of deposition.

Beta Radiation

2-4. Beta particles are identical to electrons and like alpha particles, they are ejected from a nucleus when the nucleus rearranges itself into a more stable configuration. Radioactive materials that emit beta particles are generally the by-products of fission of heavy nuclides such as plutonium. These by-products include elements such as cesium-137, strontium-90, and iodine-131. Most of energetic beta particles can only penetrate a few millimeters of tissue. Beta particles are often associated with the gamma emission that will penetrate deeper. If the beta-emitting material is on the surface of the skin or eye, the resulting beta irradiation causes damage to the epithelial basal stratum, cornea or lens of the eye. The lesion initially appears similar to a superficial thermal burn but significantly more damage has actually occurred. If the radionuclide is incorporated internally, the damage will be in small spheres of tissue around each fragment or radioactive source. However, internal exposures to beta radiation can be more homogeneous if associated with ingestion of a soluble nuclide in foodstuffs. The total tissue damage is a function of the number of such sources within the affected tissue volume, the nuclide's intrinsic radioactivity, and the radiosensitivity of the tissue. Dead cells are replaced within a few lifecycles in most tissues. The less dense energy deposition of beta radiation may simply damage rather than kill affected cells, thereby causing cells to become malignant or otherwise malfunction, which in turn, may lead to late effects.

Neutron Radiation

2-5. Neutrons are electrically neutral, yet because of their relatively large mass, they can severely disrupt atomic structures. Neutron sources may vary. Although typically associated with fission/fusion events, neutron generators may also be formed when an isotope producing an energetic alpha is mixed with an isotope with a low atomic weight. Typically mixtures include americium-beryllium, radium-beryllium, plutonium-beryllium, or americium-lithium. Compared to gamma rays, neutrons can cause much more damage to tissue. Collisions with atomic nuclei slow a neutron so it may undergo nuclear capture. In nuclear capture, the neutron is actually absorbed into a nucleus, increasing the neutron to proton ratio and potentially causing the nucleus to become unstable (radioactive).

ELECTROMAGNETIC (NONPARTICULATE PHOTON) IONIZING RADIATION

2-6. Gamma and x rays constitute the most abundant form of ionizing radiation associated with a nuclear detonation. Most radioactive materials also emit gamma or x-ray radiation as part of their decay processes. Gamma rays and x rays have energy and momentum, but no mass, and travel at the speed of light (3×10^8 meters per second). They possess no net electrical charge. The difference between gamma and x ray photons is the point of origin. Gamma photons originate from the nucleus and x rays come from electron transitions. Photons are highly penetrating and a large fraction may pass through the human body without interaction. Consequently, energy deposition can occur anywhere in the body along a photon's path. A significant portion of the body may be exposed to gamma radiation during a nuclear detonation, a nuclear reactor accident, or during an industrial accident. This is in marked contrast to the highly localized exposure pattern that occurs with alpha and beta radiation. High-energy gamma emitters deposited within the body may also result in total body irradiation just as effectively as exposure to external sources.

UNITS OF MEASURE

2-7. There are several different, but interrelated, methods of measuring and quantifying ionizing radiation. For comparison, U.S. conventional units and SI units of measurement are discussed in this paragraph (also see Table 1-1).

- In the SI system, one unit of exposure is defined as that quantity of x- or gamma radiation that produces, in air, ions carrying one coulomb of charge (of either sign) per kilogram of air and is symbolized by X. Before the SI system was introduced, the unit of x-ray exposure was called the roentgen and was symbolized by R. The roentgen is defined as that quantity of x- or gamma radiation that produces ions carrying one statcoulomb of charge (either sign) per cubic centimeter of air at 0°C and 760 millimeters of mercury.
- Absorbed dose is defined as the radiation energy absorbed per unit mass. The U.S. conventional units of absorbed dose is the radiation absorbed dose (rad), and is defined as 100 ergs of energy deposited per gram of medium. The SI unit of measure for absorbed dose is the Gy, defined as one joule of energy deposited per one kilogram of medium. It is easy to convert the two, since 1 Gy equals 100 rads (see Figure 2-1).

rad
1 rad = 100 ergs/gram

Gy
1 Gy = 1 joule/kilogram = 100 rads

Legend:
Gy gray
rad radiation absorbed dose

Figure 2-1. Units of absorbed dose

DOSE EQUIVALENT

2-8. It is recognized that the absorbed dose needed to achieve a given level of biological damage is often different for different kinds of radiation. Dose equivalent allows for the different biological effectiveness of different types of radiation and provides for measurement of biological damage and resulting risk, from a radiation dose. When radiation is absorbed in biological material, ionizations occur in a localized fashion along the tracks of the particular photon or particle with a pattern that depends upon the type of radiation involved. As a result, the spatial distribution of the ionizing events produced by different radiations varies greatly. Linear energy transfer (LET) is the energy transferred per unit length of the track. Different types of radiation have different LET, and therefore, the higher the LET, the more effective the radiation is at producing biological damage. Low LET radiations (gamma and x rays) are generally sparsely ionizing and randomly interact with molecules along their path. High LET radiations (neutrons and alpha particles) are more uniformly and densely ionizing. To account for the differences in LET, each type of radiation has a different quality factor (QF). The QF relates the amount of biological damage caused by any type of radiation to that caused by the same absorbed dose of gamma or x ray (see Table 2-1). The QF is then used to determine the dose equivalent; for example, in determining the dose equivalent from internalized depleted uranium.

Table 2-1. Quality factors for various radiation types

Radiation type	*Quality factor*
X-, gamma-, and beta-rays	1
Alpha particles, fission fragments, and heavy nuclei	20
Neutrons	3 to 20 *
* Values of quality factors for neutrons are dependent upon the energy of the neutron.	

2-9. The dose equivalent is a measure of the actual biological damage in tissue. The U.S. conventional units of equivalent dose is the roentgen equivalent in man (rem), which is equal to the absorbed dose, or the rad, multiplied by the QF. The SI unit is the sievert (Sv) (see Figure 2-2). One rad is 100 ergs per gram, and 1 Gy is 1 joule per kilogram. Also, just as 1 Gy is 100 rads, 1 Sv is 100 rem.

$$\text{rem} = \text{QF} \times \text{rad}$$

$$\text{Sv} = \text{QF} \times \text{Gy}$$

$$1\ \text{Sv} = 100\ \text{rem}$$

Legend:

Gy	gray	rem	roentgen equivalent in man
QF	quality factor	rad	radiation absorbed dose
Sv	sievert		

Figure 2-2. Units of dose equivalent

DOSE RATE

2-10. Dose rate is the dose of radiation per unit of time. An example would be centigray (cGy) per hour (cGy/hr).

ACTIVITY

2-11. The activity level of a radioactive material is simply a measure of how many atoms disintegrate (decay) per unit of time. The existing unit for this is the curie (Ci). The curie is based on the activity of 1

gram of radium-226 or 3.7×10^{10} radioactive disintegrations per second. The SI unit for measuring the rate of nuclear transformations is the Bq. The Bq is defined as one radioactive disintegration per second (see Figure 2-3).

Curie (Ci)

1 Ci = 3.7×10^{10} nuclear transformations per second

Becquerel (Bq)

1 Bq = 1 disintegration per second (dps)

1 Bq = 2.7×10^{-11} Ci

Figure 2-3. Units of activity

HALF-LIFE

2-12. The half-life of a radionuclide is the amount of time it takes one-half of the nuclei to decay. For example, after one half-life, 1/2 of the original amount remains and after two half-lives, 1/4 remains. A substance with a short half-life decays quickly with a comparatively high radioactivity level. A substance with a long half-life decays slowly with a comparatively low radioactivity level. The half-life of radionuclides range from fractions of a second (polonium-212 with a half-life of 0.0000003 seconds), to billions of years (bismuth-209 with a half-life of 2×10^{18} years).

PENETRATION AND SHIELDING

2-13. Personnel can be shielded from ionizing radiation by various materials. Properly shielding personnel requires knowledge of the type and penetration characteristics of the radiation involved (see Figure 2-4).

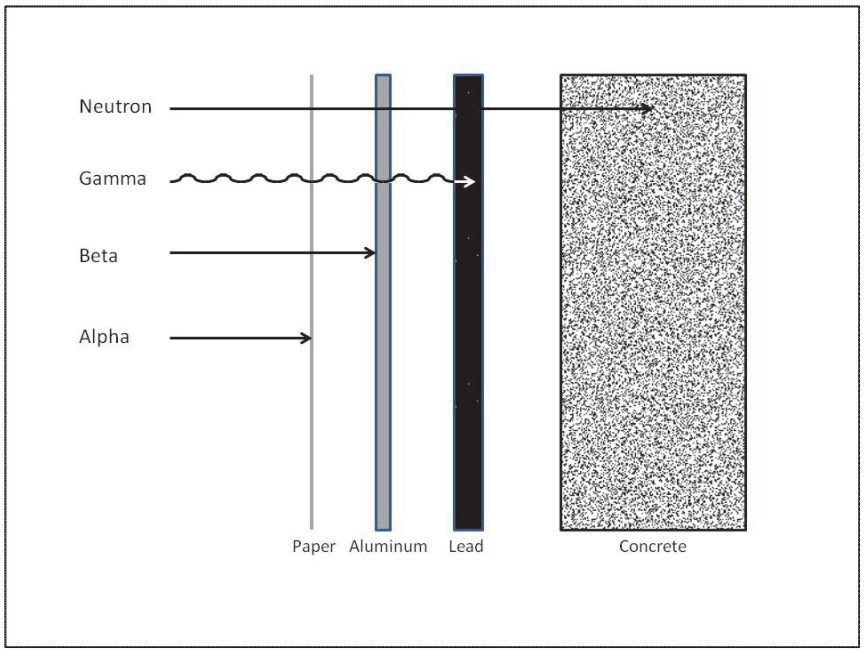

Figure 2-4. Radiation penetration and shielding

ALPHA SHIELDING

2-14. Alpha particles are heavily charged particles with a very low penetration range in air. They can be stopped with a sheet of paper or at the superficial layers of skin; therefore, any light clothing or gloves used

to prevent contamination of underlying clothing or the body will provide protection from this type of radiation.

BETA SHIELDING

2-15. Beta emitters present two potential external radiation hazards: the beta particles themselves and the x rays they can produce when they strike dense materials (such as lead). Beta particles can travel significant distances in air, however materials such as aluminum, plastic, or glass can provide appropriate shielding. Because the lens of the eye is radiosensitive, eye protection in the form of goggles or a protective mask are recommended when working with high energy beta emitters.

GAMMA SHIELDING

2-16. Gamma rays and x rays are more difficult to shield as they are more penetrating than alpha and beta particles. Shielding of gamma ray photons is a function of absorber thickness and density and is based on the probability that the gamma ray photons will interact with the medium through which they pass. As the thickness of an absorber is increased, the intensity of the gamma radiation will decrease. Higher density media like lead, tungsten, and steel are good shielding material against gamma ray photons. However, no matter how thick or dense a gamma or x ray shield is, some of the photons will still get through.

NEUTRON SHIELDING

2-17. Lead and other high-density materials do not provide effective shielding against neutrons. Neutron shielding is more complicated than shielding against gamma or x rays due to the difference in the way neutrons interact with matter. The most effective materials in slowing down neutrons are the light elements, particularly hydrogen. Many hydrogenous materials such as water, paraffin, or concrete make efficient neutron shields.

NUCLEAR DETONATION

2-18. A nuclear detonation results from the formation of a supercritical mass of fissionable material with a near instantaneous release of nuclear binding energies and large-scale conversion of mass to energy. Fission is the process where a heavier unstable nucleus divides or splits into two or more lighter nuclei and with certain materials, substantial amounts of energy are released. The materials used to produce nuclear explosions are the readily fissionable isotopes of uranium or plutonium: uranium-235 and plutonium-239. Modern weapons may boost their yield by incorporating a fusion element, which may be regarded as the opposite of fission. It is the combining of two light nuclei to form a heavier nucleus (thermonuclear reaction). The only practical way to obtain the temperatures and pressures required for fusion is by means of a fission explosion. Consequently, weapons with fusion components contain a basic fission component.

BASIC DETONATION CHARACTERISTICS

2-19. The destructive action of conventional explosions is almost entirely due to the transmission of energy in the form of a blast wave and the resultant projectiles (shrapnel). The energy of a nuclear explosion is transferred to the environment in three distinct forms—blast, thermal radiation, and nuclear radiation. The energy distribution among these three forms will depend on the weapon yield, the location of the burst, and the characteristics of the environment. The energy from a low altitude atmospheric detonation of a moderate-sized weapon in the KT range is distributed approximately as follows (see Figure 2-5 on page 2-6):

- Fifty percent as blast.
- Thirty-five percent as thermal radiation, which is made up of a wide range of the electromagnetic spectrum including infrared, visible, and ultraviolet light and some soft x rays.
- Fifteen percent as ionizing radiation, including 5 percent as initial (or prompt) radiation emitted within the first minute after detonation, consisting chiefly of neutrons and gamma rays, and 10 percent as residual nuclear radiation (fallout).

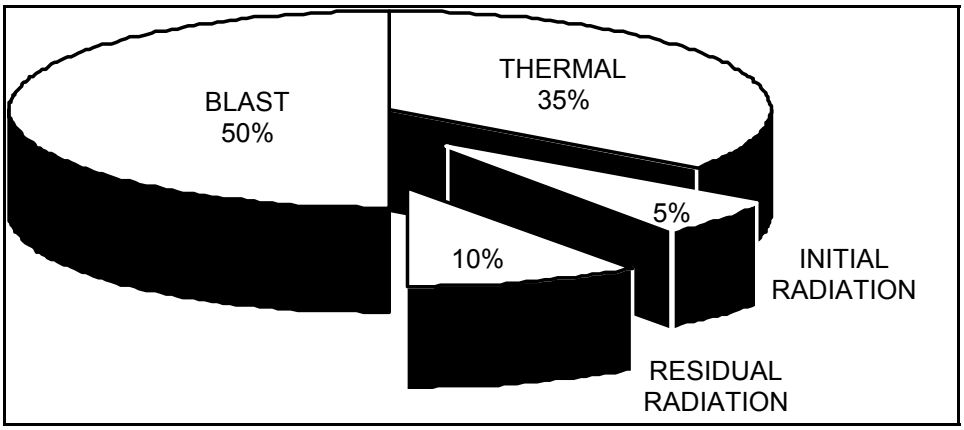

Figure 2-5. Energy partition from a nuclear detonation

2-20. It should be noted that the distribution of energy is significantly altered in an enhanced radiation nuclear weapon (neutron bomb). A neutron bomb is designed specifically to reduce the energy that is dissipated as blast and heat and increase the amount of initial nuclear radiation. Its approximate energy distribution is 30 percent blast, 20 percent thermal, 45 percent initial radiation, and 5 percent residual radiation.

TYPES OF BURSTS

2-21. The altitude at which the weapon is detonated will largely determine the relative effects of blast, heat, and nuclear radiation. Nuclear explosions are generally classified as high-altitude burst, airburst, surface burst, or subsurface burst.

High Altitude Burst

2-22. A high-altitude burst is one in which the weapon is exploded at a high altitude (typically above 50 kilometers) so that it generates an intense electromagnetic pulse which can significantly degrade the performance of, or destroy sophisticated electronic equipment. Significant ionization of the upper atmosphere (ionosphere) can occur and this radiation can travel for hundreds of miles before being absorbed. For example, a high altitude burst of strategic weapons could be employed with the intent of causing severe disruption or destruction of communications systems. There are no known biological effects of electromagnetic pulse; however, indirect effects may result from the failure of critical medical equipment.

Airburst

2-23. An airburst is an explosion in which a weapon is detonated in air at an altitude of sufficient height that the fireball does not contact the surface of the earth. The altitude of an airburst can be varied to obtain maximum blast effects, maximum thermal effects, desired radiation effects, or a balanced combination of these effects. Burns to exposed skin may be produced over many square kilometers and eye injuries over a still larger area. Initial nuclear radiation will be a significant hazard with smaller weapons, but the fallout hazard can be ignored, as there is essentially no fallout from an airburst. The fission products are generally dispersed over a very large area unless there is local rainfall which would result in a more localized fallout pattern. In the vicinity of ground zero, there may be a small area of neutron-induced ground activity that could be hazardous to troops required to pass through the area. The neutron-induced ground activity hazard is temporary lasting only a few days to a few weeks.

Surface Burst

2-24. A surface burst is an explosion in which a weapon is detonated on or slightly above the surface of the earth so that the fireball actually touches the land or water surface. Under these conditions, the area affected by the blast (thermal radiation and initial nuclear radiation) will be less than that for an airburst of

similar yield, except in the region of ground zero where destruction is concentrated. In contrast with airbursts, local fallout can be a hazard over a much larger downwind area than that affected by blast and thermal radiation.

Subsurface Burst

2-25. A subsurface burst is an explosion in which the point of the detonation is beneath the surface of the land or water. Cratering will generally result from an underground burst, just as for a surface burst. If the burst does not penetrate the surface, the only other hazard will be from ground or water shock. If the burst is shallow enough to penetrate the surface (blast, thermal, and initial nuclear radiation effects will be present), the effects will be less than for a surface burst of comparable yield. Local fallout will be very heavy if surface penetration occurs.

NUCLEAR DETONATION BLAST HAZARDS

2-26. There are two basic types of blast forces which occur simultaneously in a nuclear detonation blast wave; these are direct blast wave overpressure forces, measured in terms of atmospheres of overpressure; and indirect blast wind drag forces, normally measured in the velocities of the winds which cause them. The most important blast effects will be those due to the blast wind drag forces. Direct blast effects can contribute significantly to the immediate deaths and injuries sustained close to the point of detonation. Personnel in fortifications or unbuttoned armored vehicles who are protected from radiation and thermal and blast wind effects, may be subjected to complex patterns of direct overpressures since blast waves may be reflected and reinforced within them. Blast effects will also be present to a much lesser extent when an RDD uses a conventional explosive as the dispersal mechanism.

Direct Blast Wave Overpressure Forces

2-27. When the blast wave acts directly upon a resilient target such as the human body, rapid compression and decompression result in transmission of pressure waves through the tissues. These waves can be quite severe and will result in damage primarily at junctions between tissues of different densities (bone and muscle) or at the interface between tissue and air spaces (lung tissue and the gastrointestinal [GI] system). Perforation of the eardrums would be a common blast injury. Direct blast injuries will not occur by themselves. Other effects, such as indirect blast wind drag injuries and thermal injuries are so severe that patients with only direct blast injuries will comprise a very small part of the patient load. The range of overpressures associated with lethality can vary greatly. It has been estimated that overpressures as low as 193 kilopascal (28 pounds per square inch) can be lethal, but that survival is possible with overpressures as high as 262 kilopascal (37 pounds per square inch). It is important to note that the human body is remarkably resistant to direct blast overpressure, particularly when compared with rigid structures such as buildings.

Indirect Blast Wind Drag Forces

2-28. The drag forces of blast winds are proportional to the velocities and duration times of these winds, which in turn vary with distance from the point of detonation, yield of the weapon, and altitude of the burst. These winds are relatively short in duration but are extremely severe and may reach several hundred kilometers per hour. Indirect blast injuries will occur as crush and/or translational injuries and as missile injuries. Casualties are likely to be thrown against immobile objects and impaled by flying debris. The distance from the point of detonation at which severe indirect injury will occur is considerably greater than that for serious direct blast injuries.

Crush and Translational Injuries

2-29. The drag forces of the blast winds are strong enough to displace even large objects, such as vehicles, or to cause the collapse of large structures, such as buildings. These events can result in very serious crush injuries similar to injuries seen in earthquakes and conventional bombings. A human body can itself become a missile and be displaced a variable distance depending upon the intensity of the drag forces and the nature of the environment. The resulting injuries sustained are termed translational injuries. The probability and the severity of the injury depend on the velocity of the human body at the time of impact.

Missile Injury

2-30. The number of missiles that can be generated by the blast winds depends to some extent upon the environment; that is, different terrain types will have different quantities of material available for missile production. However, the drag forces of the blast winds produced by nuclear detonations are so great that almost any form of vegetation or structure, if present, will be broken apart or fragmented into a variety of missiles. Multiple and varied missile injuries will be common. The probability of a penetrating injury caused by glass fragments increases. Heavy blunt missiles caused by heavy objects will not ordinarily penetrate the body but can result in significant injury, particularly fractures.

NUCLEAR DETONATION THERMAL RADIATION HAZARDS

2-31. In a nuclear warfare environment, thermal burns will be the most common injuries subsequent to both the thermal pulse and the fires it ignites. The thermal radiation emitted by a nuclear detonation causes burns in two ways- by direct absorption of the thermal energy through exposed surfaces (flash burns) or by the indirect action of fires caused in the environment (flame burns). The relative importance of these two processes will depend upon the nature of the environment. If a nuclear weapon detonation occurs in easily flammable surroundings, indirect flame burns could possibly outnumber all other types of injury.

CAUTION

Because of the complexity of burn treatment and the increased logistical requirements associated with the management of burns, they will constitute the most difficult problem faced by the Military Health System.

FLASH (THERMAL PULSE) BURNS

2-32. Since thermal pulse is direct infrared, burn patterns will be dictated by spatial relationships and clothing pattern absorption. Exposed skin will absorb the infrared in a variable pattern and the victim will be burned on the side facing the explosion. Persons shaded from the direct light of the blast are protected. Light colors will reflect the infrared while dark portions of clothing will absorb it and cause pattern burns. Historical records from Hiroshima and Nagasaki bombings indicate that in some cases, dark-colored clothing actually burst into flames and ignited the undergarments causing flame burns. At temperatures below those required to ignite clothing, it is still possible to transfer sufficient thermal energy across clothing to the skin to produce flash burns. The thermal output is so great close to the fireball that everything is incinerated. The actual range out to which overall lethality would be 100 percent will vary with yield, position of burst, weather, the environment and how soon those burned can receive medical care. The mortality rate among the severely burned is much greater without early resuscitative treatment.

FLAME BURNS

2-33. Flame burns result from exposure to fires caused by the thermal effects in the environment particularly from the ignition of clothing. This could be the predominant cause of burns depending upon the number and characteristics of flammable objects in the area. Firestorm and secondary fires will cause typical flame burns but they will also be compounded by closed space fire injuries. Patients with toxic gas injury from burning plastics and other material, superheated air inhalation burns, steam burns from ruptured pipes, and all other large conflagration-type injuries will require treatment. Complications arise in the treatment of skin burns created, in part, from the melting of man-made fibers. It is recommended that clothing made of natural fibers or flame-resistant clothing should be worn next to the skin. The variables of environmental flammability are too great to allow prediction of either the incidence or the severity of flame burns. The burns themselves will be far less uniform in degree and will not be limited to exposed surfaces.

EYE INJURIES

2-34. Since most personnel will not have access to specialized protective goggles, there will be numerous eye injuries that will require treatment because of the intense light produced by a nuclear explosion. Sudden exposures to high-intensity sources of visible light and infrared radiation can cause eye injury, specifically to the chorioretinal areas. Factors that determine the extent of eye injury include pupil dilation, spectral transmission through the ocular media, spectral absorption by the retina and choroid, length of time of exposure, and the size and quality of the image. The use of direct vision optical equipment such as binoculars will increase the likelihood of damage. Night vision devices electronically amplify the ambient light and they also detect infrared energy which is a major component of the thermal pulse. Most night vision devices automatically shut down when an intense burst of energy hits the device. In addition to thermal and blast effects, eye injury is also due to photochemical reactions that occur within the retina when light wavelengths are in the range of 400 to 500 nanometers.

Flash Blindness

2-35. Flash blindness occurs with a sudden peripheral visual observation of a brilliant flash of intense light energy (for example, a fireball). This is a temporary condition that results from a depletion of photopigment from the retinal receptors. The duration of flash blindness can last several seconds when the exposure occurs during daylight. The blindness will then be followed by a darkened after-image that lasts for several minutes. At night, flash blindness can last for up to 30 minutes and may occur up to 100 kilometers from the blast at night (see Figure 2-6).

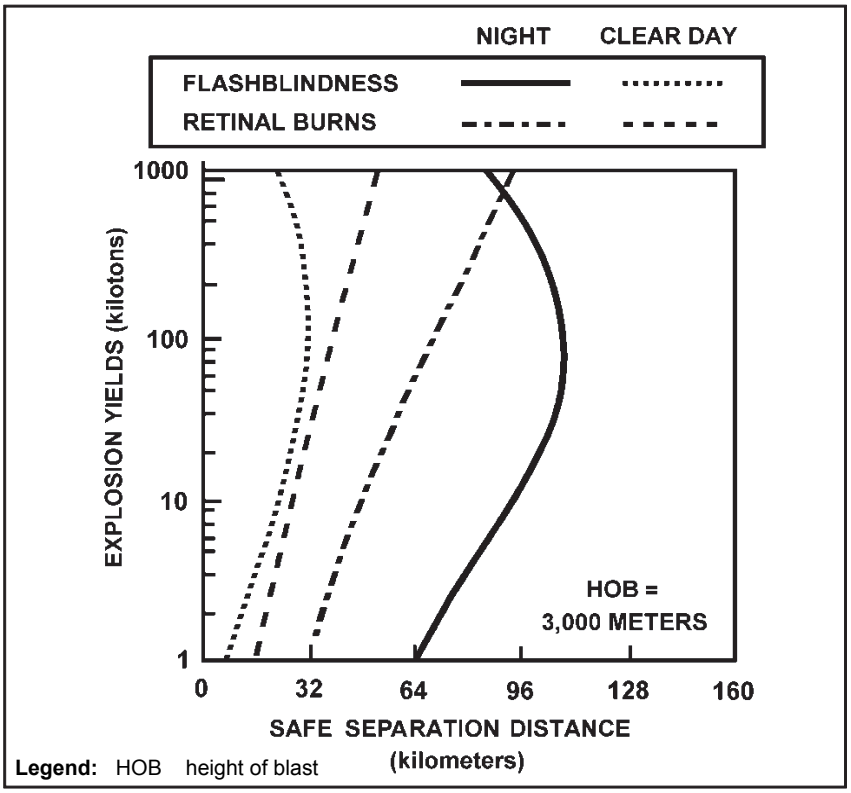

Figure 2-6. Flash blindness and retinal burn safe separation

Retinal Burns

2-36. Direct observation of a brilliant flash of light in the wavelengths of 400 to 1,400 nanometers can cause macular-retinal burns. Burns of the macula will result in permanent scarring with resultant loss in visual acuity. Burns of the peripheral regions of the retina will produce scotomas (blind spots) but overall

visual acuity will be less impaired. These burns can occur at extended distances depending upon yield (see Figure 2-6).

NUCLEAR DETONATION RADIATION HAZARDS

2-37. After a nuclear detonation, the blast and intense from the explosion will result in mass fatalities.

INITIAL RADIATION

2-38. About 5 percent of the energy released in a nuclear airburst is transmitted in the form of initial neutron, gamma, and x ray radiation. The neutrons result almost exclusively by fission and fusion reactions. The initial gamma radiation includes that arising from these reactions as well as that from the decay of short-lived fission products. The intensity of the initial nuclear radiation decreases rapidly with distance from the point of burst. The character of the radiation received at a given location also varies with distance from the explosion. Near the point of the explosion, the neutron intensity is greater than the gamma intensity but reduces quickly with distance. The range for significant levels of initial radiation does not increase markedly with weapon yield. The initial radiation becomes less of a hazard with increasing yield, as individuals close enough to be significantly irradiated are killed by the blast and thermal effects. With weapons above 50 KT, blast and thermal effects are so much greater in importance that prompt radiation effects can be ignored.

RESIDUAL RADIATION

2-39. Residual ionizing radiation from a nuclear explosion arises from a variety of sources but is primarily in the form of neutron-induced ground activity and radioactive fallout.

Fission Products

2-40. There are over 300 different fission products produced during detonation. Many of these are radioactive with widely differing half-lives. Some fission products have half-lives lasting only fractions of a second, while other materials can be a hazard for months or years. Their principal mode of decay produces beta and gamma radiation.

Unfissioned Nuclear Material

2-41. Nuclear weapons are relatively inefficient in their use of fissionable material and much of the uranium and plutonium is dispersed by the explosion without undergoing fission. Such unfissioned nuclear material decays primarily by the emission of alpha particles and is of relatively minor importance as long as it remains outside of the body. These materials are heavier and typically will not travel far in comparison to fallout. The neutrons that are emitted as part of the initial nuclear radiation will cause activation of the weapon residues.

Neutron-Induced Ground Activity

2-42. If atomic nuclei in soil, air, and water are exposed to neutron radiation and capture neutrons, they may become radioactive neutron-induced ground activity depending on their composition and distance from the burst. The activated products then decay, primarily through the emission of beta and (or) gamma radiation over an extended period of time. For example, a relatively small area around ground zero may become radioactive due to the activation of minerals within the soil from the neutron flux at the time of detonation. Due to the relatively short half-lives of the activated minerals, this hazard normally decays very rapidly within the first few hours following the detonation event, although longer-lived activation products such as strontium-90 and cesium-137 may be present.

Fallout

2-43. In a nuclear weapon surface burst, large amounts of earth or water will be vaporized by the heat of the fireball and drawn up into the radioactive cloud especially if the explosive yield exceeds 10 KT. This material will become radioactive when it condenses with fission products and other radioactive

contaminants or if it becomes neutron-activated. These materials will then be dispersed by atmospheric winds and depending upon meteorological conditions, will gradually settle to the earth's surface as fallout. The larger particles will settle back to earth within 24 hours as local fallout. Severe local fallout contamination can extend far beyond the blast and thermal effects particularly in the case of high-yield surface detonations. In cases of water surface bursts (and shallow underwater), the particles tend to be lighter and smaller. This produces less local fallout but extends the spread of contamination out over a greater area. For subsurface bursts, there is an additional phenomenon called base surge. The base surge is a cloud that rolls outward from the bottom of the column produced by a subsurface explosion.

2-44. Scavenging refers to processes that increase the rate at which radioactivity is removed from the fallout cloud and deposited on the earth's surface. Precipitation scavenging is the process in which rain or snow falls through the fallout cloud and carries contaminated particles down with it. Precipitation scavenging occurs in two forms, rainout and washout. Rainout occurs when a rain cloud forms within the fallout cloud while washout occurs when the rain cloud forms above the fallout cloud. The strength of the rain and the length of time the radioactive cloud is washed markedly affect the percentage of radioactivity scavenged. Evidence indicates that washout is far less effective than rainout. Even in the case of an airburst, which does not usually produce early fallout, rainout or washout can cause significant contamination on the ground as a result of scavenging of radioactive debris. This contamination is typically found in concentrated hotspots created between ridges in the earth's surface or wherever rainwater collects.

RANGE OF DAMAGE

2-45. Table 2-2 on page 2-12 shows the ranges in kilotons of biological damage for the hazards discussed above. The ranges noted are for weapons of various yields including very low yield improvised nuclear devices. These effects were calculated using Lawrence Livermore National Laboratory's *HotSpot*, Version 8.0, simulating a surface burst with 25-mile visibility and no intervening shielding or sheltering.

Table 2-2. Comparison of weapons effects in kilometers by yield (kilotons)

Weapon effect	*Weapon yield (KT)*					
	0.01 KT	**0.1 KT**	**1 KT**	**10 KT**	**100 KT**	**1 MT**
Blast: Lethality [1]						
Threshold: 30 psi (30 - 50)	0.038	0.081	0.18	0.38	0.81	1.8
50%: 50 psi (50 -75)	0.030	0.065	0.14	0.30	0.65	1.4
100%: 75 psi (75 - 115)	0.025	0.055	0.12	0.25	0.55	1.2
Blast: Lung Damage						
Threshold: 8 psi (8 - 15)	0.074	0.16	0.34	0.74	1.6	3.4
Severe: 20 psi (20 - 30)	0.046	0.098	0.21	0.46	0.98	2.1
Blast: Eardrum Rupture						
Threshold: 5 psi	0.096	0.21	0.44	0.96	2.1	4.4
50%: 14 psi	0.055	0.11	0.25	0.54	1.1	2.5
Thermal: Skin Burns [2]						
50% First degree (2 - 3 cal/s/cm^2)	0.13	0.37	1.2	3.4	8.3	17
50% Second degree (4 - 5 cal/s/cm^2)	0.089	0.24	0.86	2.5	6.5	14
50% Third degree (6 - 8 cal/s/cm^2)	0.073	0.18	0.71	2.1	5.6	12
Retinal burns (0.0001 cal/s/cm^2)	10	20	33	49	66	84
Flash blindness (0.16 cal/s/cm^2)	0.44	1.3	3.7	9	18	31
Ionizing Radiation Effects						
100% death, < 1 day: 10,000 cGy	0.14	0.21	0.36	0.66	1.1	1.9
100% death, few days: 1000 cGy	0.21	0.36	0.65	1.0	1.6	2.4
50% death, weeks: 450 cGy	0.25	0.45	0.77	1.2	1.7	2.6
< 5% deaths, years: 100 cGy	0.36	0.64	1.0	1.5	2.0	3.0
Start acute effects: 50 cGy	0.43	0.75	1.1	1.6	2.2	3.1

[1] Blast lethality data is only for direct pressure effects.
[2] 50% incidence rates are limited to exposed skin.

Legend:
psi pounds per square inch
cal/s/cm^2 calorie per square centimeter
cGy centigray
KT kiloton
MT megaton

RADIOACTIVE CONTAMINATION HAZARDS

2-47. Radioactive material released to the environment can pose both internal and external contamination hazards to forces operating in these environments. External hazards are generally associated with skin contamination that include the biological effects of cutaneous irradiation and increased probabilities of internal contamination. Internal contamination hazards are associated with the exposure of internal organs from radioactive material that has been taken into the body via inhalation, ingestion or absorption through the skin or a wound. For a detailed discussion of contamination see Chapter 4, Radioactive Contamination.

EXTERNAL CONTAMINATION

2-48. Significant amounts of radioactive material may be deposited on personnel and ground surfaces after the use of nuclear weapons, RDD or any radiological event. In severe cases of fallout contamination, LDs of external radiation may be incurred if protective or evasive measures are not undertaken. Military operations in these contaminated areas could result in military personnel receiving sufficient radiation exposure or particulate contamination to warrant medical evaluation and treatment. For more information on nuclear weapons accident and incident response, refer to AFI 10-2518. In general, the presence of external contamination does not represent a significant exposure hazard to either the patient or attending medical staff. Treatment of life-threatening injuries or medical conditions takes precedence over

radiological concerns. If external contamination is detected, internal contamination may also be present. For more information on evaluation and treatment of contaminated personnel, refer to BUMEDINST 6470-10B.

INTERNAL CONTAMINATION

2-49. In a nuclear explosion, many radioactive isotopes are released into the biosphere most of which are not potentially hazardous to humans due to their short half-life. This fallout may be deposited onto clothing and/or skin and then, may enter the body. In a nuclear reactor accident scenario, radionuclides may enter the body through wounds or gaseous material or particulate matter which may be inhaled and subsequently absorbed or deposited throughout the respiratory tract. Radioactive material that falls onto food or into the water supply or that is transferred from hand to mouth may be ingested. A source of chronic exposure is radioactive material incorporated into the food chain as in the case of contaminated cow's milk and mushrooms in countries of the former Soviet Union after the Chernobyl accident. Other sources of internal contamination are medical procedures and the internalization of radioactive materials from an RDD.

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Chapter 3

Treatment of High-Dose Radiological and Combined Injury Casualties

NUCLEAR DETONATION

3-1. Casualties from a nuclear detonation that have been exposed to extremely high doses of radiation are normally in the range where they would be killed or severely injured by the blast and thermal effects. High-dose radiological casualties without some form of trauma are the more likely scenarios involving RDD or nuclear incidents. Refer to Table 3-1 for more information on predicted distribution of injuries sustained from a nuclear detonation.

Table 3-1. Predicted distribution of injuries sustained from a nuclear detonation

Injury types	*Percentage of total injuries*
Radiation only	15
Burn only	15
Wound only	3
Combined injury	***Percentage of total injuries***
Irradiation, Burns, and Wounds	17
Irradiation and Burns	40
Irradiation and Wounds	5
Wounds and Burns	5
Total Combined Injury	**67**

IONIZING RADIATION EFFECTS ON CELLS AND TISSUES

3-2. A wide range of biological effects in cells and tissues may follow exposure to ionizing radiation. These may include rapid death following extremely high radiation doses of penetrating whole-body radiation or delayed radiation effects following lower doses. Differing biological factors such as age and health of exposed individual, as well as the type of radiation, total dose and dose rate, produce a wide variety of responses by the biological systems.

CELLULAR EFFECTS OF IONIZING RADIATION

3-3. Bystander effect is the induction of biologic effects in cells that are not directly traversed by a charged particle, but are in proximity to cells that are. The existence of the bystander effect indicates that the target for radiation damage is larger than the cell itself. Its importance is primarily at low doses, where not all cells are *hit* and it may have important implications in risk estimation.

3-4. Observed cellular effects of radiation are similar for different types and doses of ionizing radiation and are related to two modes of action in the cell. Direct action is when the radiation hits a particularly sensitive atom or molecule (such as deoxyribonucleic acid in the cell). This damage is sometimes irreparable with the cell either dying or malfunctioning. Indirect action is when the radiation damages a cell by interacting with water molecules within the cells of the body. The interaction with the water molecules leads to the creation of unstable, toxic hyperoxide molecules that lead to damage in other subcellular structures within the cell.

Relative Cellular Radiosensitivity

3-5. Cellular radiosensitivity is described by the *Law of Bergonié and Tribondeau*. Cellular radiosensitivity tends to vary inversely with the degree of cell differentiation and is directly proportional to the rate of mitotic activity. Cells may be classified in decreasing order of sensitivity into four categories as described by *Rubin and Casarett*—vegetative intermitotic cells, differentiating intermitotic cells, reverting postmitotic cells, and fixed postmitotic cells.

Vegetative Intermitotic Cells

3-6. These cells are generally the most radiosensitive, divide regularly with no differentiation between divisions. Examples include—

- Erythroblasts.
- Germinal cells of epidermis.
- Intestinal crypt cells.

Differentiating Intermitotic Cells

3-7. These cells are somewhat less sensitive to radiation. They divide regularly with some differentiation between divisions. An example includes myelocytes.

Reverting Postmitotic Cells

3-8. These cells do not divide regularly and are variably differentiated. An example includes the liver.

Fixed Postmitotic Cells

3-9. This group of cells does not divide and are highly differentiated. This group of cells is the most radioresistant and includes the nerve and muscle cells.

Relative Tissue Radiosensitivity

3-10. The relative radiosensitivity of a specific tissue depends upon its component cell sensitivities. Table 3-2 lists various tissues and organs in decreasing order of radiosensitivity. Characteristics of specific tissues in critical organ systems are discussed in the following paragraphs.

Table 3-2. Relative radiosensitivity of various tissues and organs

Organs	*Relative radiosensitivity*	*Chief mechanism of tissue loss*
Lymphoid organs, bone marrow, testes and ovaries, small intestines, embryonic tissue	High	Destruction of parenchymal cells especially the vegetative or differentiating cells.
Skin, cornea, gastrointestinal organs: oral cavity, esophagus, stomach, rectum	Fairly high	Destruction of vegetative and differentiating cells which serve as the renewal source for the surface of these tissues.
Growing cartilage, vasculature, growing bones	Medium	Destruction of proliferating chondroblasts or osteoblasts, damage to the endothelium, destruction of connective tissue cells, and chondroblasts or osteoblasts.
Mature cartilage or bone, lungs, kidneys, liver, pancreas, adrenal gland, pituitary gland	Fairly low	Hypoplasia secondary damage to the fine vasculature and connective tissue elements.
Muscle, brain, spinal cord	Low	Hypoplasia secondary damage to the fine vasculature and connective tissue elements with little contribution by the direct effects on parenchymal tissues.

The Hematopoietic System

3-11. The hematopoietic cells in the bone marrow have a high turnover rate. In addition, bone marrow has a large number of hematopoietic cells in reserve. In other words, a large fraction of the hematopoietic system in the bone marrow is normally nonfunctioning but has the potential to be functional if required. The bone marrow contains three cell renewal systems or lines of cells—the erythropoietic (red cell) system, the myelopoietic (white cell) system, and the thrombopoietic (platelet) system. The time cycles and cellular distribution patterns and postirradiation responses of these three systems are quite different. Studies suggest that a pluripotential stem cell gives rise to these three main cell lines in the bone marrow. Beyond this pluripotential stem cell, however, each cell renewal system or line of cells consists of a specific stem cell compartment for the production of—

- Erythrocytes, leukocytes (for example, lymphocytes, granulocytes, monocytes) or platelets.
- Specific compartment for dividing and differentiating erythrocytes, leucocytes, or platelets.
- Specific compartment for maturing (nondividing) erythrocytes, leucocytes, or platelets.
- Specific compartment for mature, functional erythrocytes, leucocytes, and platelets.

3-12. Research studies suggest that each of these cell renewal systems operates under the influence of regulating factors, primarily at the stem cell level, through a negative feedback system initiated in large measure by the level of mature circulating cells in the peripheral blood.

3-13. Radiation exposure at an LD_{50} level (the dose that will result in death to 50 percent of the exposed population) will deplete the hematological stem cell population drastically. As the functionally mature cells die, they cannot be replaced. The overall population of these mature cells in the system decreases with the resultant clinical consequences. When the capability for stem cells to mature is recovered, a gradual return of a functional cellular population ensues.

The Gastrointestinal System

3-14. The vulnerability of the small intestine to radiation is primarily due to the cell renewal kinetics of the intestinal villi. This is where epithelial cell formation, migration, and loss occur. The four cell compartments involved are the—

- Stem and proliferating cell compartment.
- Maturation compartment.
- Functional compartment.
- Extrusion zone compartment.

3-15. Stem cells and proliferating cells move from crypts in the villi into a maturation compartment at the neck of the crypts. Functionally mature epithelial cells migrate up the villus wall and are extruded at the villus tip. In man, the overall transit time from stem cell to extrusion on the villus is estimated at 7 to 8 days.

3-16. Because of the high turnover rate occurring within the stem cell and the proliferating cell compartment of the crypt, marked damage occurs in this region by whole-body radiation doses above the midlethal range. Destruction as well as mitotic inhibition occurs within the highly radiosensitive proliferating cell compartment within hours after high-dose radiation exposure. Maturing and functional epithelial cells continue to migrate up the villus wall and are extruded, although the process is slow. Shrinkage of villi and morphological changes in mucosal cells occur as new cell production is diminished within the crypts. This eventually results in denudation of the intestinal mucosa. Concomitant injury to the microvasculature of the mucosa and submucosa in combination with this epithelial cell denudation results in hemorrhage and marked fluid and electrolyte loss contributing to shock. These events normally occur within one to two weeks after irradiation. A second mechanism of injury has recently been detected at the lower range of the GI syndrome or before major denudation occurs at higher doses of radiation. This response is a functional increase in fluid and electrolyte secretion from the epithelial cells without visible cell damage. This second mechanism may have important implications for fluid replacement therapy.

Central Nervous System

3-17. At extremely high doses of radiation (2000 cGy and higher), damage to the central nervous system (CNS) is severe and irreversible. The damage is related to interruptions of the normal regulatory control systems such as controlling responses in heart rate, respiration, blood pressure, and body temperature. The visible morphological changes at the cell level of the CNS are limited to a few tissues including the granule cell layer of the cerebellum and the meningeal lining of the brain. There might also be a breakdown of the *Blood-brain barrier* that leads to cerebral edema.

Cardiovascular System

3-18. The microvasculature of all tissue and organ systems is susceptible to damage by ionizing radiation exposure. The amount of tissue damage and the degree to which repair ensues are dependent on the level and duration of exposure, on the extent of tissue exposed, and on the type of radiation. Exposure-induced lesions on luminal surfaces of endothelial cells appear to provide initial sites for thrombogenic foci that not only extends endothelial damage but also activates a reparative molecular cascade in an attempt to correct the vascular defect. The major molecular players in this cascade include von Willebrand factor (vWF, clotting factor-8) which is released from damaged endothelial cells, the selected binding of angiogenic cytokines (angiogenic and platelet-derived endothelial growth factors) which stimulate the regrowth of damaged endothelial sites, and the damage-mediated release of cytokines by blood platelets and lymphocytes. These cytokines selectively stimulate proliferation of new perivascular elements. Within limits of exposure, this repair sequence commonly results in a restructured and fully functional vessel.

Cutaneous System

3-19. Acute skin injury occurs with radiation doses ranging from several hundred cGy to 2000+ cGy. Delayed, irreversible changes of the skin usually do not develop as a result of sublethal whole-body irradiation, but instead follow higher doses limited to the skin. These changes are a common complication in radiation therapy, but they should be uncommon in nuclear warfare. They could occur with an RDD if there is heavy contamination of bare skin with beta emitter materials, or due to mishandling of an industrial radiography source.

Cutaneous Radiation Effects

3-20. Effects follow a distinct clinical pattern that defines the Cutaneous Radiation Syndrome. The different stages of development, including the symptoms are summarized in Table 3-3 on page 3-5. Within minutes to hours after exposure an erythematous reaction develops that may be associated with a burning urticaria. This transient prodromal phase usually lasts less than 36 hours. It is followed by a clinically inapparent latent phase. The manifest phase is characterized by occurrence of an intensively erythematous skin which may show scaling and desquamation. In more severe conditions, subepidermal blisters and even ulcerations may develop. Though similar skin lesions are produced by thermal injury, the time course and underlying processes involved in the development of the Cutaneous Radiation Syndrome are so different from thermal burns that the term radiation burns or beta-burns are considered inappropriate and misleading for this clinical condition and should therefore be abandoned.

Table 3-3. Clinical stages of the cutaneous radiation syndrome

Stage	*Symptoms*	*Occurrence (postexposure time)*	*Duration*	*Synonyms*
Prodromal	Erythema itch	Minutes to hours	4 to 36 hours	Early erythema
Manifest	Erythema	Days to 2 weeks	2 to 12 weeks	Main erythema
Manifest	Blisters; Dry/moist desquamation Burn	Days to 2 weeks	2 to 12 weeks	Main erythema
Manifest	Ulcers	Days to 2 weeks	2 to 12 weeks	Main erythema
Subacute	Erythema; Ulceration	6 to 9 weeks	2 to 4 months	Late erythema
Chronic Fibrosis	6 months-Keratosis Ulceration Telan-giectasias	Indefinite to 2 years	progressive	
Late	Neoplasia Ulceration Angiomas Photosensitivity	Years to decades	indefinite	

Chronic Cutaneous Radiation Syndrome

3-21. In the chronic stage of the Cutaneous Radiation Syndrome, three clinical manifestations dominate the course:

- Radiation keratoses can develop in any exposed area. These lesions must be considered pre-cancerous and should be monitored thoroughly. Single lesions may be excised.
- Radiation fibrosis is caused by an increase of collagenous tissue from dermal and subcutaneous fibroblasts and may lead to pseudoatrophy of fatty tissue. Fibrosis may lead to vasculature occlusion and cause secondary ulceration.
- Telangiectasis is a characteristic sign of the chronic stage of the Cutaneous Radiation Syndrome in humans. Apart from cosmetic disfiguring, they may cause a permanent itching sensation and a disturbing feeling of warmth.

Treatment of the Cutaneous Radiation Syndrome

3-22. Standardization of treatment is difficult to achieve due to the rarity of this syndrome. An established treatment scheme does not exist. Differing procedures in documentation of accidents further reduce the comparability of therapeutic efforts in differing accident situations. Whatever the circumstance, treatment must provide symptomatic relief and minimization of additional risk to the patient. Recommended therapies, doses, and the therapeutic outcome are summarized in Table 3-4 on page 3-6.

Table 3-4. Symptom-oriented therapy for the cutaneous radiation syndrome

Symptom	*Treatment*	*Application*	*Dosage*	*Result*	*Side effects*
Pruritus	Antihistamines	Oral	As appropriate	Relief of itch	Sedation
Erythema	Steroids	Topical	2 × daily	Alleviation	None when used less than 3 weeks
Blisters	Steroids tetrachloro-decaoxide	Wet dressing	3 × daily	Alleviation	Not applicable
Dryness	Linoleic acid cream	Topical	1 × daily	Inhibition of water loss	Not applicable
Keratoses	Tretinoin Acitretin	Topical oral	1 × daily 0.1 to 0.3 mg/kg	Clearance moderate	Irritation; dryness of lips
Inflammation	Mometasone	Topical	3 to 4 × week	Alleviation	Not applicable
Fibrosis	Interferon gamma	Subcutaneous	50 µg 3 × week	Reduction	Fever
	Pentoxifylline and Vitamin E	Oral	400 mg 3 × daily 400 IU 1 × daily	Reduction	Not applicable
Legend: mg milligram; kg kilogram; IU International units; µg microgram					

3-23. Experience in the management of the manifest stage of Cutaneous Radiation Syndrome is limited to radiotherapy patients. In these conditions, an erythematous and erosive condition occasionally occurs that is often associated with a burning itch. Treatment with Loratadine (a nonsedating and mast-cell-stabilizing antihistamine), induced a marked relief of these symptoms and a shortening of the erythematous phase. Topical steroids generally have been used with success. Additional treatment modalities that have been reported to be of value in the manifest stage are cleansing of the oral cavity and administration of mouthwash formulations such as viscous lidocaine/antacids/diphenhydramine elixir to relieve mucositis. Heparinization and antibiotic prophylaxis for bacterial and viral infections may be beneficial.

3-24. Treatment modalities for the chronic stage of the Cutaneous Radiation Syndrome were developed from Chernobyl sequelae and from therapeutic irradiation patients. Chernobyl patients responded well to a basic therapy with a linoleic acid ointment that blocked transepidermal water loss. Symptomatic telangiectasias disappeared after treatment by an argon laser. Tretinoin cream 0.005 percent applied once daily, led to clearance of focal and patchy radiation keratoses, however, the cream appeared to cause more irritation than is common in patients with actinic keratoses. Intermittent anti-inflammatory treatment with topical nonatrophogenic steroids (Mometasone Buroate) was necessary. In more extensive lesions, oral application of the retinoid Acitretin was used, analogous to the reported treatment of radiation-induced keratoacanthomas. Pilocarpine is useful for the treatment of radiation induced xerostomia. For more information, refer to the International Atomic Energy Agency Technical Document–1300 (see reference section of this publication).

3-25. Subcutaneous administration of Interferon has been beneficial to patients with severe and extensive radiation fibrosis (Interferon gamma, 50 mg subcutaneously three times per week for 18 months). Using a protocol for scleroderma patients, fibrosis may be reduced almost to the level of uninvolved contralateral skin. Side effects included low-grade fever to 101.3 °F after the first two injections. The efficacy of Interferon gamma may be explained in part by its antagonistic effect towards the cytokine transforming growth factor-beta which is of importance for the induction of radiation fibrosis. Another therapeutic option for radiation fibrosis is the combined administration of pentoxifylline and vitamin E. This regimen,

applied for a minimum of 6 months, ameliorated persistent radiation fibrosis that had been progressive for over 20 years. Topical dressings of tetrachlorodecaoxide induce considerable granulation and re-epithelization in erosive skin conditions. Radioprotective properties of tetrachlorodecaoxide have been reported in experimental models that also demonstrated regenerative capacities in complicated wounds.

3-26. Appropriate surgical procedures include excision of ulcers and contractures, wound closure by split and full thickness skin grafts, and in certain instances, vascularized flaps. Grafts usually heal without complications including situations where the surrounding tissue may be affected by late radiation effects. Skin grafts do not heal if the surrounding affected tissue is not completely removed from patients with skin fibrosis after deeply penetrating radiation therapy.

SYSTEMIC EFFECTS OF HIGH-DOSE RADIATION

3-27. This section focuses on the systemic effects of high-dose radiation resulting from nuclear warfare or a high-dose radiation incident. Examples of a high-dose radiation incident would be—

- An actual nuclear detonation resulting from a weapon such as in Hiroshima and Nagasaki.
- When weapons or fuel-grade nuclear material is allowed to form a critical mass (*a criticality incident*).
- When an individual is exposed to a highly concentrated form of radioactive material, as would be present in irradiator facilities or from unshielded spent nuclear reactor fuel.
- When individuals repairing a radiation source and standing in radiation unknowingly.

3-28. Whole-body irradiation is potentially the most damaging radiation. Partial body irradiation is most likely to occur in both tactical scenarios and in radiological incidents since terrain, obstacles, and shielding would preclude whole-body exposure. Partial exposure would limit the amount of radiation actually transmitted to the body.

ACUTE RADIATION SYNDROME

3-29. Acute radiation syndrome is a complex clinical presentation of injuries that occur after exposure to a high-dose of ionizing radiation. The clinical presentation is dependent on the type, rate, and dose of radiation received. Acute radiation syndrome has been encountered after the detonation of nuclear weapons or after industrial radiation accident. There are four phases to the acute radiation syndrome—

- Prodromal or initial phase occurring during the first few hours after exposure.
- Latent phase which becomes shorter with increasing dose of radiation exposure.
- Manifest phase in which the clinical symptoms appear.
- Recovery phase in which most patients who do not recover will die.

Prodromal or Initial Phase

3-30. The prodromal symptoms (prodrome) include the rapid onset of nausea, vomiting, and malaise. This is a nonspecific clinical response to acute radiation exposure. The speed of onset and duration of symptoms vary with the degree of exposure to acute doses of radiation, and alone are not precisely diagnostic of the degree of radiation injury, but do have significant predictive value. An early onset of symptoms in the absence of associated trauma does suggest a large radiation exposure.

Latent Phase

3-31. Following recovery from the prodromal phase, there will be a latent phase during which the exposed individual will be relatively symptom-free. The length of this phase varies with the dose and the nature of the later manifest phase. The latent phase is longest preceding the bone marrow depression of the hematopoietic syndrome and may vary between 2 and 6 weeks. It is somewhat shorter prior to the GI syndrome lasting from a few days to a week. It is shortest of all preceding the neurovascular syndrome lasting only a matter of hours. These times are exceedingly variable and may be modified by the presence of other disease, injury, or by medical intervention.

Manifest Phase

3-32. This phase is when the clinical symptoms associated with the major organ system involved (marrow, intestine, neurovascular system) become evident. The clinical symptoms are classified under four subsyndromes: hematopoietic, cutaneous, GI, and neurovascular.

Recovery Phase

3-33. In most cases during recovery phase, bone marrow cells will begin to repopulate the marrow. Full recovery is expected for a large percentage of individuals from a few weeks up to two years after exposure. Death may occur in some individuals at 1.2 Gy (120 rads).

Without Medical Intervention

3-34. A dose that is lethal to 50 percent of a given population within a specific time frame after exposure is annotated as LD_{50}. The LD_{50} may define acute lethality but can be modified to allow for mortality over a specific length of time. The common time periods used are 30 days for most small laboratory animals and 60 days for large animals and man. The specific time period is indicated by a second number in the subscript: $LD_{50/30}$ and $LD_{50/60}$ indicate 50 percent mortality within 30 days and 60 days, respectively. Figure 3-1 is a graphic representation of a typical mortality response to radiation. The LD_{50} of radiation that will kill 50 percent of exposed persons within a period of 60 days without medical intervention ($LD_{50/60}$) is an acute dose to the whole body of approximately 400 cGy, as measured free in air. Medically, other figures of interest are the dose that will kill 5percent (LD_5) and the dose that will kill virtually everyone (LD_{95}). Approximations of those doses are within the free-in-air ranges of 200 to 300 cGy and 600 to 700 cGy, respectively. These values are important in determining treatment priorities.

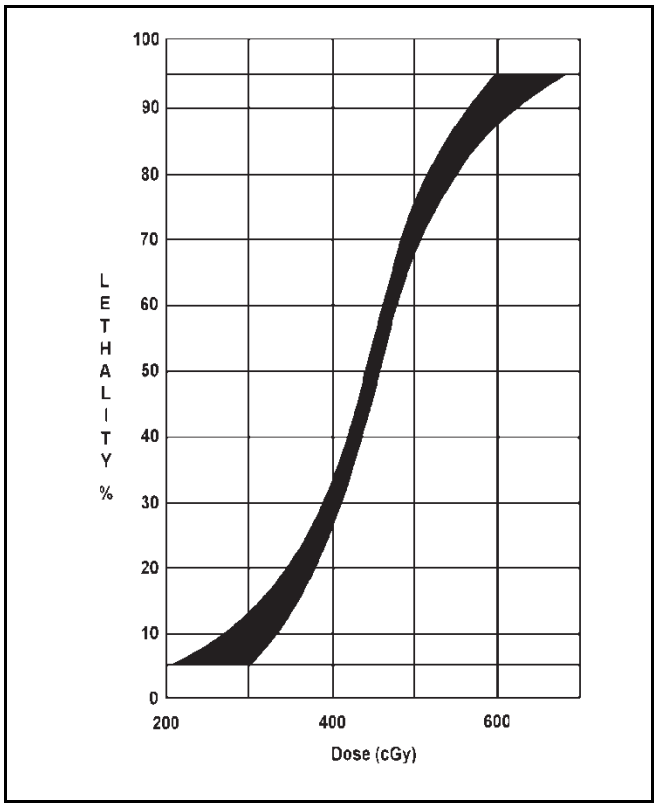

Figure 3-1. Lethality as a function of dose without medical intervention

With Medical Intervention

3-35. Adequate medical intervention significantly increases the LD_{50} and markedly diminishes mortality. The LD_{50} for radiation moves from approximately 400 cGy to approximately 600 cGy if the exposed individual receives timely medical treatment that is generally available within a theater of operations. For more information on medications, refer to Appendix A. The list of medications in Appendix A is predominantly off-label recommendations for bone marrow support and treatment of infections and symptoms. Other than decorporation agents, there are no specific countermeasures approved by the Food and Drug Administration (FDA) for treatment of acute radiation syndrome.

SUBSYNDROMES OF ACUTE RADIATION SYNDROME

3-36. The subsyndromes of acute radiation syndrome include the hematopoietic, cutaneous, GI, and neurovascular. The syndromes are dose-dependent, interrelated and cumulative. As dose is increased, the hematopoietic system, GI system and cardiovascular/neurovascular are each affected in turn, based largely on the radiosensitivity of the underlying cell and tissue system. Clearly, a dose sufficient to impact the GI system will also impact the hematopoietic system. Doses sufficient to impact the CNS will likely result in lethality before expression of the syndromes associated with lower doses. In this section, hematopoietic, GI, and neurovascular subsyndromes will be discussed in length.

Hematopoietic Subsyndrome

3-37. Patients who received doses of radiation in excess of 200 cGy will have depression of bone marrow function with cessation of blood cell production leading to pancytopenia. Changes within the peripheral blood profile will occur as early as 24 hours after irradiation (see Figure 3-2). The exact time sequence of the depression of various circulating cell lines will vary. Lymphocytes will be depressed most rapidly and erythrocytes least rapidly. Other leukocytes and thrombocytes will be depressed somewhat less rapidly than lymphocytes. If the bone marrow depression is the result of multiple, fractionated exposures, or to an exposure that occurs over a period of hours to days, it may be difficult to estimate when the depression will occur. A reasonable average time for onset of clinical problems of bleeding and anemia and decreased resistance to infection is 2 to 3 weeks. If an infection occurs, there may be little clinical response because of the concomitantly depressed inflammatory response.

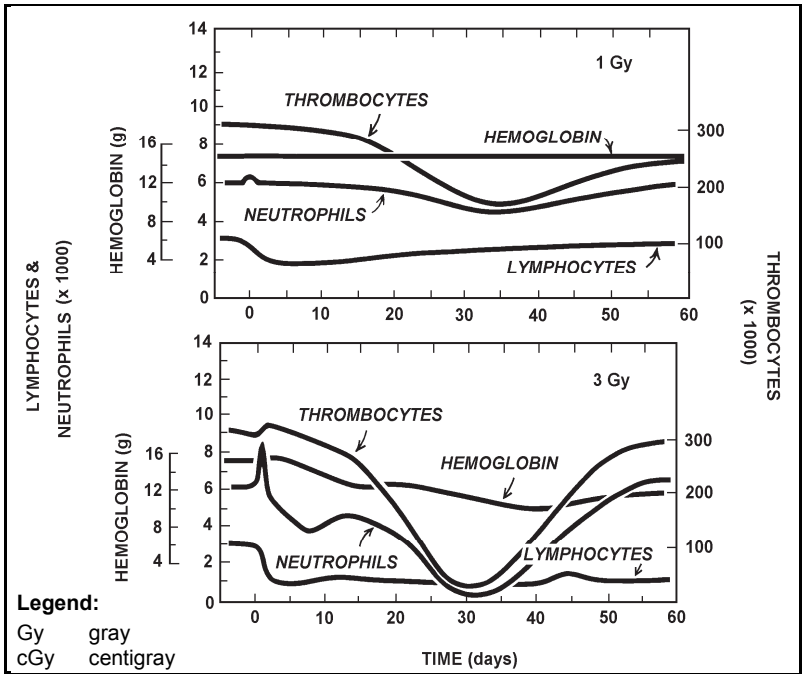

Figure 3-2. Hematological response to whole-body exposure of 1 Gy (100 cGy) and 3 Gy (300 cGy)

Erythropoiesis

3-38. The erythropoietic system is responsible for the production of mature erythrocytes (red cells). Because immature erythroblasts and proerythroblasts proliferate rapidly, they are markedly sensitive to cell killing by ionizing radiation. Deaths of stem cells and of those within the dividing and differentiating compartment are responsible for the depression of erythropoietic marrow. If sufficiently severe, this depression is responsible for the subsequent radiation-induced anemia. Because of the relatively slow turnover rate (approximately one percent loss of red cell mass per day) evidence of anemia is usually manifested after depression of the other cell lines. This system has a marked propensity for regeneration following irradiation. After sublethal exposures, marrow erythropoiesis normally recovers slightly earlier than granulopoiesis and thrombopoiesis and occasionally overshoots the baseline level before levels at or near normal are reached.

Lymphopoiesis

3-39. Lymphocytes are the most radiosensitive cells of the hematopoietic system. Shortly after exposure to ionizing radiation, mature lymphocytes show early necrosis and immature splenic lymphocytes have evidence of chromatin clumping and early necrotic changes. Lymph nodes show nuclear debris within hours of irradiation. The number of cells in the blood-forming organs is not related to radiation dose, but further cell reproduction seems to be inhibited. Surviving lymphocytes may have either an increased cellular metabolism or altered behavior. The greater the radiation exposure, the more profound the lymphopenia. The lymphopenia will begin within hours and shows a steep dose-dependent (1-10 Gy) decline spanning 1 to 10 days after irradiation. The fall in circulating lymphocytes can be utilized as a crude biodosimetry tool to estimate the effective radiation dose received. The steeper the fall in circulating lymphocytes, the higher the dose and the more severe the injury.

Leukopoiesis

3-40. The function of the myelopoietic cell renewal system is mainly to produce mature granulocytes (neutrophils, eosinophils, and basophils) for the circulating blood. The most important type in this cell line is the neutrophils because of their role in combating infection. The stem cells and those developing cells within the dividing and differentiating compartment are the most radiosensitive. Normally, 3 to 7 days are required for the mature circulating neutrophil to form from its stem cell precursor stage in the bone marrow. Mature functional granulocytes are available upon demand from venous, splenic, and bone marrow pools. Following an initial increase in circulating granulocytes (of unknown etiology), these pools are normally depleted before granulocytopenia is evident soon after radiation-induced bone marrow injury. Because of the rapid turnover in the granulocyte cell renewal system (approximately 8-day cellular life cycle), evidence of radiation damage to marrow myelopoiesis occurs in the peripheral blood within 2 to 4 days after whole-body irradiation. Recovery of myelopoiesis lags slightly behind erythropoiesis and is accompanied by rapid increases in numbers of differentiating and dividing forms in the marrow. Prompt recovery is occasionally manifested and is indicated by increased numbers of band cells in the peripheral blood.

Thrombopoiesis

3-41. The thrombopoietic cell renewal system is responsible for the production of platelets (thrombocytes). Platelets are produced by megakaryocytes in the bone marrow. Both platelets and mature megakaryocytes are relatively radioresistant, however the stem cells and immature stages are very radiosensitive. The transit time through the megakaryocyte proliferating compartment in man ranges from 4 to 10 days. Platelets have a life span of 8 to 9 days. The time of beginning platelet depression is influenced by the normal turnover kinetics of cells within the maturing and functional compartments. Thrombocytopenia is reached in 3 to 4 weeks after doses in excess of 200 cGy with the nadir likely occurring earlier as the dose is increased and occurs from the killing of stem cells and immature megakaryocyte stages with subsequent maturational depletion of functional megakaryocytes. Regeneration of thrombocytopoiesis after sublethal irradiation normally lags behind both erythropoiesis and myelopoiesis. Supranormal platelet numbers overshooting the preirradiation level have occurred during the intense regenerative phase in human nuclear accident victims. Blood coagulation defects with concomitant hemorrhage constitute important clinical sequelae during the thrombocytopenic phase of bone marrow and GI syndromes.

Gastrointestinal Subsyndrome

3-42. The radiation doses that will result in the GI syndrome are higher than those that will cause the hematopoietic syndrome alone. An acute dose that will cause this syndrome will be at least 800 cGy. Some facets of the GI syndrome may manifest at doses of 600 cGy depending on abdominal dose and individual sensitivity. Exposures to high doses at low-dose rates or as fractionated exposures (multiple individual exposures totaling a specific dose) may not cause GI syndrome. Regardless of the dose involved, the GI syndrome has a very serious prognosis, because it will almost always be accompanied by bone marrow suppression.

3-43. The effects of radiation on the GI tract and the associated symptomatology can be categorized into four major phases that correspond to the elapsed time from exposure to manifestation. These phases are—

- The Prodromal Phase—severe nausea, vomiting, and watery diarrhea occur minutes to hours after exposure.
- The Latent Phase—generally a period of a few days to a week in which symptoms abate prior to manifest illness.
- The Manifest Phase—patients experience severe fluid loss, hemorrhage, and diarrhea. The pathologic basis for this syndrome is an early physiologic derangement of the epithelial cells followed by a combination of severe loss of intestinal mucosa and injury to the fine vasculature of the submucosa.
- The Recovery/Death Phase—survivors may develop fibrosis, predisposition to bowel obstruction, bleeding, and fistulas months to years after exposure.

Neurovascular Subsyndrome

3-44. This syndrome is associated only with very high acute doses of radiation. The lower limit is probably 2000 cGy, although hypotension (significant decline in systemic blood pressure) may be seen at even lower doses. Because of the very high doses of radiation required to cause this syndrome, personnel close enough to a nuclear detonation would generally be located well within the range of 100 percent lethality due to blast and thermal effects. Doses of this magnitude have been seen during criticality accidents where there is no blast and limited thermal effects and have always been lethal even with very aggressive treatment. The effects include combat ineffectiveness due to partially degraded performance that may result from slower reaction to the task, task stress or prodromal effects of acute radiation sickness.

3-45. Acute radiation doses of 3000 cGy and above uniformly bring death within 72 hours and usually between 24 to 48 hours well before the insult to the GI or bone marrow systems becomes clinically apparent. Doses in this range cause significant direct effects as well as the free radical overload of the cells and basement membranes of the microcirculation system. This leads to massive loss of serum and electrolytes through leakage into the extravascular space, circulatory collapse, edema, increased intracranial pressure, and cerebral anoxia.

3-46. In less than an hour and possibly within minutes of exposure, patients receiving these doses begin experiencing prodromal symptoms—a burning sensation of the skin within minutes and severe nausea and usually projectile vomiting within an hour. The symptoms are severe (may last more than 24 hours) including diarrhea that is occasionally bloody, cutaneous edema and erythema, hypotension, hyperpyrexia, disorientation, prostration, loss of coordination, and possibly seizures. Following the prodromal phase, there may be a brief latent phase of apparent clinical improvement but this will last only in the range of hours to days. Finally, the victim will succumb to a complex of gross CNS dysfunction and total cardiovascular collapse leading to a relatively prompt death.

RADIATION-INDUCED EARLY TRANSIENT INCAPACITATION

3-47. Early transient incapacitation is a temporary inability to perform physically or cognitively demanding tasks and is associated with very high acute doses of radiation (lower limit is approximately 2000 cGy). The latent period is very short, varying from several hours to 1 to 3 days. Hypotension, emesis, and/or diarrhea may accompany a progressive deteriorating state of consciousness as a result of vascular

instability. Death typically occurs within a few days. Convulsions without increased intracranial pressure may or may not occur.

3-48. The frequency of incapacitation produced by a given radiation dose is proportional to the demands or the level of stress of the task being performed. Current combat casualty criteria are based on the incapacitating dose levels for both physically demanding tasks and undemanding tasks. Exposure to doses of ionizing radiation of approximately 2000 cGy results in an immediate precipitous decline in cerebral blood flow which is followed by a partial recovery at 20 to 30 minutes and subsequent slower secondary decrease in cerebral blood flow and then accompanied by parallel changes in systemic blood pressure. The activity of certain brain enzymes involved in neurotransmitter metabolism is also considerably affected during early transient incapacitation.

3-49. For yields of 5 KT or less, initial nuclear radiation will be the dominant casualty producer on the battlefield. Military personnel close enough to ground zero who receive an acute incapacitation dose of 2000 cGy would more likely die due to blast and thermal effects. However, in nuclear detonations above the atmosphere with essentially no blast, very high fluxes of ionizing radiation may extend out far enough to result in high radiation doses to aircraft crews. Such personnel could conceivably manifest early, transient incapacitation uncomplicated by blast or thermal injury. Personnel protected from blast and thermal effects in shielded areas could also sustain doses that might manifest as early transient incapacitation. Doses in this range could be a result from military operations in a reactor facility or a fuel processing plant where personnel are accidentally or deliberately injured by a nuclear criticality event. Personnel suffering from early, transient incapacitation will become performance degraded almost immediately and combat ineffective within several hours. However, they will not die until 5 to 6 days after exposure unless they received other injuries that would make them more susceptible to death from the radiation dose.

DIAGNOSIS, SEVERITY, AND TRIAGE OF RADIATION CASUALTIES

3-50. A precise history of exposure may be very difficult to obtain since many individuals may not know that they actually have been exposed to radiation particularly if the exposure is due to fallout, or due to exposure to a low-level radiation source.

CLINICAL FINDINGS

3-51. One of the sources of information available to the medical staff is the medical physicist, health physicist, or radiation safety officer. Personnel may be able to provide unit operational history information and perhaps collective unit exposure data. An accurate and prompt diagnosis of radiation sickness is most likely based upon the clinical picture presented by the patient. The key signs and symptoms of radiation sickness that would make one suspicious that radiation exposure has occurred are described below.

Nausea and Vomiting

3-52. Nausea and vomiting occur with increasing frequency as the radiation dose exceeds 100 to 200 cGy. Their onset may be seen as long as 6 to 12 hours postexposure and usually subsides within the first day for these lower doses. The occurrence of vomiting within the first two hours is usually associated with a severe radiation dose. Vomiting within the first hour, especially if accompanied by explosive diarrhea, is associated with doses that frequently prove fatal. Due to the transient nature of these symptoms, it is possible the patient will have already passed through the initial phase of GI distress before being seen by a physician. It will be necessary to inquire about these symptoms at the initial examination. The use of antiemetics such as granisetron, has been approved by the FDA for prophylactic use for high-dose radiation exposure. Medical personnel may encounter patients whose nausea and vomiting symptoms have been reduced or mitigated by the use of this drug. The approval of granisetron was in the context of medical radiation therapy. It should not be considered an approved military prophylaxis as it may result in operational performance decrements due to adverse reactions.

WARNING

The use of antiemetics such as granisetron is in the context of medical radiation therapy. It should not be considered an approved military prophylaxis as it may result in operational performance decrements due to adverse reactions.

Hyperthermia

3-53. Casualties who have received a potentially lethal radiation injury show a significant rise in body temperature within the first few hours postexposure. The occurrence of fever and chills within the first day postexposure is associated with a severe, life-threatening radiation dose. Hyperthermia may occur in patients who receive lower, but still serious, radiation doses (200 cGy or more).

Erythema

3-54. A person who has received a whole-body dose of more than 1000 cGy will develop erythema within the first day postexposure. Erythema is less frequently seen with lower doses (200 cGy or less).

Hypotension

3-55. Victims who have received a supralethal whole-body radiation dose will noticeably and sometimes clinically develop significant decline in systemic blood pressure. In persons who received several hundred cGy, a drop in systemic blood pressure of more than 10 percent will be noted. Severe hypotension after irradiation is associated with lethal injury. However, if the radiation dose has been determined to be less than 1000 cGy, then a physical injury should be suspected as being responsible for the hypotension.

Neurologic Dysfunction

3-56. Experience indicates that almost all persons who demonstrate obvious signs of damage to the CNS within the first hour postexposure have received a supralethal dose. Symptoms include mental confusion, convulsions, and coma. Intractable hypotension will probably accompany these symptoms. These patients generally will succumb within 48 hours unless aggressive medical support is provided; even with such support, death is imminent.

DOSIMETRY

3-57. Dosimetry can help determine that an exposure has occurred but will not give an entirely adequate picture that can be used to determine either the extent of radiation injury or the prognosis. Dosimeters cannot tell whether a radiation exposure is whole body or partial body and they do not display the dose rate of the exposure. Dosimeters cannot differentiate between single exposures and multiple exposures unless they are read at regular intervals. In a mass casualty situation where time is critical, decisions based only on dosimetric data may be all that is practical.

BIODOSIMETRY

3-58. Biodosimetry is the use of a biological response as an indicator of radiation dose. There is no FDA-approved biodosimetry devices. Current practice involves use of a multiple parameter diagnostic approach including assessment of physical/biophysical dosimetry measurements, if available, radionuclide contamination, cytogenetic biodosimetry, and clinical signs and symptoms. For more information, refer to the Armed Forces Radiobiology Research Institute Special Publication 10-1, Medical Management of Radiological Casualties Handbook.

3-59. Fliedner and colleagues established an acute radiation syndrome severity scoring system, Medical Treatment Protocols for Radiation Accident Victims or *METREPOL*, to manage accident victims on the

basis of bioindicators of effect and repair considering multiorgan involvement. Radiation injury victims are categorized into response categories (RC) levels representing mild (RC1), moderate (RC2), severe (RC3), and very severe (RC4) degrees of radiation injury, which can be used to guide medical providers for potential treatment options. Organ-specific injury biomarkers of acute radiation syndrome provide early-phase prognostic indication of the acute radiation syndrome response category and when combined with clinical symptoms provide the best diagnostic approach for medical management of radiation casualties (see Figure 3-3).

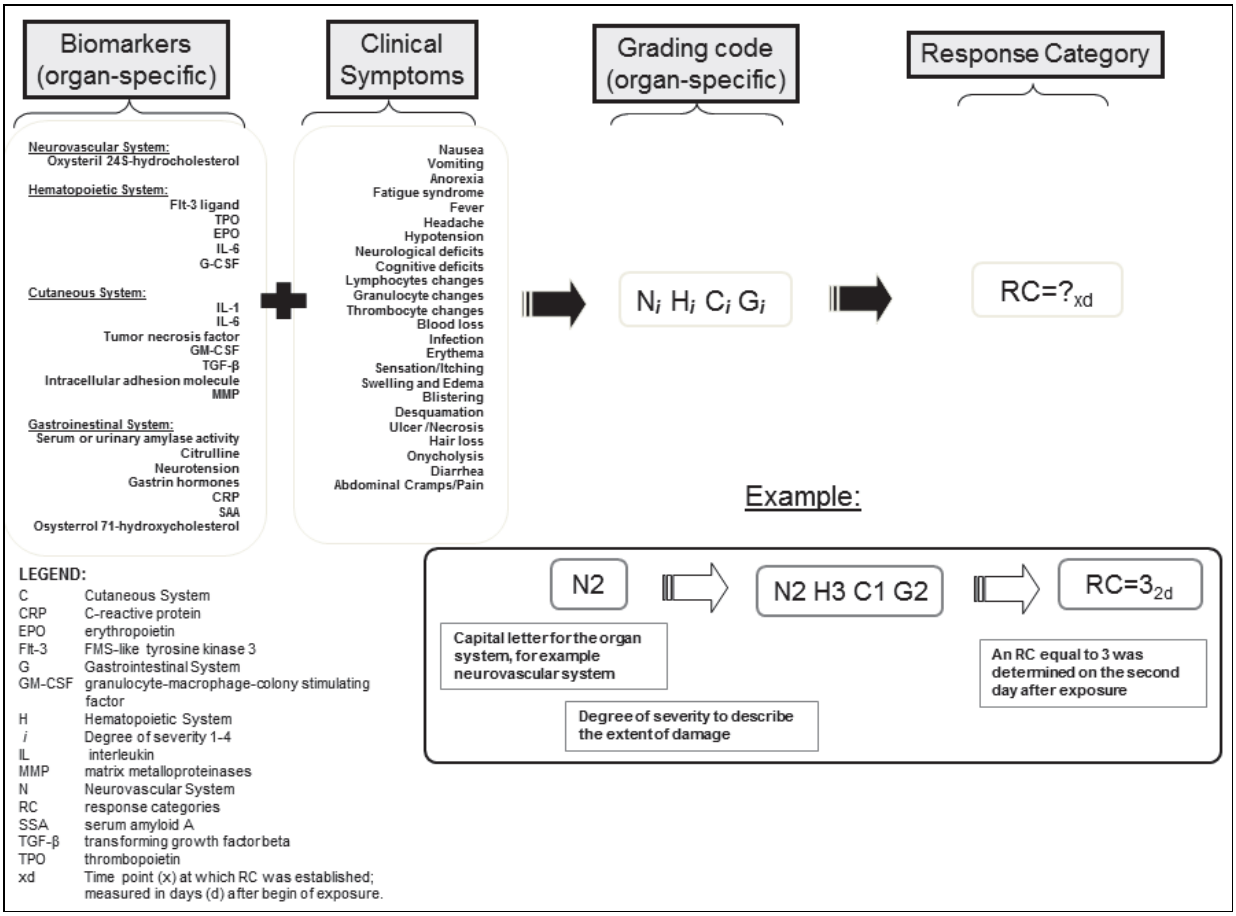

Figure 3-3. Organ-specific biomarkers are being developed that can assist in establishing response categories for each of the patients

EARLY RESPONSE MULTIPARAMETER BIODOSIMETRY

3-60. No single assay is sufficiently robust to address all potential radiation scenarios, including management of mass casualties and diagnosis for early medical treatment. Recommendations for use by first responders involve a prioritized multiple-assay biodosimetric-based strategy. Multiparameter triage involving time to emesis, lymphocyte kinetics, and other biodosimetry and biochemical indicates as the current best early assessment of a victim's absorbed dose. Rapid dose assessment by cytogenetic biodosimetry, using triage scoring, is critical to provide useful diagnostic value for the development of medical management decisions. Biodosimetry is not intended to replace other methods of dose assessment, such as early health physics dose estimation and formal dose reconstruction.

3-61. Consensus biodosimetric guidelines currently include the measurement of—

- Signs and symptoms.
- Cytogenetics.
- Radioactivity assessment.

- Electron Paramagnetic Resonance.
- Hematology.
- Serum amylase.
- Personal and area dosimetry.
- C-reactive protein.

3-62. The normal range of lymphocyte counts span from 1.4 to 3.5 x 10^9 per liter. From Table 3-5 below it is evident that emesis within 1 to 2 hours is particularly serious while a drop in lymphocyte count to less than 1/2 (0.7 x 10^9 per liter) of the low baseline values (1.4 x 10^9 per liter) within 24 hours signals a potentially lethal dose.

Table 3-5. Multiple parameter biodosimetry

Dose, Gy	*Emesis %*	*Onset of Emesis, h*	*Absolute lymphocyte count, % of normal*					*Relative increase in serum amylase, day 1*	*Number of dicentrics per 50 metaphases*
			1d	**2d**	**4d**	**6d**	**8d**		
0	-	-	100	100	100	100	100	1	0.05-0.1
1	19	-	88	78	60	47	36	2	4
2	35	4.6	78	60	36	22	13	4	12
3	54	2.6	69	47	22	10	4.9	6	22
4	72	1.7	60	36	13	4.9	1.8	10	35
5	86	1.3	53	28	8.2	2.4	0.82	13	51
6	94	0.99	47	22	4.9	1.2	0.24	15	-
7	98	0.79	41	17	2.9	0.49	0.082	16.5	-
8	99	0.66	36	13	1.8	0.24	<0.04	17.5	-
9	100	0.56	32	10	1.2	0.12	<0.04	18	-
10	100	0.48	29	8	0.82	0.04	<0.04	18.5	-

Note. The gray shaded areas represent lymphocyte values similar to baseline levels.

Legend:
d day
Gy gray
H hours

Note. There is no FDA-approved biodosimetry devices. Current practice involves use of a multiple parameter diagnostic approach including assessment of physical/biophysical dosimetry measurements, if available, radionuclide contamination, cytogenetic biodosimetry, and clinical signs and symptoms.

CYTOGENETIC BIODOSIMETRY

3-63. Cytogenetic biodosimetry is considered the gold standard for determination of patient whole-body radiation dose. Cytogenetic biodosimetry has been used for decades to estimate dose on the basis of radiation-induced chromosome aberrations in circulating lymphocytes. The gold standard is the metaphase-spread dicentric chromosome aberration assay (Figure 3-4 on page 3-16). It is mainly applicable to recent whole-body acute radiation exposures. Due to the low background level of dicentric chromosomes in lymphocytes the assay's sensitivity is comparatively high, with a threshold whole-body dose of 0.1 to 0.2 Gy (based on analysis of 1000 cells), and it shows a strong dose dependence up to 5 Gy for acute photon exposures. This assay is generally accepted as the most specific and sensitive methods (0.2 Gy) for determining doses from recent exposures to ionizing radiation (for example within days to about six months). Additionally, statistical techniques are available that can determine if the body received a homogeneous dose distribution or if the dose was delivered in a nonhomogeneous manner. The usefulness of this assay is greatly reduced for measuring doses received more than six months before the assay because the half-life of lymphocytes, resulting in the instability, and thus loss, of dicentric chromosomes. The reproducibility, relative specificity of dicentric aberrations to radiation, and its sensitivity to doses below acute medical significance have allowed the assay to become the gold standard in radiation biodosimetry.

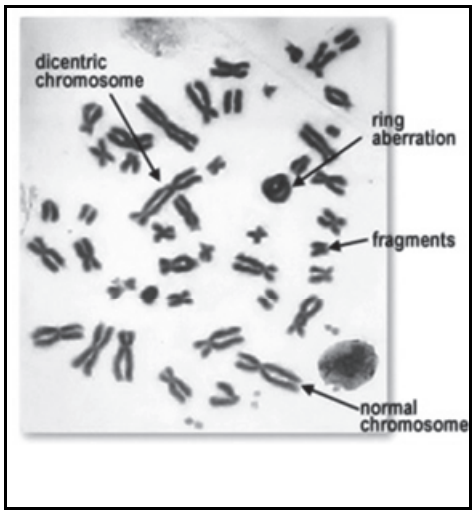

Figure 3-4. Irradiated lymphocyte chromosomes fixed on a slide in the metaphase stage of mitosis.

3-64. Other methods currently used in cytogenetic dosimetry include the translocation, premature chromosome condensation, and the cytokinesis-block micronucleus assays (see Table 3-6), which have applications to varied radiation exposure scenarios.

Table 3-6. Cytogenetic chromosome aberration assays

	Dicentric (and ring)	***Translocation***	***Premature chromosome condensation***	***Cytokinesis-blocked micronuclei***
Photon equivalent, acute dose (Gy) range for whole-body exposure	0.1-5	0.25-4	0.2-20	0.3-5
Partial-body exposure assessment	Yes	No	Yes	No
Typical exposure applications	Low level; acute, protracted; prior exposures (<6 months)	Protracted, prior exposures (>6 months)	Acute (including high dose) exposures	Acute
Legend: Gy gray				

ELECTRON PARAMAGNETIC RESONANCE

3-65. Exposure of humans to ionizing radiation results in radiation-induced changes that can be measured and depending on the absorbed dose, quantified. The use of Electron Paramagnetic Resonance (EPR) for biodosimetry is based on the capability of the technique to provide specific and sensitive measurement of unpaired electrons in solid tissue which are created in proportion to the absorbed dose. The lifetimes of these electrons are very short (nanoseconds) in aqueous systems, such as most biological tissues, but can be extremely stable in non-aqueous media, including teeth, bone, fingernails, and hair. Electron Paramagnetic Resonance-based detection of free radicals is a well accepted and validated method for measuring dose to dental enamel from tooth biopsy. Low thresholds of detection are possible when measuring EPR signals in extracted teeth, however, confounders still exist for *in vivo* teeth EPR measurements. Electron Paramagnetic Resonance-based dose assessment has been applied in radiation accident cases using extracted and recently with nail clippings to provide diagnostic information about heterogeneous exposures. Provisional protocols for sample collection of nail clippings are established. Biophysical dose assessment using in-vivo EPR from teeth, along with ex-vivo EPR from nail-clipping samples from the extremities

would contribute to mapping partial-body exposures and allow an estimate of regional (head, extremities) radiation exposure, and could point to bone-marrow sparing.

MOLECULAR MARKERS IN BODY FLUIDS AND TISSUES

3-66. Molecular markers (biomarkers) represent underlying changes in physiology arising from physical damage, (for example, cell lysis and the release of intracellular proteins into the circulation, oxidation by-products or DNA breakage), underlying changes in biochemistry (the presence of new metabolites or changes in levels of key gene products), plasma bioindicators of organ injury, and/or changes in cellular composition of tissues. These markers include molecules as diverse as proteins and small molecule metabolites. Within minutes to hours after exposure to ionizing radiation, proteins are modified and activated, and large-scale changes occur in the gene expression profiles involving a broad variety of cell-process pathways. There are presently about 90 known proteins that show changes in expression or undergo post-translational modifications after exposure to ionizing radiation. Some of these change in a dose-dependent fashion. Use of biochemical markers in a multiparameter assay represents new development in radiation dosimetry that can also provide diagnostic information on absorbed dose as well as injury to relevant organ systems useful for treatment decisions.

DOSE VERSUS BIOEFFECTS DIRECTED DIAGNOSTICS

3-67. Radiological diagnostics inform treatment by aiding in the decisions regarding which patient to treat, what treatment to provide; when to provide the treatment; and determine the effectiveness of the treatment. The first and second are treatment-triage steps that are both based on the patient's condition, the number of patients, and the availability of treatment resources including evacuation assets. The following analysis is intended to discern the criteria for a radiological diagnostic to support treatment-triage and treatment.

3-68. Table 3-7 illustrates the relationship between biodosimetry versus bioeffects—based grouping of expected bone marrow status and general therapeutic interventions. Dose ranges are shown for photon equivalent acute exposures and RC levels are based on the Medical Treatment Protocols for Radiation Accident Victims radiation injury severity scoring system. Dose ranges for the expected bone marrow status and therapeutic interventions are influenced by several confounders including the presence of combined injury, partial-body exposures, and the dose rate of exposures.Table 3-7. Photon equivalent acute dose and response category ranges: general guidelines for expected bone marrow status and therapeutic interventions

Table 3-7. Photon equivalent acute dose and response category ranges: general guidelines for expected bone marrow status and therapeutic interventions

Dose range[1]	*Response category (RC)*	*Bone marrow status*	*General therapeutic interventions*
7-10 Gy	RC 4	Autologous recovery most unlikely	Stem cell-transplantation
>3-7 Gy	RC 3	Autologous recovery possible	Stimulation (growth factor therapy); supportive care: Substitution (blood component therapy) as needed
>0.5-<3 Gy	RC 2	Autologous recovery likely	Supportive care: Substitution (blood component therapy) as needed
<0.5 Gy	RC 1	Autologous recovery certain	General support of recovery processes; usually no specific therapy

[1]Dose ranges are based on photon equivalent acute exposures to the whole body for a mass casualty exposure of healthy persons with no other injuries.

Legend: Gy gray RC response category

LABORATORY TESTING

3-69. The most useful forward laboratory procedure to evaluate marrow depression is the peripheral blood count. The resultant lymphocyte levels may be used as a biologic dosimeter to help make the diagnosis and determine only the severity of radiation injury (see Figure 3-5). In the event of combined injuries, the use of lymphocytes may be unreliable because patients who have received severe burns or multisystem trauma often develop lymphopenia. The rate and degree of decrease in blood cells are dose dependent. An initial baseline sample should be obtained as early as possible after irradiation. Blood samples should be taken at least daily during the first two weeks. More frequent sampling will increase the reliability of dose estimates. A useful rule of thumb is—if lymphocytes have decreased by greater than 70 percent and are less than 1.0×10^9 /liter within 24 to 48 hours, the patient may have received at least a moderate dose of radiation. However, all personnel with lymphocyte levels of less than 2000 per cubic millimeter at 24 hours postirradiation will need medical treatment.

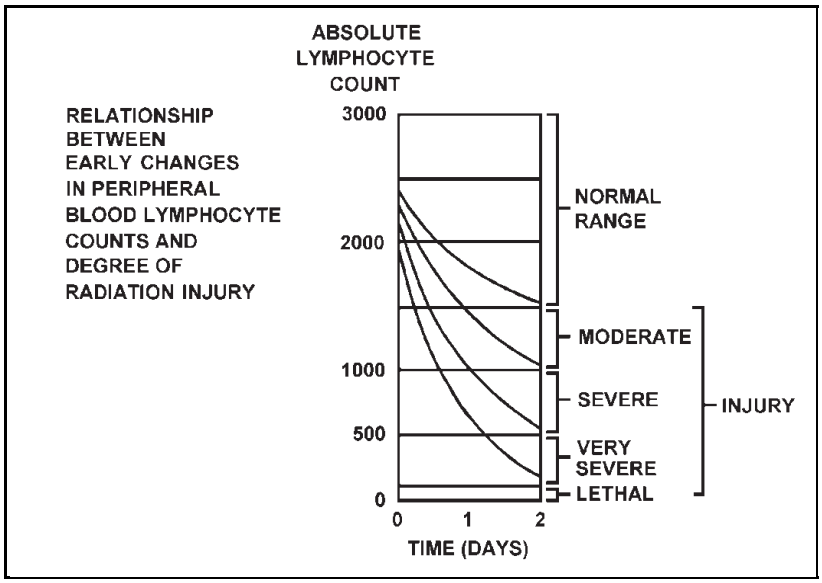

Figure 3-5. Lymphocyte nomogram

3-70. Other medical assays can be used to determine the severity of radiation exposure and/or presence of serious viral illness. Table 3-8 found on page 3-19 (adapted from AMedP-6 [C]) lists clinical laboratory tests and the treatment levels where they should be performed.

Table 3-8. Medical assay of the radiological patient

	Location/facility			
Test	***Decontamination point***	***Medical treatment unit (Role 2)***	***Hospital (Role 3)***	***Tertiary care (Role 4)***
Nasal swabs/nasal blows for inhalation of contaminants	+			
External contamination	+	+	+	
Urine and stool sample for internal contamination		Baseline sample	24-hour sample	+
Complete blood count (CBC)/platelets	If practical	Baseline sample and then daily	Daily for 2 weeks	Daily for 2 weeks
Absolute lymphocyte count		Every 4 to 12 hours	Every 4 to 12 hours for 3 days	
Human leukocyte antigen subtyping		Draw sample	Draw sample before lymphocyte count falls	Draw sample before lymphocyte count falls
Cytomegalovirus			+	+
Hemoglobin agglutinin			+	+
Human syncytial cell virus antibodies				+
Lymphocyte cytogenetics		Draw sample	Draw sample before lymphocyte count falls	+
+ Indicates test should be performed at this location/role of care.				

TRIAGE OF NUCLEAR AND RADIOLOGICAL CASUALTIES

3-71. Triage classifications for radiation-exposed patients differ from conventionally injured patients. Nuclear and radiological casualties may have combined injuries that will impact limited resources (medical personnel, treatment consumables, and hospital beds). Because survivable radiation injury is not manifested until days to weeks after exposure, triage is based primarily on the presentation of conventional injuries and is then modified by radiation injury level. Triage and care of life-threatening injuries should be rendered without regard for the probability of radiation exposure or contamination to the health care providers. The medical provider should make a preliminary diagnosis of radiation injury for those patients who display the appropriate radiation exposure symptoms such as nausea, vomiting, diarrhea, and hyperthermia or for those patients thought to be in a region of exposure or contamination. Nuclear patient triage classifications follow the recommendations for general trauma and are delayed, immediate, minimal, and expectant (DIME), qualified by the complicating factor of radiation exposure. For more information on Treatment Briefs (Clinical Guidelines), refer to Appendix C.

Delayed Treatment Group (D)

3-72. Patients in the delayed category include those wounded who are badly in need of time-consuming surgery, but whose general condition permits delay in surgical treatment without unduly endangering life. Life-sustaining treatment such as intravenous (IV) fluids, antibiotics, splinting, catheterization, gastric decompression, and relief of pain may be required in this group. Types of injuries include large muscle wounds, fractures of major bones, intra-abdominal and/or thoracic wounds, and burns less than 50 percent of total body surface. In the face of trauma combined with radiation injury, all surgical procedures must be completed within 36 to 48 hours of radiation exposure or else may need to be delayed until at least two months after the injury, depending on the extent of the radiation exposure. Consequently, combined injury patients become the highest priority immediately after those requiring life- or limb-saving surgery.

Immediate Treatment Group (I)

3-73. Patients in the immediate category include those that require immediate lifesaving surgery. The surgical procedures should not be time-consuming and should concern only those with a high chance of survival (such as respiratory obstruction, unstable casualties with chest or abdominal injuries or emergency amputation). Pure radiation injury is not acutely life-threatening unless the irradiation is massive.

Minimal Treatment Group (M)

3-74. Patients in the minimal category have relatively minor injuries (such as minor lacerations, abrasions, fractures of small bones, and minor burns) and can effectively care for themselves or can be helped by nonmedical personnel. Buddy care is particularly important in this situation. Patients with radiological injury should have all wounds and lacerations cleaned meticulously and then closed. Follow up care is recommended to assess degree of systemic exposure.

Expectant Treatment Group (E)

3-75. Patients in the expectant category include those casualties that have wounds that are so extensive that even if they were the sole casualty and had the benefit of optimal medical resource application, their survival would be unlikely. They should not be abandoned, but should be separated from the view of other casualties Expectant casualties are unresponsive patients with penetrating head wounds, high spinal cord injuries, mutilating explosive wounds involving multiple anatomical sites and organs, second and third degree burns in excess of 60 percent total body surface area (BSA), profound shock, with multiple injuries, and agonal respiration. Using a minimal but competent staff, provide comfort measures for these casualties. These casualties may be removed from this category as additional medical assets become available.

3-76. Table 3-9 provides radiation dose, designation of treatment, and treatment priorities for radiation and combined injuries. Figure 3-6 on page 3-21 illustrates how radiation can impact triage categories.

Table 3-9. Radiation dose and treatment priority

Serial starting priority	*Final priority*		
	Less than 150 cGy	*Greater than 150 cGy*	*Gross neurological symptoms*
Radiation only	DUTY, D, or M*	D**	E
I	I	I	E
D	I	I	E
M	D**	D	E
E	E	E	E

* Placement in one of the categories is dependent upon command guidance, the tactical situation, and availability of replacements. Select DUTY if mission completion is mandatory regardless of casualty rate. Select M if less than 50 cGy and combat operations are ongoing. Select D if combat personnel resources are adequate.

** Includes the probable requirements for antibiotics and transfusion at a later time. This classification does not suggest that the patient is not in need of treatment, but rather that the patient does not need immediate specialized care. Marrow resuscitative therapy should begin as soon as practical.

Legend:
cGy centigray
D Delayed
I Immediate
M Minimal
E Expectant

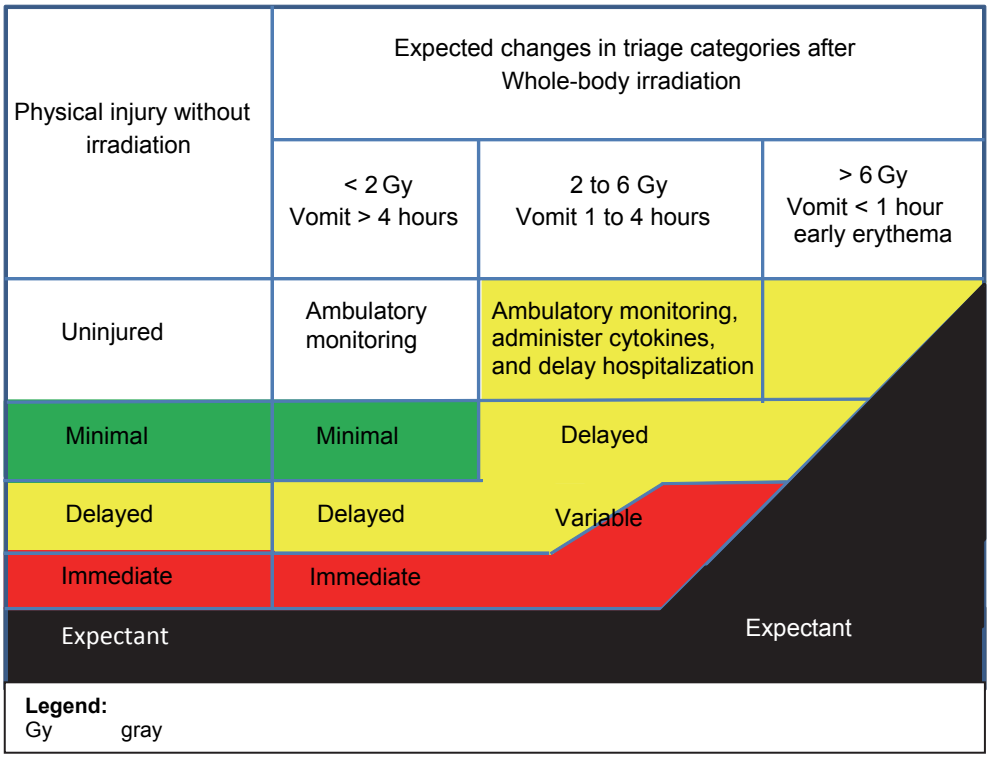

Figure 3-6. Radiation can impact triage categories

TREATMENT OF RADIATION SUBSYNDROMES

3-77. There is no direct first aid for radiological casualties. In addition to decontamination, the first action in dealing with these casualties is to administer first aid for any conventional injuries, such as combat wounds, blast injuries, and thermal burns in accordance with the procedures in FM 4-25.11/NTRP 4-02.1.1/AFMAN 44-163(1)/MCRP 3-02G.

MANAGEMENT OF THE HEMATOPOIETIC SYNDROME

3-78. The primary goal of treating the hematopoietic patient is a reduction in both the depth and duration of leukopenia and thrombocytopenia. The therapeutic modalities for treatment will vary according to the medical facility, the current medical knowledge and experience of the providers, the number of casualties, and the available resources to treat the patients. In the patient with signs and symptoms consistent with hematopoietic syndrome, changes within the peripheral blood profile can occur as early as 24 hours after irradiation. Therefore, blood specimens should be drawn for biodosimetry analysis. The tendency toward uncontrolled hemorrhage, decreased resistance to infection, and anemia will vary considerably from as early as ten days to as much as 6 to 8 weeks after exposure. However, a reasonable average time for the onset of bleeding and anemia and decreased resistance to infection is 2 to 3 weeks postexposure.

CONVENTIONAL THERAPY OF NEUTROPENIA AND INFECTION

3-79. The prevention and management of infection is the mainstay of therapy. There is a direct relationship between the degree of neutropenia and the increased risk of infectious complications. Antibiotic prophylaxis should be considered in afebrile patients at the highest risk for infection. These patients have profound neutropenia ($< 1.0 \times 10^9$ cells/l or 1000 cells/microliter) with an expected duration of greater than 7 days. Although the degree of neutropenia is the greatest risk factor for developing infection, other factors also influence the choice to start treatment and the medications that are to be used to treat the patient. Such factors include duration of neutropenia, bactericidal functionality of surviving

neutrophils, alteration of physical defense barriers, the patient's endogenous microflora, and organisms endemic to the hospital and community. As the duration of neutropenia increases, the risk of secondary infections such as invasive mycoses also increases. Some of the recommended medications (see Appendix A) for prophylaxis are ciprofloxacin as an antibiotic, acyclovir as an antiviral agent, and fluconazole as an antifungal agent.

PREVENTION OF INFECTION

3-80. Initial care of medical casualties with moderate and severe radiation exposure should probably include early institution of measures to reduce pathogen acquisition with emphasis on low microbial content food, acceptable water supplies, frequent handwashing (or wearing of gloves), and air filtration. During the neutropenic period, prophylactic use of selective gut decontamination with antibiotics that suppress aerobes but preserve anaerobes has been used but is dependent upon the clinical setting, provider preference, and the resources available. These measures can help control the alimentary canal source (mouth, esophagus, and intestines) of postinjury infections. Maintenance of gastric acidity (avoidance of antacids, H2 blockers, and proton pump inhibitors) may prevent bacteria from colonizing and invading the gastric mucosa and may reduce the frequency of nosocomial pneumonia due to aspiration of these organisms. The use of sucralfate or prostaglandin analogues may prevent gastric hemorrhage without decreasing gastric activity. When possible, an early oral feeding is preferred to IV feeding in order to maintain the immunologic and physiologic integrity of the gut. Surgical implantation of a subcutaneously tunneled central venous catheter can be considered to allow frequent venous access. Meticulous attention to proper care is necessary to reduce catheter associated infections.

MANAGEMENT OF INFECTION

3-81. The management of established or suspected infection (neutropenia and fever) in irradiated persons is similar to that used for other febrile neutropenic patients such as solid tumor patients receiving chemotherapy. An empirical regimen of antibiotics should be selected based on the pattern of bacterial susceptibility and nosocomial infections in the particular institution and the degree of neutropenia. Broad spectrum empiric therapy with high doses of one or more antibiotics should be initiated at the onset of fever. Aminoglycosides should be used cautiously due to associated toxicities. Therapy should be continued until the patient is afebrile for 24 hours and the absolute neutrophil count is greater than or equal to 0.5×10^9 cells/l (500 cells/microliter). Combination regimens often prove to be more effective than monotherapy. The potential for additivity or synergy should be present in the choice of antibiotics (see Appendix A).

3-82. Modifications of this initial antibiotic regimen should include a thorough evaluation of the history, physical findings, laboratory data (including appropriate cultures and a chest radiograph), and epidemiological information. Antifungal coverage with amphotericin B should be added, if indicated, for patients who remain persistently febrile for 7 days or more on antibiotic therapy in association with clinical evidence of infection or if they have new fever on or after day seven of treatment with antibiotics. If there is evidence of resistant gram-positive infection, vancomycin should be added. If diarrhea is present, stool cultures should be examined for Salmonella, Shigella, Campylobacter, and Yersinia. If oral/pharyngeal mucositis and/or esophagitis are present, then empiric use of antiviral and/or antifungal therapy should be considered.

3-83. Surveillance cultures may be useful for monitoring acquisition of resistant bacteria during prophylaxis and emergence of fungi. A once or twice weekly sampling of surveillance cultures from natural orifices and skin folds (for example, axillae and groin) would be reasonable, but should be modified based on the institutional patterns of nosocomial infections. A chest radiograph should be considered at initiation of empiric therapy. This may aid in definitive diagnosis of a new pulmonary infiltrate obtained during the course of neutropenia. The principles described above are generally applicable to the febrile neutropenic patient and provide a foundation upon which a specific initial regimen may be selected. These principles are summarized as follows—

- Principle 1: The spectrum of infecting organisms and antimicrobial susceptibility patterns vary both among institutions and over time.

- Principle 2: Life-threatening, gram-negative bacterial infections are universal among neutropenic patients but the prevalence of life-threatening, gram-positive bacterial infections varies greatly among institutions.
- Principle 3: Current empiric antimicrobial regimens are highly effective for initial management of febrile, neutropenic episodes.
- Principle 4: Search for the nidus of infection or look for the reason the patient is infected and eliminate it.

3-84. Overall recommendations for managing infections are summarized as follows—

- A standardized plan for the management of febrile, neutropenic patients must be devised.
- Empiric regimens must contain antibiotics broadly active against gram-negative bacteria but antibiotics directed against gram-positive bacteria need be included only in institutions where these infections are prevalent.
- No single antimicrobial regimen can be recommended above all others, as pathogens and susceptibility vary with time.
- If infection is documented by cultures, the empiric regimen may require adjustment to provide appropriate coverage for the isolate. This should not narrow the antibiotic spectrum while the patient is neutropenic.

Immune Globulin Administration

3-85. Immune globulins have not been shown to be beneficial for radiation casualties on a general basis. However they may be beneficial in bolstering the diminished immunoglobulin blood plasma levels that are critical in combating a variety of infectious agents or in selectively controlling the pathogenic responses related to septic shock and associated overexpression of inflammatory cytokines.

Hematopoietic Growth Factors (Cytokines)

3-86. Hematopoietic growth factors such as granulocyte colony-stimulating factor (G-CSF) (filgrastim) and granulocyte-macrophage colony-stimulating factor (sargramostim) are potent stimulators of hematopoiesis and shorten the time of recovery of neutrophils. The risk of infection and subsequent complications are directly related to depth and duration of neutropenia. In severe radiation-induced myelosuppression, where clinical support in the form of antibiotics and fresh irradiated platelets or whole blood is used concurrently with G-CSF or sargramostim, a marked reduction in infectious complications translates to reduced morbidity and mortality. Currently, G-CSF is the preferred cytokine because of its relatively low cost, greater efficacy, and fewer side effects. An additional benefit of the cytokines is their ability to increase the functional capacity of the neutrophil and thereby contribute to the prevention of infection as an active part of cellular host defense. Granulocyte colony-stimulating factor and granulocyte-macrophage colony-stimulating factor are not approved by the FDA for radiation induced neutropenia. Their administration would be off-label use based on physician discretion.

Conventional Therapy of Thrombocytopenia

3-87. The requirement for platelet support depends on the patient's condition. In irradiated patients with or without other major medical problems (infection, GI problems, or trauma), the platelets should be maintained at greater than 20×10^9/liter. Analysis of platelet counts versus hemorrhage suggests that 10×10^9/liter is adequate in the absence of any indication of accompanying frank hemorrhage. If surgery is needed, the platelet count should be greater than 50×10^9/liter. Transfusion of platelets remains the primary therapy to maintain adequate platelet counts. As general supportive measures, one should avoid the use of aspirin and nonsteroidal anti-inflammatory drugs. Limited platelet support is likely to come from random donors. Should refractoriness develop, family members as well as human leukocyte antigen (HLA)-compatible donors from the general population can be considered as platelet donors. The use of platelet products from which white blood cells have been removed is desirable to minimize both allosensitization and the risk of transmission of viral illnesses such as cytomegalovirus. All blood products should receive 2000 cGy of radiation and should be filtered before infusion to prevent graft-versus-host

disease through infusion of mononuclear cells present in the products. If an allotransplant is contemplated, the use of platelets from related donors should be avoided.

Growth Factor/Cytokine Therapy for Thrombocytopenia

3-88. Use of thrombopoietic agents after radiation injury is of questionable efficacy. Currently, there is no proven benefit in the bone marrow transplant model. Further drug development may alter the accepted pattern of care.

Conventional Therapy of Anemia

3-89. Transfusion of packed red blood cells remains the primary therapy to maintain hemoglobin above 8 gram/deciliter. Packed red blood cell transfusions should be irradiated, leukocyte-filtered (whenever possible), and from an unrelated donor if allogeneic transplantation is a consideration. Risks of packed red blood cells transfusion may include cytomegalovirus transmission and alloimmunization. Gamma irradiation of blood products with 2000 cGy will diminish graft-versus-host reactions common in radiation casualties.

Erythropoietin Therapy of Anemia

3-90. Use of erythropoietin after radiation injury is not recommended even though it is likely to be safe. Endogenous erythropoietin levels are often already elevated after highly cytotoxic therapy and evidence of benefit is not yet available from clinical chemotherapy models. Anemia is not generally life-threatening in this situation.

Bone Marrow/Stem Cell Transplantation

3-91. Stem cell transplantation usually has a limited role in the management of radiation casualties and can only be applied at select Role 4, fixed continental United States facilities. If possible, HLA typing should be done early. The decision to pursue a transplant must occur within two weeks of initial acute exposure to the patient. Candidates for such transplants generally have had whole-body doses in the 700 to 1000 cGy range and only a fraction of these patients would pass screening tests before actually receiving a tissue transplant.

MANAGEMENT OF THE GASTROINTESTINAL SYNDROME

3-92. During the manifest phase, fluids and electrolytes should be administered to prevent or correct dehydration. If blood transfusions are administered, the blood should be irradiated to diminish graft-versus-host reactions. Diarrhea associated with the prodromal and possibly continuing into the latent phases of GI injury is most likely related to neurohumoral factors affecting GI motility and transport. Loss of the epithelial cell lining is not observed until later during the manifest phase of GI injury. As a result, treatment for postirradiation diarrhea will require several different approaches. For diarrhea in the early prodromal and latent phases, agents directed against, or counteracting the effects of neurohumoral factors on GI cells should be considered. These include antidiarrheal/antisecretory agents such as anticholinergics, psyllium, aluminum hydroxide, and loperamide. Loperamide may offer distinct advantages as the drug affects both intestinal cell transport and motility that may contribute to diarrhea. Antisecretory agents will be of limited effectiveness against the manifest phase of GI injury during which the loss of epithelial cell lining has progressed to denudation of the intestine.

3-93. Sufficient data concerning the efficacy of cytokines on gut-related growth factors and elemental diets in stimulating GI regeneration are not yet available. Therefore, specific therapies to stimulate proliferation and/or to maintain the intestinal cell lining following radiation exposure cannot be recommended.

3-94. The use of antibiotics should be considered for specific infections. Prophylactic use of selective gut decontamination with antibiotics that suppress aerobes but preserve ordinarily commensal anaerobes has been used but is dependent upon the clinical setting, provider preference, and the resources available. In the future, the capability to maintain intestinal integrity following radiation exposure may reduce any emphasis on gut decontamination.

3-95. The bactericidal effect of gastric acid on intestinal flora is well known. Gastric acid also stimulates pancreatic and biliary secretions both of which have adverse effects on postirradiation GI integrity. Reduction of gastric acidity may be beneficial in the GI syndrome. Thus, the need to maintain gut integrity may preempt the desire to stimulate normal bactericidal mechanisms by increasing gastric acid secretion.

3-96. At the present time, it is believed that enteric feeding may be the best alternative even for those patients with radiological enteric mucosal damage. The direct stimulation by nutrient drips appears to stimulate mucosal crypt formation. This regeneration of the damaged mucosal barriers inhibits bacterial movement from the lumen into the interstitial spaces. There is very limited research into this treatment regimen in the irradiated casualty, however, in nonirradiated trauma patients, total parenteral nutrition is inferior to direct enteric feedings. These data have not been replicated in trauma combined with radiation injury.

MANAGEMENT OF THE CARDIOVASCULAR/CENTRAL NERVOUS SYSTEM SYNDROME

3-97. This syndrome is associated with very high acute doses of radiation probably within the 2000 to 4000 cGy range. Massive loss of fluid into extravascular tissues through leaky vascular beds at these high doses causes a distributive shock. The ensuing problems from edema, increased intracranial pressure, and cerebral anoxia can bring death in approximately 2 days. Radiation doses in this range are uniformly fatal regardless of therapies attempted. Aggressive medical support with pressors, fluids, and steroids only bring temporary improvement and may only serve to prolong suffering. Therapy should only include palliative measures such as opiates or tranquilizers.

RECOVERY

3-98. Repopulation occurs by stem cell proliferation and is a particularly important recovery mechanism for both the bone marrow and the GI tract whenever the radiation exposure has been large enough to reduce cell numbers. Stem cells divide normally in both these tissues because stem cell turnover is required to compensate for the normal continuous removal of differentiated cells. Stem cell division will be accelerated by large doses of radiation just as any other severe insult would do. The effects of small doses are not recognized soon enough for accelerated proliferation to take place. In bone marrow, large macrophage cells produce factors and cytokines that either stimulate or shut down the stem cells that are the progenitors of the erythropoietic, granulopoietic or thrombopoietic series of blood cells. The *factor-producing* cells influence one another and depress the production of one factor while the opposite is being produced. Stem cell responses continue until the factor is changed.

SUMMARY OF MEDICAL ASPECTS OF ACUTE RADIATION INJURY

3-99. Tables 3-10 through 3-13 on pages 3-26 through 3-29 summarize the current ideas on the treatment of radiation casualties at progressively increasing dose levels. The treatment modalities are meant as guidelines applicable to both the nuclear environment and to other operations where high- or low-level radiation hazard exists; this includes Defense Support of Civil Authorities during weapons of mass destruction consequence management operations. Refer to Appendix C for more information on Treatment Briefs (Clinical Guidelines) and refer to FM 3-11.21/MCRP 3-37.2C/NTTP 3-11.24/AFTTP(I) 3-2.37 for more information on consequence management.

Table 3-10. Medical aspects of radiation injury (0 to 300 cGy)

Dose (estimate)	*Initial symptoms*	*Initial symptoms interval onset–end*	*Antiemetic pretreatment effect*	*Medical problems*	*Indicated medical treatment*	*Disposition without medical care*	*Disposition with medical care*	*Clinical remarks*
0–35 cGy	None	Not applicable	Dry mouth, headache	Anxiety	Reassurance. Counsel at redeployment.	Duty	Duty	Potential for combat anxiety manifestation.
35–75 cGy	Nausea, mild headache.	ONSET 6 hours END 12 hours	Not determined	Anxiety	Reassurance. Counsel at redeployment.	Duty	Duty	Mild lymphocyte depression within 24 hours.
75–125 cGy	Transient mild nausea, vomiting in 5–30% of personnel.	ONSET 3–5 hours END 24 hours	5–30% of personnel nauseated without emesis.	Potential for delayed traumatic and surgical wound healing, minimal clinical effect.	Debridement and primary closure of any and all wounds. No delayed surgery.	Restricted duty. No further radiation exposure, elective surgery, or wounding.	Restricted duty. No further radiation exposure.	Moderate drop in lymphocyte, platelet, and granulocyte counts. Increased susceptibility to opportunistic pathogens.
125–300 cGy	Transient mild to moderate nausea and vomiting in 20–70% of personnel. Mild to moderate fatigability and weakness in 25–60% of personnel.	ONSET 2–3 hours END 2 days	Decreased vomiting. Possible increase of fatigability.	Significant medical care may be required at 3–5 weeks for 10–50% of personnel. Anticipated problems should include infection, bleeding, and fever. Wounding or burns will geometrically increase morbidity and mortality.	Fluid and electrolytes for GI losses. Consider cytokines for immunocompromised patients (follow granulocyte counts).	LD_5 to LD_{10} Restricted duty. No further radiation exposure, elective surgery, or wounding. May require delayed evacuation from theater during nuclear war according to command guidance.	Restricted duty. No further radiation exposure, elective surgery, or wounding.	If there are more than 1.7 × 10^9 lymphocytes per liter 48 hours after exposure, it is unlikely that an individual has received a fatal dose. Patients with low (300–500) or decreasing lymphocyte counts, or low granulocyte counts should be considered for cytokine therapy and biologic dosimetry using metaphase analysis where available.

Legend:
cGy centigray
GI gastrointestinal
LD lethal dose

Table 3-11. Medical aspects of radiation injury (300 to 530 cGy)

Dose (estimate)	*Initial symptoms*	*Initial symptoms interval onset–end*	*Antiemetic pretreatment effect*	*Medical problems*	*Indicated medical treatment*	*Disposition without medical care*	*Disposition with medical care*	*Clinical remarks*
300–530 cGy	Transient moderate nausea and vomiting in 50–90% of personnel. Early: Mild to moderate fatigability and weakness in 80–100% of personnel.	Nausea/ vomiting ONSET 2 hours. END 3–4 days. Diarrhea ONSET at 10 days. END 2–3 weeks.	Undetermined	Frequent diarrheal stools, anorexia, increased fluid loss, ulceration, death of crypt cells and Peyer's Patches lymphoid tissue. Increased infection susceptibility during immunocompromised time frame. Bleeding diathesis at 3–4 weeks due to megakaryocyte loss.	Fluid and electrolytes for GI losses. Consider cytokines for immunocompromised patients (follow granulocyte counts). Specific antibiotic therapy for infections. May require GI decontamination with quinolones, use alimentary nutrition.	LD_{10} to LD_{50} Survivors may be able to return to light duty after 5 weeks. No further radiation exposure. May require delayed evacuation from theater.	Increased percentage of survivors may be able to return to duty after 5 weeks. No further radiation exposure. May require evacuation from theater for adequate therapy.	Moderate to severe loss of lymphocytes. Follow counts every 6 hours in first few days if possible for prognosis. Moderate loss of granulocytes and platelets. Hair loss after 14 days. Thrombocytopenic purpura appears after 3 weeks. Consider cytokine therapy and biologic dosimetry using metaphase analysis where available. Loss of crypt cells and GI barriers may allow pathogenic and opportunistic bacterial infection. Use alimentary nutrition to encourage crypt cell growth. Avoid parenteral nutrition and central intravenous lines. Anticipate anaerobic colonization. All surgical procedures must be accomplished in initial 36–48 hours after irradiation. Any additional surgery must be delayed until 6 weeks postexposure.

Legend: cGy centigray GI gastrointestinal LD lethal dose

Table 3-12. Medical aspects of radiation injury (530 to 830 cGy)

Dose (estimate)	*Initial symptoms*	*Initial symptoms interval onset–end*	*Anti-emetic pretreatment effect*	*Medical problems*	*Indicated medical treatment*	*Disposition without medical Care*	*Disposition with medical care*	*Clinical remarks*
530–830 cGy	Moderate to severe nausea and vomiting in 50–90% of personnel. Early: Moderate fatigability and weakness in 80–100% of personnel, frequent diarrhea.	ONSET under 1 hour END indeterminate, may proceed directly to GI syndrome without a break.	None	At 10 days to 5 weeks, 50–100% of personnel will develop pathogenic and opportunistic infections, bleeding, fever, loss of appetite, GI ulcerations, bloody diarrhea, nausea, severe fluid and electrolyte shifts, third space losses, capillary leak, and hypotension.	Tertiary-level intensive care required to improve survival. Fluid and electrolytes for GI losses, may require transfusion and/or colloids. Cytokines for immunocompromised patients. Specific antibiotic therapy for infections, to include antifungals. Will require GI decontamination with quinolones, use alimentary nutrition.	LD_{50} to LD_{90} At low end of exposure range, death may occur before 6 weeks in more than 50% of personnel. At high end of exposure range, death may occur before 3 weeks in 90% of personnel.	Early evacuation to tertiary-level medical center before onset of manifest illness. Patients will require extensive reverse isolation to prevent cross contamination and nosocomial infection.	Practically no lymphocytes after 48 hours. Severe drop in granulocytes and platelets later. In pure radiation exposure scenarios, these patients will require highest priority evacuation. The latent period between prodromal symptoms and manifest illness may be very short. When this radiation injury is combined with any significant physical trauma, survival rates will approach zero. All surgical procedures must be accomplished in initial 36–48 hours after irradiation. Any additional surgery must be delayed until 6 weeks post-exposure. Partial marrow shielding may complicate bone marrow transplant. Steroid therapy is ineffective.

Legend:
cGy centigray
GI gastrointestinal
LD lethal dose

Table 3-13. Medical aspects of radiation injury (830 to 3000+ cGy)

Dose (estimate)	*Initial symptoms*	*Initial symptoms interval onset–end*	*Anti-emetic pretreatment effect*	*Medical problems*	*Indicated medical treatment*	*Disposition without medical care*	*Disposition with medical care*	*Clinical remarks*
830–3000+ cGy	Severe nausea, vomiting, fatigability, weakness, dizziness, and disorientation. Moderate to severe fluid and electrolyte imbalance, hypotension, possible high fever, and sudden vascular collapse.	ONSET less than 3 minutes. END death	None	LD_{100} at 10 Gy death is before 2–3 weeks. Minimal if any break between prodromal syndrome and manifest illness. At high radiation levels, CNS symptoms predominate, with death secondary to cerebral vascular incompetence.	Supportive therapy in higher dose ranges. Aggressive therapy if pure radiation injury and some evidence of response.	LD_{90} to LD_{100} Expectant category	If assets are available, then early evacuation to tertiary-level medical center during manifest illness. Patients will require extensive reverse isolation to prevent cross contamination and nosocomial infection. Most patients will remain expectant.	Bone marrow totally depleted within days. Bone marrow transplant may or may not improve ultimate outcome, due to late radiation pneumonitis and fibrotic complications. Even minor wounds may prove ultimately fatal. Aggressive therapy is indicated when resources are available and transport to a tertiary care medical center is possible.

Legend:

cGy	centigray	Gy	gray
CNS	central nervous system	LD	lethal dose
GI	gastrointestinal		

COMBINED INJURY: BLAST, THERMAL, AND RADIOLOGICAL INJURIES

3-100. A combined injury is when a radiation injury is combined with the effects of blast trauma and/or thermal burn injury from a nuclear detonation. Combined injuries will be the norm when dealing with nuclear detonations (two-thirds of the casualties will have combinations of injuries from the detonation). Chemical and biological weapons effects are not combined injuries in the classical sense but are discussed in this section since there is a potential for combined use of CBRN weapons.

BLAST INJURIES

3-101. The blast injuries caused by nuclear weapons or from high-explosive components of nuclear weapons and RDDs, will frequently be complicated by associated thermal and/or radiation injuries. The diagnosis of blast injuries can often be difficult because there is often unrecognized internal injury. About half of the patients seen will have wounds to their extremities. In those with injuries to the thorax, abdomen, and head, the distribution of wound is about equal. Injuries of the thorax, neck, and the head will

be responsible for a large percentage of deaths because these types of injuries have a high probability of immediate fatality.

TREATMENT OF BLAST INJURIES

3-102. The treatment is divided into the following four basic phases: resuscitative phase, surgical phase, recovery phase, and convalescent phase.

Resuscitative Phase (First Aid)

3-103. Missile, crush, and translational injuries are generally manifested as wounds of the head, neck, face, chest, stomach, and extremities (fractures) and require immediate attention at the individual level. Blast casualties will require evaluation for acute trauma in accordance with trauma management standard therapies. Lifesaving resuscitative measures designed to prepare the patient for definitive surgical treatment come first. These include the establishment of the airway and assuring the adequacy of respiration, replacement of lost blood and fluids, and splinting of possible fractures particularly those involving the cervical vertebrae. Some resuscitative measures must be started prior to evacuation particularly if ground transportation is used rather than helicopter evacuation. All wounds are considered to be contaminated because of infection-producing organisms (germs) and radiological material due to fallout. A contaminated wound does not lessen the importance of protecting it from further contamination, therefore, first aid providers must dress and bandage a wound as soon as possible to prevent further contamination. For a detailed discussion on first aid for typical blast injury wounds, see FM 4-25.11/NTRP 4-02.1.1/AFMAN 44-163(1)/MCRP 3-02G.

Surgical Phase

3-104. Definitive surgery should be done after resuscitative measures have been used to stabilize the patient. Occasionally, lifesaving surgery must be done without delay but normally there is time to prepare patients for surgery if they have survived long enough to reach a treatment facility. The treatment of blast injuries is best managed by applying accepted principles of combat surgery as outlined in the *Textbook of Military Medicine, Conventional Warfare: Ballistic, Blast and Burn Injuries*. Of note, traditionally, combat wounds are not closed primarily due to the high level of contamination, devitalized tissue, and the subsequent morbidity and mortality associated with closed space contamination. In the case of the radiation combined injury patient, wounds that are left open and allowed to heal by secondary intention will serve as a potentially fatal nidus of infection. If at all possible, wounds should be closed primarily within 36 to 48 hours of radiation exposure. If surgery is required and cannot be completed at forward locations, patients with moderate injury will need early evacuation to a level where surgical facilities are immediately available. Refer to FM 4-02.2 and Air Force Tactics, Techniques, and Procedures (AFTTP) 3-42.5 for more information on evacuation.

Recovery Phase

3-105. In the immediate postoperative period, patients require minimal movement. Transportation to other facilities should be delayed until the patient's condition has stabilized.

Convalescent Phase

3-106. Patients in this phase of treatment should be evacuated back to specialized convalescent facilities in order to keep the patient load of supporting hospitals as low as possible. Many injuries may require a prolonged recovery period before the individual has recovered to the point where personnel can resume their duties. Both the convalescent and recovery phases will be more protracted with the addition of a radiation injury.

ORTHOPEDIC INJURIES

3-107. Special circumstances exist for the treatment of orthopedic injuries that are associated with radiation exposure. Research with rabbit long bones demonstrates lack of adequate callus formation and subsequent nonunion in the irradiated animal. Animals that receive no treatment for irradiation will have

nonunion of fractures. There has been no research into modern techniques of orthopedics and wound healing in the irradiated patient. At present, it is recommended that any reconstructive surgery be delayed until complete healing of the radiation injury has occurred. There has also been no documentation of the effects of aggressive medical resuscitation in these patients. Primary amputation may be the most efficacious method of dealing with severely injured extremities. Conservative attempts at salvage by repeated debridement and reconstruction may well result in disaster for the irradiated patient.

TETANUS

3-108. All personnel receive mandatory prophylaxis against tetanus through the Tetanus-Diptheria-Pertussis (Tdap) vaccine series and/or regular Tetanus-Diptheria (Td) boosters as part of the vaccination requirements when entering the Service. Failure to obtain regular tetanus boosters every 10 years increases the risk of developing life-threatening tetanus if wounded. Irrespective of radiation exposure, an individual with an open wound or who sustains a burn may need an additional dose of Td or Tdap to prevent tetanus infection. An individual who sustains radiation exposure, but no open wounds or burns, does not need Td or Tdap vaccination.

3-109. Although radiation exposure presents a risk of immunological impairment decreasing the body's response to vaccines, the same immunological process will also impair response to infection. Therefore, all casualties with open wounds and/or burns in a nuclear or radiological environment should get a tetanus toxoid booster. When in doubt regarding administration of Td or Tdap, follow the Advisory Committee on Immunization Practices guidance.

THERMAL INJURY

3-110. Thermal burns caused by fire, hot objects, hot liquids, gases, or by a nuclear detonation or fireball often cause extreme pain, scarring, or even death. Experimental data demonstrate that the mortality of patients with thermal burns markedly increases when combined with exposure to radiation. Burn patients with 50 percent mortality may be transformed into more than 90 percent mortality when irradiated with doses as small as 150 cGy. Therefore, this may be considered the most significant type of combined injury. Infection is the primary cause of death in these patients since full-thickness burns are ideal for naturally culturing bacteria.

Determining Severity of Thermal Injuries

3-111. Certain factors are of prime importance in the early evaluation of burns because of their relation to overall prognosis. These factors include—

- Area of the burn expressed in percentage of body surface involved.
- Involvement of critical areas and organs (head and respiratory tract).
- Depth of burn: superficial (first or second degree), deep (second degree), and full thickness (third degree).

Area of Burn

3-112. The most accurate way to estimate the severity of the burn is to measure the extent of the body surface burned. Direct measurement is difficult and a shortcut method of estimating the percent of the body surface involved can be very useful. The *Rule of Nines* method is a simple and reasonably reliable guide in which the various parts of the body are divided into surface areas of 9 percent each (or multiples of 9 percent) as shown in Table 3-14 and Figure 3-7 found on page 3-32.

Table 3-14. Rule of Nines for establishing extent of body surface burned

Anatomic surface	*Percentage of total surface*
Head and neck	9 = 9
Anterior trunk	2 × 9 = 18
Posterior trunk	2 × 9 = 18
Upper limbs	9 each = 18
Lower limbs	18 each = 36
Genitalia and perineum	1 = 1

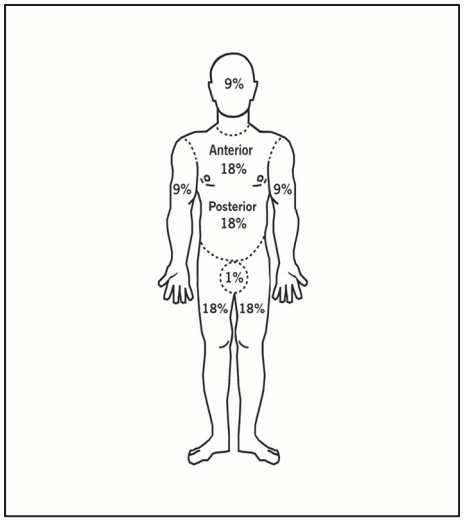

Figure 3-7. Rule of Nines

3-113. As the percent of body surface burned increases, predicted morbidity and mortality increases sharply. Burns that cover 20 percent or more of the body surface can be fatal without treatment. Determination of the percent of the body surface involved will aid in planning resuscitative treatment and estimating fluid requirements during the first 48 hours after the burn injury. Patients with severe burns will suffer extensive fluid and electrolyte losses resulting in severe hypovolemic shock requiring aggressive fluid replacement therapy as early as possible.

Involvement of Critical Organs

3-114. When certain organ systems are involved, the clinical effects of burns are potentially more serious in spite of the fact that only a small fraction of the body is involved.

Head and Neck Burns

3-115. Burns of the head and neck can be associated with upper tract edema which can result in airway obstruction.

Burns of the Deep Respiratory Tract

3-116. These injuries may result in pulmonary edema with a resultant high probability of mortality.

Depth of Burn

3-117. Burns are classified on the basis of the depth of the injury as follows:

- Superficial or partial skin thickness burns affect only the epidermis and thus are typically very painful. These burns will heal readily if treated appropriately.

- Deep or full-thickness burns are burns that require extensive resuscitation and surgical intervention. They involve the full thickness of the skin and usually result in healing by scarring which causes contractions and loss of function.

Treatment of Thermal Injuries

3-118. Proper first aid will minimize further injury of the burned area and generally includes performing the basic lifesaving measures, lifting away any clothing covering the burned area, and applying a clean and dry field dressing to the burn. For a detailed discussion on first aid for burns, see FM 4-25.11/NTRP 4-02.1.1/AFMAN 44-163(1)/MCRP 3-02G.

3-119. Initial treatment of burn patients will be resuscitative. When such patients are first seen, a simple plan of treatment must include maintenance of airway with ventilation support as needed, adequate fluid therapy, monitoring and management of electrolytes, and careful maintenance of medical records.

Maintenance of Airway

3-120. This is of particular importance in head and neck burns or in unconscious patients. If large numbers of patients are seen requiring transportation over long distances early in the postburn period, tracheotomies or intubation may be done on a routine basis. These procedures done prior to the onset of edema are much easier to perform than when they are done after edema has resulted in respiratory obstruction.

Fluid Therapy

3-121. The shock that is associated with an extensive burn will be severe, and survival of these patients depends upon adequate, balanced fluid replacement therapy. Standard formulae for determining the fluid requirements of burn patients have been developed and can be used in combat. The basic principle in these formulae is that the amount of fluid required is proportional to the percent of body surface burned and body weight. Detailed fluid resuscitation procedures can be found in the *Textbook of Military Medicine, Conventional Warfare, Ballistic, Blast and Burn Injuries*.

Intake and Output Records

3-122. It is extremely important to accurately follow the intake and output of fluids in burn patients even to the point of catheterizing patients to accurately track output. It would be impossible to modify fluid therapy according to individual needs without accurate records.

Care of Burn Wound

3-123. Although the first priority in patient care is resuscitation, proper care of the burn wound is essential both for survival as well as for optimum healing and preservation of function. As soon as the patient's overall condition permits, initial debridement and cleaning of the burn should be done. The main purpose of this treatment is to remove foreign material and dead tissue to minimize infection. Thorough irrigation and the application of topical antimicrobial creams such as mafenide acetate cream and silver sulfadiazine cream and sterile dressings should complete the initial procedures. Special attention should be given to critical areas such as the hands and surfaces over joints. No studies are available regarding the use of modern skin graft techniques in these combined irradiation-burn injuries. There is also no data available regarding the response to clostridial infection but strong consideration should be given to the use of tetanus toxoid boosters. Patients whose burns are contaminated by radioactive material should be gently decontaminated to minimize absorption of these materials through the burned skin. Most radiological contaminants will remain in the burn eschar when it sloughs.

HEMATOPOIETIC EFFECTS OF COMBINED INJURY

3-124. Radiological injury significantly compounds the morbidity and mortality of patients with other injuries by compromising the integrity of the hematopoietic and immune systems. Early healing and active biological damage control systems rapidly deplete reserves that are then unable to regenerate due to the radiation injury. Since reserves are depleted and consumed without adequate regeneration, pancytopenia

develops more rapidly than in the pure radiologically injured patient. Anemia results from the poor production of new erythrocytes, therefore acute blood loss that occurs as a result of a physical trauma cannot be replenished by increased marrow output. Similarly, megakaryocytes are unable to replicate as platelets are consumed. Fibroblasts that promote wound healing are damaged by irradiation and do not replicate at a normal rate. Immunosuppression is magnified due to the more rapid depletion and slower production of lymphocytes and neutrophils which increases the risk of infection (see Table 3-15).

Table 3-15. Hematopoietic effects of combined injury

Radiation	*Trauma*
Anemia	Depletion of vascular reserves.
Bleeding	Abnormal clotting; increased viscosity.
Infection	Consumption of marrow progenitors.

CHEMICAL WEAPONS AND RADIATION

3-125. Mustard agents and radiation can cause many similar effects at the cellular level. Their use in combination will likely increase morbidity. The immediate effects of the chemical agents must be countered before attention is paid to the effects of radiation that may not manifest for days or weeks. Research into these combined effects is only now just beginning. Currently, little is known about the combined effect of radiation and nerve agents. It is known that radiation will lower the threshold for seizure activity and thus may enhance the effects of nerve agents on the CNS.

BIOLOGICAL WEAPONS AND RADIATION

3-126. There is currently insufficient data to reliably predict casualties from combined injuries of subclinical or sublethal doses of ionizing radiation and exposure to aerosols with biological warfare agents or exposure to infectious diseases. Research suggests a shortened fatal course of disease when a virulent strain virus is injected into sublethally irradiated test models. Minimally symptomatic doses of radiation depress the immune response and will dramatically increase the infectivity and apparent virulence of biological agents. Biological weapons may be significantly more devastating against a population which has recently been irradiated. Alternatively, the lethality resulting from radiation exposure may be significantly higher in populations with existing high incidence of infectious disease that may have already compromised population health. Usually ineffective portals of infection which are made accessible by partial immunoincompetence may cause unusual infection profiles.

IMMUNIZATION AND RADIATION

3-127. Recent research indicates that previous immunizations may provide some protection by way of circulating antibodies against infectious agents in casualties with significant radiological injury. Although leukocyte numbers and function decrease following irradiation, circulating antibodies are not appreciably affected by ionizing radiation. The secondary response of the irradiated immune system to previously recognized antigens has not been thoroughly evaluated. Passive immunization against tetanus may be indicated in the presence of tetanus-prone injuries despite a nominally adequate prior immunization status. Killed virus vaccines may fail to elicit an adequate immunogenic response because of the loss of lymphocytes. As a precaution, live-agent vaccines should be avoided because the use of live-agent vaccines after irradiation injury could conceivably result in disseminated infection from the inoculated strain. No data are available on this phenomenon, but experience with immunocompromised patients predicts its occurrence. Preliminary investigations with nonvirulent agents and radiation injury indicate a significant level of infection will occur. Therefore, inoculation with live-virus vaccines should be postponed until after complete recovery of the immune system. Killed viral and bacterial vaccines may likewise fail to elicit an adequate immunogenic response. Little data are available concerning the effect of ionizing radiation on cell-mediated immunity.

Chapter 4

Radioactive Contamination

MEASURING LEVELS OF CONTAMINATION

4-1. A number of methods are used to detect contamination and to estimate the extent of contamination. Direct methods include measuring skin contamination with handheld RADIAC instruments or internal contamination with specialized instruments placed outside the body (in vivo monitoring). Models of how the radionuclide is metabolized in the body are then used to estimate the total amount of radioactivity that was originally inhaled, ingested or introduced through a wound. Indirect methods of assessing internal contamination measure the concentration of a given nuclide in the urine or feces (in vitro monitoring). Metabolic models of systemic excretion are then used to estimate the original amount of radioactive material internalized at the time of exposure. These estimates of the original intake of radioactive material, in turn, can be used to estimate patient organ doses, total effective doses, and aid in determining long-term patient risks of adverse health effects, and guide treatment protocols to reduce contamination levels.

DIRECT EXTERNAL CONTAMINATION ASSESSMENT

4-2. Surface detectors are usually used for skin and wound monitoring in the field. The most common form of surface detector is the tube or pancake probe. The use of RADIAC meters allow operational forces to survey patients for external contamination, determine whether decontamination efforts have been effective, or establish when forces have exceeded operational exposure guidance levels. Specialized small probes may be used for deep wounds and can be cold sterilized for this purpose. Wounds contaminated with alpha particles are difficult to detect because blood or body issue may block the radiation. Therefore, alpha contamination measurement usually relies on the detection of gamma/beta radioactivity of daughter products or other contaminants.

DIRECT INTERNAL CONTAMINATION MEASUREMENT

4-3. Direct measurement methods use instrumentation external to the body to measure contamination within the body. The advantage of direct measurement is that it allows for a *direct* assessment of internal contamination without relying on uncertain excretory rates that are necessary to interpret urine and fecal bioassay data. Disadvantages are that measurements can only be made for nuclides that emit penetrating radiations (x rays and gamma rays). Measurements can also be influenced by external contamination and background radiation levels. Both total- and partial-body counters exist. Partial-body counters are used for chest and thyroid measurements. Chest counters detect respiratory tract levels of contaminants such as plutonium and uranium. Whole-body counters scan the whole body to give total estimates of internal contamination.

INDIRECT CONTAMINATION MEASUREMENT

4-4. Nasal swipes and/or nasal blows are used to indicate the extent and type of contamination that has been internalized. Nasal swipes are taken bilaterally, using moistened, cotton-tipped applicators to swab the nares. The swabs are then placed individually in test tubes or envelopes which are labeled with the subject's name and the sample collection time and date. The swabs are sent to a laboratory where contamination can be measured, or dried and quick scanned locally. Another less invasive method than nasal swipes may be a nose blow into a tissue, with the contents then analyzed. The nasal swipes and/or nasal blows are usually done to determine the potential for an intake, not to measure quantitatively the amount of material that was inhaled. For more information on the levels of identification for radiological samples, refer to Appendix D. The detection of radioactive material in the nares usually indicates respiratory inhalation.

4-5. Bioassay sampling of urine and feces provides indirect measurement of internal contamination. Radioactivity and concentration of the nuclide in urine and feces depend on many factors including individual metabolic and clearance rates. Subsequent estimates of the amount of radioactive material initially inhaled and ingested are prone to significant variance. According to the National Council on Radiation Protection and Measurements, Report No. 161, Volume I, *Management of Persons Contaminated With Radionuclides*, in vitro monitoring provides the only acceptable assay technique for alpha and pure beta emitting radionuclides which cannot be assayed through in vivo methods. Metabolic models are used to estimate internal contamination based on average human metabolic and clearance rates. Bioassay sampling and excretion data are the principal methods of determining the presence of alpha and pure beta emitters which are the most hazardous internal contaminants. Initial samples to be used to establish baseline levels of urine and fecal radioactivity should be obtained from a patient as soon as practical. Measures should be taken to avoid the accidental contamination of these samples. For example, contaminated clothing from the victim should be removed and initial skin decontamination steps should be accomplished before sampling. Gloves should be worn by all personnel handling capture containers. Bioassay accuracy depends on baseline levels, multiple postexposure samples, and knowledge of the precise time of contamination and type of contaminant(s). Table 4-1 shows general guidelines for bioassay sampling.

Table 4-1. Guidelines for bioassay sampling

Optimum sample time after exposure			
Material	***Feces***	***Urine***	***Quantity***
Plutonium	24 hours	2 to 3 weeks	24-hour total
Uranium	24 hours	24 hours	24-hour total
Tritium	Not applicable	12 hours	1 voiding

Note. Urine collection should not be omitted just because a 24-hour urine cannot be collected. Spot urines normalized to urine creatinine or specific gravity have been found to be as useful as 24-hour urines in predicting body burden of internalized radionuclides.

EXTERNAL CONTAMINATION, IRRADIATION, AND ACUTE LOCAL RADIATION INJURY

EXTERNAL CONTAMINATION AND IRRADIATION

4-6. When external contamination occurs, personnel are irradiated by the contamination until the contamination is removed. The most serious injuries resulting from radiation accidents have been due to penetrating radiation from external sources. External contamination by radionuclide's can occur when an individual or unit traverses a contaminated area without appropriate protection or remains in a hazardous downwind area when fallout occurs. Contamination can also occur via other pathways such as medical use isotopes, industrial use isotopes or nuclear power generation stations. If the individual has an open wound while in the contaminated area, the individual may become internally contaminated. The radioactive contamination hazard of injured personnel to both the patient and attending medical personnel will be minimal, so necessary medical or surgical treatment must not be delayed because of possible contamination.

4-7. Medical personnel minimize the risk of exposure by following decontamination principles similar to those for biological warfare and chemical warfare agents. If circumstances allow, medical personnel should don protective clothing before coming into contact with contamination. Protective clothing consists of gloves, overshoes, and a plastic apron (surgical gowns are acceptable). Irrigation fluid should be collected and disposed of properly, and contaminated clothing and medical supplies are disposed of in a designated contaminated trash bag. For more information on shipboard protection and decontamination, refer to NAVSUP P-409 and NTTP 3-20.31.

4-8. Medical personnel are subject to the same operational exposure guidance as other military personnel. Limited data and actual experience with contaminated patients exist. However, hypothetical studies and subject matter expert recommendations indicate the risk to medical personnel from contaminated patients is very low. The highest dose rate predicted to a surgeon under very conservative assumptions is 0.39 mGy/hr (39 mrad/h).

4-9. To determine if an individual is contaminated or not, use a RADIAC meter with a tube or pancake Geiger-Mueller probe for the initial radiation survey of the skin and clothing. If contamination is present on the clothing, remove clothing and repeat the monitoring over the patient's skin. The initial survey or data collection or documentation should not slow down the decontamination process.

Note. According to AFIs 10-2501 and 41-106, the USAF does not recommend surveying patients in which contamination is known or apparent; the time required for an adequate screening is excessive and impedes care in a mass-exposure.

4-10. Contaminants may be held to the surface of the skin by electrostatic forces, surface tension, or binding with skin proteins. Skin penetration is relative to the type of radiation. Alpha particles from radionuclides on the skin surface do not reach the basal cell layer of the epidermis. Beta particles are reduced by a factor of two for every 1 millimeter of skin. Skin on most areas of the body has a depth of 2 millimeters. The epidermis is approximately 0.1 millimeter in depth, except over areas of external friction. Those areas include the palms, digits, and soles of the feet where the thickness of the stratum corneum can reach 1.4 millimeter. Health and medical physicists use the estimate of skin radiation dose at the basal epithelium, since that is the area that lies adjacent to the small blood vessels of the dermis, and is the area that can be affected by beta and gamma radiation. Gamma-radiation emitters may cause whole-body irradiation, while beta emitters left on the skin may cause significant localized burns and scarring. However, it is highly improbable to be so contaminated that the patient is a radiation hazard to health care providers.

DECONTAMINATION

4-11. Removal of the contamination should be accomplished as soon as possible. Decontamination should be part of the operational plans and procedures of all divisions and departments. This ensures flexibility of response and action and will prevent delay in needed medical treatment. The simple removal of outer clothing and shoes will, in most instances, effect a 90 percent to 95 percent reduction in the patient's contamination. The presence of radiological contamination can be readily confirmed by slowly passing a radiation detector over the entire body. Open wounds should be decontaminated, then covered, and then the rest of the body decontaminated to include surrounding skin. Contaminated clothing should be carefully removed, placed in designated contaminated trash bags, and transported to the contaminated waste consolidation or holding area (designated dirty dump). Refer to FM 4-02.7/MCRP 4-11.1F/NTTP 4-02.7/AFTTP 3-42.3 for a detailed discussion on patient decontamination.

Note. In general, the presence of external contamination does not represent a significant exposure hazard to either the patient or attending medical staff. *Treatment of life-threatening injuries or medical conditions with a risk of morbidity, takes precedence over radiological concerns.* If external contamination is detected, internal contamination may also be present.

SKIN DECONTAMINATION

4-12. Skin decontamination should be undertaken to decrease the risk of acute dermal injury, to lower the risk of internal contamination of the patient, and to reduce the potential of contaminating medical personnel and the environment. After the patient's clothing is removed, washing the patient with soap and water is 95 percent effective because this method removes contamination. Gentle brushing or the use of an abrasive soap or abrasive granules dislodge some contamination physically held by skin protein. Addition of a chelating agent helps by binding the contaminant in a complex as it is freed from the skin. The stratum corneum of the epithelium is replaced every 12 to 15 days, thus, contamination that is not removed and is not absorbed by the body will be sloughed within a few days.

Decontamination Techniques

4-13. Avoid unnecessary damage to the skin and cease washing before abrasion occurs. If washing will not remove stubborn hand and distal extremity skin contamination, wrap the contaminated area. Over time, sweating will decrease contamination. To decontaminate hair, use any commercial shampoo without conditioner. Conditioners bind material to hair protein making contamination removal more difficult. Consider clipping hair to remove contaminants (last resort if contamination cannot be removed). Do not remove eyebrows without significant cause since they grow back slowly if at all. For skin and wound decontamination refer to FM 4-02.7.

Local Tissue Irradiation

4-14. Local irradiation of tissues occurs when highly radioactive material, such as a medical mishap or inadvertent exposure is placed in proximity to tissue. As radiation intensity increases because of increasing proximity to the source, the tissue immediately adjacent to the source receives a tremendous dose. The total body dose may be only 200 cGy, but the local skin dose can easily be in the thousands of cGy (see Table 4-2).

Table 4-2. Local tissue damage

Dose (cGy)	*Symptom*	*Time postexposure*
> 300	Epilation	2 to 3 weeks
~ 600	Erythema	Minutes to weeks
> 600	Edema	Minutes to weeks
1000 to 2000	Blistering	2 to 3 weeks
~ 3000	Ulceration	1 to 2 months
5000 to 6000	Gangrene, necrosis, deep ulceration	Weeks
Legend: cGy centigray		

4-15. Initial skin changes will be similar to those of Cutaneous Radiation Syndrome but with penetrating gamma radiation, damage will be seen in the deeper tissues over time. Development of deep-base ulcers with marked erythema at the margins is common. Granulation tissue develops and months can be required for healing. Deep tissues respond in a similar fashion if the radioactive source is placed in their immediate proximity. For more information regarding Cutaneous Radiation Syndrome, refer to Chapter 3.

INTERNAL CONTAMINATION AND IRRADIATION

4-16. Internal irradiation occurs when personnel ingest or inhale radioactive contaminants, or have contaminants become internalized via a wound. Personnel are irradiated by the radioactive material they have internalized until the radioactive material is removed by biological processes or other means. Large intakes of some radioactive contaminants pose significant health risks. These risks are largely long-term in nature and depend not only on the type and concentration of the radioactive contaminant absorbed, but also on the health background of the exposed individual. Potential cancers of the lung, liver, thyroid, stomach, and bone among others are the principal long-term health concerns. Contamination evaluation and therapy must never take precedence over treatment of conventional acute injuries. Early recognition of internal contamination provides the greatest opportunity for removal of the contaminant reducing the potential for further injury.

INTERNALIZATION OF RADIOACTIVE MATERIALS

4-17. The severity of internal contamination is dependent on the same processes that determine clinical severity related to exposure to nonradioactive toxins. Severity is dependent on the route of exposure, chemical and physical form of the nuclide, total intake of the radionuclide(s), and its distribution and metabolism within the body.

Intake

4-18. Contaminants enter the body principally by the following four routes:

- Inhalation
- Ingestion
- Wound contamination
- Skin absorption

Inhalation

4-19. Inhalation is the primary intake route for radioactive contamination. Absorption is dependent on the particle size of the contaminant and on its solubility in the lung. The contaminant's particle size determines its deposition within the respiratory tract. For example, particles smaller than 5 microns will reach the alveolar area. Most of the particles smaller than 1 micron will be naturally respired as the individual breathes out (although it is also possible that it will be absorbed through mucosa of the mouth, nose, and eyes) and some will be retained in the alveoli. Ninety percent of the particles greater than 5 microns never reach the alveoli. For those particles deposited in any area of the respiratory tract, their absorption depends on the chemical solubility of the contaminant. Soluble particles will be absorbed directly into the circulatory system through either the blood stream or the lymphatic system and will ultimately be distributed throughout the body. The rate of absorption will probably be quicker via the alveoli than via the upper respiratory tract due to the enhanced blood supply in the alveolar beds. Insoluble particles will remain within the respiratory tract. Those insoluble particles within the upper respiratory tract will be cleared by the mucociliary apparatus but until they are cleared, they will continue to irradiate the surrounding tissues which can lead to fibrosis and scarring in the respiratory tract. Most of the secretions from the upper respiratory tract will reach the pharynx and be swallowed and result in internal exposure through the GI tract. Refer to Table 4-3 for clearance times of various branches of the human respiratory tract for insoluble particulates.

Table 4-3. Clearance times of various branches of the human respiratory

Structure	*Clearance time (hours)*	*Cumulative time (hours)*
Trachea	0.1	0.1
Bronchi	1.0	1.1
Bronchioles	4.0	5.1
Terminal bronchioles	10.0	15.1
Alveoli	100+ days	100+ days

Ingestion

4-20. Radioactive material can enter the GI tract through eating contaminated foodstuffs, transferring contamination from hands to mouth, or by swallowing contaminated mucous transported to the pharynx from contamination in the lung. Absorption of the radionuclide through the crypts of the small intestine is dependent again on the contaminant's physical and chemical characteristics. Most ingested heavy metal radionuclides will pass through the GI tract without being absorbed into the systemic circulation. For example, only 20 percent of radium that is ingested is absorbed, only 30 percent of strontium that is ingested is absorbed, but majority of tritium, iodine, and cesium that is ingested is absorbed. It is the large intestine that receives the greatest radiation exposure due to the slower transit time for ingested materials. Clearance times of the human GI tract are shown in Table 4-4 on page 4-6.

Table 4-4. Clearance times of the human gastrointestinal tract

Organ	*Mean emptying time (hours)*	*Average occupancy time (hours per day)*
Stomach	1	6
Small intestine	4	14
Upper large intestine	13 to 20	18
Lower large intestine	24	22

Wound Contamination

4-21. Wounds are classified as abrasions, lacerations or punctures. The differing characteristics of each type of wound affect the absorption and decontamination of radioactive substances. Abrasions present a large surface area denuded of intact skin that decreases the skin barrier and increases the potential for absorption. Generally, they are easy to decontaminate due to easily accessible contaminants. Lacerations also are easy to decontaminate because the contaminated tissue can be excised. Puncture wounds, however, are difficult to decontaminate because of poor access to the contaminants and because of difficulty in determining the depth of the wound as well as the depth of contamination. Solubility, acidity/alkalinity, tissue reactivity, and particle size affect the absorption of a contaminant within a wound. The more soluble the contaminant, the greater the absorption rate. Smaller particles may be phagocytized in the tissues more rapidly and thus internalized more rapidly.

Skin Absorption

4-22. The skin acts as a physical barrier with the horny epithelial layer acting as the primary barrier. Percutaneous absorption occurs by passive diffusion and is not a major concern except with tritium. Skin that has been mechanically damaged as from repeated abrasive scrubbing, allows for greater absorption. Skin that has been exposed to certain chemicals like dimethyl sulfoxide is also more permeable. Absorption through sweat glands and hair follicles is a minor concern since they constitute only a small surface area.

Distribution

4-23. Once a radionuclide is absorbed, it is distributed throughout the body via the circulatory system. The rate of distribution to each organ is relative to the blood flow through that organ and the metabolic rate of the organ. Deposition is related to the ease of transport of the radionuclide or its metabolites across cell barriers in a given organ and the metabolic processes of the tissue that may involve an affinity for a given radionuclide or nuclide metabolites.

Metabolism and Excretion

4-24. After uptake into a particular organ, a radionuclide will be metabolized according to its chemical properties and will be excreted either in its original state or as a metabolite. The biologic half-life of a radionuclide determined by its rate of metabolism and excretion is as important as its radiological half-life in determining the significance of the exposure to a specific tissue. Most ingested heavy metal nuclides (depending upon the oxide state) will pass through the GI tract unchanged. The primary routes of excretion for absorbed radionuclides are through the urinary tract via the kidneys, the GI tract via the liver and common bile duct, and the lungs. Minor routes of excretion include sweat, saliva, milk, and seminal fluid. Compounds that are water soluble are excreted through the urine while lipid-soluble compounds are excreted via the bile into the intestine.

INTERNAL CONTAMINATION TREATMENT

4-25. Skin or wound contamination is almost never immediately life-threatening to the patient or to medical personnel. Attending to conventional trauma injuries is the first priority.

Immediate Care

4-26. As soon as the patient's condition permits, steps should be taken to determine if internal contamination has occurred. Samples (nasal blows and sputum samples should be used prior to nasal swabs) for radioactivity should be obtained as early as possible. If contamination is present (especially in both nostrils), it is presumptive evidence that inhalation of a contaminant has occurred.

Treatment Procedures

4-27. Treatment of persons with internal contamination focuses on reducing the radiation dose from absorbed radionuclides and hence the risk of long-term biological effects. Two general processes are used to achieve this goal: reducing the absorption of radionuclides and their deposition in target organs and increasing excretion of the radionuclides from the body. A number of procedures are available for respiratory contamination and GI contamination. As with any medical treatment, the clinician should consider the risks and benefits to the patient. The benefit of removing the radioactive contaminant using modalities associated with significant side effects and morbidity must be weighed against the short- and long-term effects of contamination without treatment. The radioactivity and the toxicity of the internalized radionuclide must also be considered. Risk estimates include professional judgment combined with the statistical probability of radiation-induced diseases occurring within a patient's lifetime. Some of the immediate simple treatment procedures include:

- Oral and nasopharygeal irrigation.
- Stomach lavage until stomach washings are relatively free of radioactive material.
- Emetics to induce vomiting. Emetics are most effective when taken with 200 to 300 milliliters of water. However, they are contraindicated if the state of consciousness is impaired, such as in the states of shock or inebriation or after ingestion of corrosive agents or petroleum hydrocarbons.
- Purgatives or laxatives to enhance intestinal motility.
- Enemas or colonic irrigations to reduce the time radioactive materials remain in the colon.

Therapeutic Agents

4-28. The most important considerations in treatment are the selection of the proper drug for a particular radionuclide and the timely administration of the drug after the exposure. Some of the treatment agents which could be used are presented below with specifics for each agent shown in a detailed listing in Appendix A and in the National Council on Radiation Protection and Measurements No. 65 publication.

Prussian Blue

4-29. The U.S. FDA has determined that the 500 mg Prussian blue capsules, when manufactured under the conditions of an approved New Drug Application, can be found safe and effective for the treatment of known or suspected internal contamination with radioactive cesium, radioactive thallium, or nonradioactive thallium. Prussian blue works using a mechanism known as ion exchange. Cesium or thallium that have been absorbed into the body are removed by the liver and passed into the intestine and are then reabsorbed into the body (entero-hepatic circulation). Prussian blue works by trapping thallium and cesium in the intestine, so that they can be passed out of the body in the stool rather than be reabsorbed. If persons are exposed to radioactive cesium, radioactive thallium, or non-radioactive thallium, taking Prussian blue may reduce the risk of death and major illness from radiation or poisoning. Prussian blue should be taken as soon as possible after exposure. However, even when treatment cannot be started right away, patients should be given Prussian blue as soon as it becomes available because it is still effective even after time has elapsed since exposure. For more information regarding Prussian blue, check the FDA Web site. For more information regarding Prussian blue and rubidium internal contamination, check the Oak Ridge Institute for Science and Education Web site. The links to the Web sites are found in the reference section of this publication.

4-30. Blocking and diluting agents work by preventing the uptake of a radionuclide in a target organ or by overwhelming the organ with stable compounds that reduce the uptake and incorporation of the radionuclide into that target organ. Potassium iodide (KI) is an excellent example of a blocking agent and

should be given before or within 4 hours of exposure to radioiodine. A single dose of KI protects the thyroid gland for 24 hours. A one-time dose at the recommended levels is usually all that is needed to protect the thyroid gland. Refer to Table 4-5 for recommended prophylactic single doses of KI. In situations involving continuing or ongoing contamination, if primary public health protection measures (evacuation, sheltering, and control of the food supply) cannot be readily put into place, multidosing of KI may be required. When KI is unavailable or contraindicated, propylthiouracil and methimazole may be considered alternative drugs for blocking thyroid uptake of radioiodine. However, propylthiouracil is not FDA-approved as a substitute for KI, and it should be used only in the case of documented and serious internal contamination with radioiodine when KI is unavailable or unlikely to be effective.

4-31. Some of the contraindications to potassium iodide are:

- It should not be given to individuals with known iodine sensitivity. A seafood or shellfish allergy does not necessarily indicate allergy to iodine.
- It should not be given to individuals with certain skin disorders (such as dermatitis herpetiformis or hypocomplementemic or urticaria vasculitis).
- It should be used with caution and with careful medical monitoring in individuals with thyroid disease (such as multinodular goiter, Graves disease, and autoimmune thyroiditis), especially if dosing extends beyond a few days. Such individuals should have monitoring of thyroid function.
- For more information regarding contraindication of potassium iodide refer to the Radiation Emergency Medical Management Web site (link found in the reference section).

Table 4-5. Recommended prophylactic single doses of stable iodine

Adults > 40 years of age with thyroid exposure ≥ 5 Gy (500 rad)	130 mg per day
Adults 18 to 40 years of age with thyroid exposure ≥ 0.1 Gy (10 rad)	130 mg per day
Pregnant or lactating women with thyroid exposure ≥ 0.05 Gy (5 rad)	130 mg per day
Children and adolescents 3 to 18 years of age with thyroid exposure ≥ 0.05 Gy (5 rad)	65 mg per day
Infants 1 month to 3 years of age with thyroid exposure ≥ 0.05 Gy (5 rad)	32 mg per day
Neonates from birth to 1 month with thyroid exposure ≥ 0.05 Gy (5 rad)	16 mg per day
Legend: Gy gray rad radiation absorbed dose mg milligram	

Mobilizing Agents

4-32. Mobilizing agents are compounds that increase the excretion of internal contaminants. Examples of mobilizing agents are ammonium chloride (best if given with IV calcium gluconate) and diuretics.

Chelating Agents

4-33. Chelators are a specific type of mobilizing agent that enhances the elimination of metals from target organs. Chelators are organic compounds (ligands) that exchange less firmly bonded ions for metal ions. Calcium-diethylenetriaminepentaacetic acid (Ca-DTPA) and Zinc-diethylenetriaminepentaacetic acid (Zn-DTPA) have been used to speed up excretion of the transuranium elements. Calcium-diethylenetriaminepentaacetic acid and Zn-DTPA bind to these elements and are then excreted in the urine. Both of these products can be safe and effective for the treatment of internal contamination with plutonium, americium, or curium and are FDA approved for this indication. Calcium-diethylenetriaminepentaacetic acid and Zn-DTPA should not be administered simultaneously. If both products are available, Ca-DTPA should be given as the first dose. If additional treatment is needed, treatment should be switched to Zn-DTPA. This treatment sequence is recommended because Ca-DTPA is more effective than Zn-DTPA during the first 24 hours after internal contamination. After the initial 24 hours, Zn-DTPA and Ca-DTPA are similarly effective, but Ca-DTPA causes more loss of essential metals, such as zinc, from the body. Therefore, Zn-DTPA is preferred for maintenance therapy. Continuation of

therapy is determined by assessing chelation yield in urine and feces with remaining body burden. Chelation therapy should not be used for uranium, iodine, and neptunium.

WARNING

Calcium-diethylenetriaminepentaacetic acid and Zn-DTPA do not treat contamination with radioactive iodine, uranium and neptunium, or the complications of radiation exposure (bone marrow suppression). Other treatments should be initiated if these conditions are suspected.

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Chapter 5

Low-Level Radiation

LOW-LEVEL RADIATION CHARACTERISTICS AND HAZARDS

5-1. For the purpose of this manual, low-level radiation exposures are doses of 75 cGy or less. Low-level radiation may come from dispersed radioactive material in solid, liquid, gaseous or vapor form, or in the form of discrete point sources. All of the types of radiation described in Chapter 2 may be emitted by the material present in low-level radiation sources. Low-level radiation exposures can come from many sources including but not limited to material from nuclear facilities (power plants), industrial and medical commodities, RDDs, nuclear weapons incidents, and military commodities.

5-2. The current threat to U.S. Armed Forces involves primarily terrorist actions with improvised nuclear devices or RDDs and hazards due to nuclear incidents. In contrast to the risks associated with a nuclear war, the risk of exposure to low-level radiation is more limited geographically, involves a limited number of individuals, requires more documentation of exposure history and treatment, and the immediate health risks to exposed personnel are generally much lower. Except in rare circumstances, the radiation doses received if these hazards are encountered would likely be well below those that would cause observable deterministic health effects, with only minor changes in blood complete blood count (CBC) expected at the highest doses in this range. However, they could be above the U.S. and host nation occupational dose limits that are applied to civilian workers and military personnel assigned to routine duties involving radiation exposure.

EXPOSURE GUIDANCE

5-3. Information regarding Occupational Ionizing Radiation Protection Program for the Department of Defense (DOD) workplaces, including military operations and deployments are found in Department of Defense Instruction (DODI) 6055.08 and DODI 6490.03.. These limitations are comparable to civilian worker protection regulations that govern radiation protection *practices*. However, they do not specifically address nonoccupational exposures for military operations, such as a maneuver unit moving into a radiologically hazardous area. Radiation exposure control measures in these situations must balance the requirement to adequately protect individual Service members with mission execution. The fundamental radiation protection principle of *as low as reasonably achievable* (ALARA) still applies. It is DOD policy to reduce exposures to ionizing radiation associated with DOD operations to a level ALARA consistent with operational risk management. Commanders should consider the risks of ionizing radiation exposure while balancing the requirements of completing military missions. Complying with the principle of ALARA should not introduce other (nonradioactive) risks above those associated with the risks from ionizing radiation exposure. For more information on risk management, refer to FM 5-19 and Marine Corps Order 3500.27B.

5-4. The occupational annual dose limit is 5 cGy, while the threshold for the development of acute health effects that become a concern in nuclear war is 75 cGy. The most current exposure guidance between these two limits is found in Table 5-1 on page 5-2 which is from NATO STANAG 2473. Crisis response operations cover all military operations conducted by NATO in a Non-Article 5 situation. Non-Article 5 crisis response operations can be described as multifunctional operations that encompass those political, military, and civil activities, initiated and executed in accordance with international law, including international humanitarian law, contributing to conflict prevention and resolution and crisis management, or serve humanitarian purposes, in the pursuit of declared Alliance objectives.

5-5. The exposure guidance applies to missions with durations ranging from minutes to one year. The risks associated with radiation exposure within this range of 5 cGy to 75 cGy are confined primarily to the risk of increased incidence of malignant diseases, including solid tumors and leukemias. Added to this

table, are medical notes for each radiation exposure state and the stochastic risk of long-term health effects as adapted from AMedP-6(C), Volume II. Military operations may require that national peacetime regulations governing exposure be exceeded, as when performing humanitarian, lifesaving, and/or emergency operations. All exposure to radiation must be justified by necessity and subjected to controls that maintain doses within the concept of ALARA. Refer to STANAG 2473 for exposure guidance while operating in contaminated areas.

Table 5-1. Radiation guidance for Non-Article 5 crisis response operations

Total cumulative dose (see notes 1 and 2)	*Radiation exposure state category*	*Recommended actions*
0 to 0.05 cGy	0	- Routine Monitoring for Early Warning Protocols or Goals.
0.05 to 0.5 cGy	1A	- Record individual dose readings. - Initiate specific monitoring protocols or goals (including air and water).
0.5 to 5 cGy	1B	- Record individual dose readings. - Initiate radiation survey and continue monitoring. - Prioritize tasks. - Establish dose control measures as part of operations.
5 to 10 cGy	1C	- Record individual dose readings. - Update survey and continue monitoring. - Continue dose control measures. - Execute priority tasks only (see note 3).
10 to 25 cGy	1D	- Record individual dose readings. - Update survey and continue monitoring. - Continue dose control measures. - Execute critical tasks only (see note 4). - Medical evaluation recommended upon normally scheduled return to home station.
25 to 75 cGy	1E	- Record individual dose readings. - Update survey and continue monitoring. - Continue dose control measures. - Execute critical tasks only (see note 4). - Medical evaluation required upon normally scheduled return to home station.
Legend: cGy – centigray		

Note. 1. For crisis response operations, radiation measurement in either centisievert or millisievert is preferred in all cases. However, due to the fact that the military may have the capability to measure centigray or milligray, the radiation guidance tables are presented in units of cGy for convenience. For whole-body gamma radiation, since the quality factor equals one, 10 milligray = 1centigray = 1 centisievert = 10 millisievert.

2. All doses should be kept ALARA. This will reduce individual Service member's risk as well as retain maximum operational flexibility for future employment of exposed Service members.

3. Examples of *priority* tasks are those that contain the hazard, avert danger to persons or allow the mission to continue without major revisions in the operational plan.

4. Examples of *critical* tasks are those that save lives or allow continued support that is deemed essential by the operational commander to conduct the mission.

5-6. Although an upper bound for radiation exposure state 1E is provided in the table, it is conceivable that doses to personnel could exceed this amount. A low incidence of acute radiation sickness can be expected at whole-body doses of 75 cGy. Personnel exceeding the radiation exposure state 1E upper bound should be considered for prompt medical evacuation.

DELAYED/LATE HEALTH EFFECTS

5-7. Delayed health effects may appear months to years after irradiation and include a wide variety of effects involving almost all tissues or organs. Some of the possible delayed consequences of radiation injury are carcinogenesis, cataract formation, chronic radiodermatitis, and decreased fertility. However, it should be emphasized that many victims of exposure to radiation do not manifest late term effects. The Hiroshima, Nagasaki, and Russian experiences have not shown any genetic effects in humans. At the lower levels of exposure (background levels to 75 cGy), the risk of effects such as cancer and genetic effects is stochastic in nature and relates to exposed populations not to exposed individuals. Health risks incurred tend to be long-term in nature and not immediate, therefore lacking significant operational impact. These risks may, however, manifest themselves as a significant disease long after the completion of the military operation. For more information on delayed effects, refer to the Armed Forces Radiobiology Research Institute Special Publication 10-1, Medical Management of Radiological Casualties Handbook.

PRINCIPLES

5-8. In relation to associated long-term health risks, several principles need to be reviewed. For purposes of radiation protection, it is assumed that the risk of stochastic health effects is proportional to the dose received. In addition, biological factors relative to the irradiated individual should be considered (for example, age and sex of the individual, health status, and the individual's genetic makeup). In addition to the total dose factor, radiological parameters that factor into long-term health risks include—

- Exposure rate and quality of the radiation.
- Location of the source (external versus internal).
- Nature of exposure (continuous versus fractionated versus protracted; prompt external exposure versus chronic dosing).
- Time after exposure and requisite repair times and latency times required for pathologies to manifest.

TYPES OF LONG-TERM EFFECTS

5-9. Deterministic effects are those that require a certain threshold dose to be exceeded before the effect is observed and for which the severity of the effect is proportional to the dose. They include both acute and delayed effects. While individual variations will occur due to individual sensitivity, the severity of the effect is still directly dose related. Tissue fibrosis, chronic immune system suppression, reproductive tissue dysfunction, and selected ocular problems are some of the more common and serious symptoms of the late-arising deterministic pathologies. Formation of ocular cataracts is the most common delayed radiation injury. Higher doses tend to increase the degree of opacity and shorten the period of latency. Immune system defects occur at doses of 50 cGy and larger.

5-10. A stochastic effect is a consequence based on statistical probability. For radiation, tumor induction is the most important long-term sequela for a dose of less than 100 cGy. Most of the data utilized to construct risk estimates are taken from radiation doses greater than 100 cGy and then extrapolated down for low-dose probability estimates. There is no substantive epidemiological data that demonstrates stochastic health effects for whole-body doses less than 10 cGy. Subsequently, there is considerable scientific debate on the actual dose-response relationship for low-level exposures.

EMBRYONIC AND FETAL EFFECTS

5-11. Radiation-induced embryonic/fetal effects have been clearly documented by the increased mental disabilities and congenital birth defects in Japanese children irradiated in utero as the result of the nuclear bomb detonations over Hiroshima and Nagasaki. The direct military relevance of these fetal effects may

be pertinent. There are thousands of possible birth defects and congenital anomalies that can be impacted by the fetal exposure to ionizing radiation. The National Vital Statistics System monitors and documents birth defects including anencephaly, cleft palate/lip, Down's syndrome, omphalocele or gastroschisis, neural tube defects, and skeletal defects. Further, the embryonic responses appear to have a broad exposure threshold for induction, with significant responses being noted only at doses greater than 15 cGy. The current normal incidence rate of occurrence of congenital abnormalities is 3 to 5 percent of live births. There had been reported increases in the incidence of birth defects in inhabitants of the Marshall Islands exposed to nuclear fallout. The incidence of congenital and early childhood leukemia appears to be increased as well by fetal radiation exposure.

REPRODUCTIVE CELL KINETICS AND STERILITY

5-12. Despite the high degree of radiosensitivity of some stages of germ cell development, the testes and ovaries are only transiently affected by single sublethal doses of whole-body irradiation and generally go on to recover normal function. Temporary male sterility due to damage to spermatogonia will occur after 15 cGy of local or whole-body irradiation. As this is a maturation depletion process, the azoospermia will not occur until two months after irradiation. Protracted radiation exposure will cause a more prolonged episode of azoospermia. Serum levels of testosterone will be unaffected. Female reproductive tissues appear more resistant.

5-13. When chromosome aberrations are produced in somatic cells, the injury is restricted to the specific tissue or cell system. However, when aberrations occur in germ cells, the effects may be reflected in subsequent generations. Most frequently, the stem cells of the germ cell line do not develop into mature sperm cells or ova and no abnormalities are transmitted. If the abnormalities are not severe enough to prevent fertilization, the developing embryos will not be viable in most instances. Only when the chromosome damage is very slight and there is no actual loss of genetic material will the offspring be viable and abnormalities be transferable to succeeding generations. These point mutations become important at low radiation dose levels. In any population of cells, spontaneous point mutations occur naturally. Radiation increases the rate of these mutations and thus increases the abnormal genetic content of future cellular generations.

CARCINOGENESIS

5-14. Irradiation of any part of the body increases the probability of cancer. The type formed depends on such factors as area irradiated, radiation dose, age, and other demographic factors. Irradiation may either increase the absolute incidence of cancer or accelerate the time or onset of cancer appearance, or both. There is a latent period between the exposure and the clinical appearance of the cancer. In the case of the various radiation-induced cancers seen in man, the latency period may be several years. Latent periods for induction of skin cancers in man have ranged from 10 to 50 years after therapeutic x-ray exposures, to a reported 15 years for bone tumors after radium exposure. This latency related to bone tumors is very dependent upon the dose and type of radiation emitted by the radionuclide.

5-15. A leukemogenic effect was expected and found among Hiroshima and Nagasaki survivors. The peak incidence occurred 6 years after exposure and was less marked for chronic granulocytic leukemia than for acute leukemia. British men receiving radiotherapy for spondylitis showed a dose response relationship for leukemia, with peak incidence occurring 5 years after the first exposure. Studies have demonstrated that ionizing radiation can induce more than one kind of leukemia in man, but not chronic lymphocytic leukemia.

5-16. In 1999, the National Academy of Sciences (see Web site link listed in reference section) estimated that the lifetime risk of fatal cancer occurrence increased by 810 cases (fatal and nonfatal) per 100,000 persons/10 cGy for males and 1300 cases (fatal and nonfatal) per 100,000 persons/10 cGy for females. To illustrate this effect, the U.S. background lifetime fatal cancer incidence rate is 20,000 cases per 100,000 persons. Therefore, if a mixed group of 100,000 people receive 10 cGy single-dose irradiation, instead of 20,000 cancers, approximately 20,810 fatal cancers would occur in males. Deciding which 810 of these 20,810 cases were radiation-induced is impossible. National cancer incidence rates vary as do the corresponding risk estimates, and account should be taken of these variables. For more information, refer

to the Committee on Biological Effects of Ionizing Radiations (*Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII, Phase 2*).

5-17. The more important radiobiological conditions that factor into cancer induction (or for that matter any of the somatic effects) include those parameters previously mentioned, namely dose, dose rate, and radiation quality. Cancer is not a single disease, but a complex of diseases comprised of both cancers of the blood (leukemias), and cancers of solid tissues of both epithelial and mesothelial origins. The radiogenic nature of these specific cancers differs substantially. Bone tumors (osteosarcomas) serve as a good example, as they are prominent late arising pathologies associated with internally deposited, bone-seeking radionuclides such as strontium-90. However, bone tumors are rarely associated with the cancers that stem from exposure to external radiation sources such as cobalt-60.

5-18. Cancer types that are unequivocally inducible by ionizing radiation are the lymphohematopoietic cancers, cancers of the lung, mammary tissues, liver, thyroid, colon, stomach, pancreas, salivary glands, and kidneys. Cancers with either a low incidence or a low probability of induction include cancers of the larynx, nasal sinuses, parathyroid, nervous tissue, and connective tissue. Cancers that are probably not inducible include the chronic lymphocyte leukemias and cancers of the uterus, cervix, prostate, testis, mesentery, and mesothelium. The risks of fatal cancers for the general population are given in Table 5-2. The information presented is an International Commission on Radiological Protection summary of risks. Note that these values should not be used to interpret individual risks, which are dependent on numerous factors such as age, sex, heredity, and environment.

Table 5-2. International commission on radiological protection summary of risks per milligray

Effect	***Risk per milligray***
Hereditary	10×10^{-6} (all generations)
Cancer	***Fatal probability***
Leukemia (active marrow)	5×10^{-6}
Skin	0.2×10^{-6}
Breast (females only)	4×10^{-6}
Stomach	11×10^{-6}
Sum of fatal cancer risk for whole-body irradiation (males and females)	50×10^{-6} (1 in 20,000)
Baseline cancer mortality	0.15 (1 in 6.7) to 0.25 (1 in 4)

CATARACT FORMATION

5-19. A late effect of eye irradiation is cataract formation. It may begin anywhere from 6 months to several years after exposure. While all types of ionizing radiation may induce cataract formation, neutron irradiation is especially effective in its formation even at relatively low doses. Cataract formation begins at the posterior pole of the lens and continues until the entire lens has been affected. Growth of the opacity may stop at any point. The rate of growth and the degree of opacity are dependent upon the dose as well as the type of radiation. According to the Committee on the Biological Effects of Ionizing Radiations (*Health Effects of Exposure to Low Level of Ionizing Radiation: BEIR V*), cataract formation has been observed in atomic bomb survivors from exposures estimated at 60 to 150 cGy. However, the threshold in persons treated with x rays to the eye range from about 200 cGy for a single exposure to more than 500 cGy for multiple exposures over a period of weeks. A 50 percent cataract risk has been estimated at acute doses of approximately 300 cGy. This estimate assumes a low LET exposure and it has been recently suggested that with high LET particle irradiation, the initiating cataractogenic dose might be considerably lower, well within 70 cGy.

PREVENTION, INITIAL ACTIONS, AND MEDICAL CARE AND FOLLOW-UP

5-20. Military operations may require that regulations governing occupational exposure be exceeded. However, all exposure to radiation must be justified by necessity and subjected to controls that maintain doses ALARA.

PREVENTION

5-21. There are several measures commanders and units can take to prevent or reduce radiation exposure. For example, the commander may establish individual protective clothing measures, such as specifying mission-oriented protective posture levels. For a detailed discussion of protective measures, refer to FM 3-11.4 (FM 3-4)/MCWP 3-37.2/NTTP 3-11.27/AFTTP(I) 3-2.46 and FM 4-02.7/MCRP 4-11.1F/NTTP 4-02.7/AFTTP 3-42.3. For more information on home station medical response to a CBRN incident, refer to AFTTP 3-42.32.

5-22. Medical personnel contribute to the prevention effort by providing input into the following staff actions:

- A risk assessment that includes analysis of medical information on the area of operations. This analysis should provide information on civil nuclear facilities, industrial radioactive sources, and medical radioactive sources present in the area of operations.
- Development of contingency plans that deal with the most likely risks. These plans should identify the potential risks, possible incident scenarios, and medical response actions such as prophylaxis and dosimetry support. The plan should also specify dose limits and identify RADIAC equipment available.
- When the possibility of exposure exists, equip deploying forces with dosimeters and other radiation detection devices. Within equipment constraints, equip as many individuals as possible. Priority will go to units which have the greatest risk of exposure. Ensure that medical facilities conduct radiation detection as part of initial patient medical survey/entry procedures.
- Establishment of hazard avoidance measures including control and restriction of entry into nuclear installations and radioactive areas, ensuring personnel do not tamper with radiological containers, and clearance of suspected radioactive waste dumps.

INITIAL ACTIONS

5-23. If personnel encounter a radiological hazard, initial actions may include evacuation from the area, calling in the proper CBRN reports, informing the local civil authorities, and requesting specialized monitoring and survey teams. Medical personnel will provide input into staff estimates and plans that will establish control measures to contain the low-level radiation hazard. This would include advice on modifying the commander's operational exposure guidance and adherence to established guidance. The medical staff must also advise the commander on the monitoring and dose recording of those individuals, who for operational reasons, must remain within the hazard area.

MEDICAL CARE

5-24. Medical care following exposure to low-level radiation involves the diagnosis and management of both the early and delayed deterministic events from doses above threshold levels (bone marrow depression, skin injuries), and the management of probabilistic effects (should they occur), primarily nonspecific tumors and leukemia that may become clinically evident years after exposure to radiation. Within the low-level dose range (5 to 75 cGy), the greatest risk is the appearance of stochastic effects, that is, the appearance of benign and malignant tumors and leukemia years after the event. However, because of the uncertainty of the dose that may be received during certain situations, deterministic effects may appear within months of certain types of acute exposures.

MEDICAL FOLLOW-UP

5-25. The low-level dose range (5 to 75 cGy) is unlikely to cause delayed acute or chronic deterministic effects.

Medical Assessment

5-26. Medical assessment is the evaluation of the basic parameters of general and radiological health status after a known or suspected exposure to radiation or radioactive contamination. Such an evaluation may be prompted by the development of nonspecific symptoms, trauma, or an observed degradation of individual performance during or after a military operation conducted in an area of known or suspected radiation or radioactive contaminants. Personnel are not likely to develop symptoms of acute radiation exposure at the low-level dose range; however, medical assessment is recommended after personnel exit radiologically hazardous areas. The purpose of the assessment of asymptomatic individuals in these situations is to—

- Rule out that personnel were exposed to higher than expected doses.
- Obtain baseline clinical data to assist in estimating the individual's radiation dose.
- Establish a basis for recommendations regarding the individual's need for medical care, periodic monitoring, or specific testing.

Medical Monitoring

5-27. Medical monitoring is a systematic screening of a population of asymptomatic individuals for preclinical disease with the purpose of preventing or delaying the development and progression of chronic disease in those individuals. However, medical monitoring after radiation exposure is not routinely suggested or practiced for individuals with known or suspected exposures to radiation. An exposure or a presumed exposure to radiation is not, by itself, sufficient to justify a medical monitoring program. The decision about whether a medical monitoring program is appropriate and necessary in a given situation should be based on the consideration of a number of factors including a rigorous cost-benefit analysis. This analysis should take into account the following considerations:

- The certainty, type, intensity, and duration of the dose concerned.
- The history and population prevalence of the disease concerned.
- The effectiveness, sensitivity, specificity, and potential hazardous side effects of available screening tests.
- If test results are positive, the availability, benefits, and risks of treatment protocols.

5-28. The latent period between radiation exposure and the development of a clinically detectable tumor or leukemia may have an effect on the design of a screening program. For the U.S. Armed Forces, personnel are usually between 20 and 40 years of age when they are exposed, and most radiation-induced tumors would be expected to become clinically evident when they are older than 40, and in most cases, older than 50. Since most cancers occur spontaneously at older ages (older than 50 years) without exposure to radiation, few tests have shown to be of benefit in terms of improving either survivability or quality of life. Tests that have been recommended include the pap smear, prostate-specific antigen tests, and mammography. Since the risk of cancer in nonexposed populations is high over a normal lifetime, the risk of radiation-induced tumors due to exposure to low-level radiation would always be far less than the risk of normal spontaneous incidence.

5-29. The Institute of Medicine recommends the establishment of registries for tracking individuals who have received cumulative effective doses in excess of 5 cGy. This action may be helpful in addressing follow-on health related issues. The committee also recommends that annually, and upon demobilization or discharge, potentially exposed military personnel should be given a written record of their radiation exposure with estimated doses (annual and cumulative), even if the doses are zero.

DOCUMENTATION OF RADIATION EXPOSURE RECORDS

5-30. The operational exposure guidance concept requires that all units maintain radiation exposure records. Currently, the operational exposure guidance is set for platoon-level or equivalent unit data received daily, or after a mission in a radiological contaminated area.

Nuclear Detonation

5-31. The operational exposure guidance concept requires that all units maintain radiation exposure records. Currently, the operational exposure guidance is set for platoon-level or equivalent unit data received daily, or after a mission in a radiological contaminated area. The unit dose is an average of the doses to individuals in the unit who have dosimeters, as specified in individual service doctrine (usually one or two per squad or equivalent unit). The organization assumes that each Service member receives an individual dose equal to that of the average for the platoon-level/equivalent unit. The dosimetry exposure records are usually kept by the unit CBRN officer at battalion level or equivalent unit. In a nuclear environment, when a Service member transfers out of an exposed unit, the radiation exposure estimated to have been received by that individual is noted in the Service member's medical file. When possible, Service members are reassigned to platoons/equivalent unit with the same radiation exposure state category. Although this might create personnel strength management problems, it is intended to prevent personnel incapacitation due to acute overexposure to radiation (high total dose/high dose rate) in future operations. Each service has service-specific requirements to maintain radiation dose records. Individual dosimetry should be requested if the situation warrants, since individual dosimetry can greatly assist with patient assessment and management. Formal dose estimates and dose reconstructions are made by health physicists using available environmental radiation measurements and individual monitoring processes (in vitro/in vivo) when dosimetry data is not available.

Consequence Management

5-32. Dosimeters used within the CBRN enterprise may not be capable of recording low dose levels. Historically, the spread of radioactive material from reactor accidents (Chernobyl, Fukushima) is not uniform, and will likely result in Service members having to operate in several different, typically low dose rate, radiation gradients. Dosimetry capable of measuring low doses (micro Sv range) should be requested and issued to individuals when and where possible. Although low doses are unlikely to result in acute deterministic effects, dosimetry results will assist health physicists in determining the potential for long term (stochastic) effects to the individual and will assist in establishing formal dose estimates and dose reconstructions. Thus, administrative tracking of dosimeters issued to individuals is a priority.

5-33. In 2011, during Operation Tomodachi, a number of dosimeters were issued to personnel without having robust administrative controls in place. As a result, some dosimeters that were issued for use may have been processed by service dosimetry centers without being able to attribute the dose to Operation Tomodachi efforts. Additionally, some dosimeters were never returned to the service dosimetry centers for processing.

5-34. The Service dosimetry centers are the primary location for all exposure and dose information processing. Each Service maintains a repository of individual dose information. In some cases, dosimetry results may be forwarded from the individual Service dosimetry centers to Defense Occupational and Environmental Health Readiness System surveillance data portal for analysis and archiving. The link to the Web site is found in the reference section. For more information, refer to DODI 6490.03 and Bureau of Medicine and Surgery Publication (NAVMED)-5055.

5-35. For more information on operational exposure guidance and radiation exposure state, refer to U. S. Army Public Health Command Technical Guide 230 (when determining protective posture/risk mitigation steps) and also JP 3-11.

5-36. In a low-level radiation environment, STANAG 2473 not only reinforces the requirement to maintain dose records, it also stipulates that *commanders will need to be aware of individual dose histories when planning future operations at risk of radiation exposure*. For more information on recording of ionizing radiation exposure, refer to STANAG 2474.

Chapter 6

Psychological Effects and Treatment of Combat and Operational Stress Reaction Casualties

PSYCHOLOGICAL CASUALTIES

6-1. In a nuclear war scenario, psychological casualties would seem to be insignificant compared to the casualties from physical trauma, but they can dramatically alter the outcome of a battle. The neuropsychiatric casualties of World War II were the largest single cause of lost military strength in that war. The Arab-Israeli Yom Kippur War of 1973 lasted only 3 weeks, but combat and operational stress reaction (COSR) casualties were 23 percent of all nonfatal casualties. Complicating matters further, COSR can mimic the early symptoms and signs of acute radiation injury. Gastrointestinal symptoms (nausea, vomiting and diarrhea), fatigue, and headaches were frequently seen symptoms during episodes of COSR in World War II. In RDD or nuclear incident scenarios, COSR is also a factor. Even if neuropsychiatric trauma does not produce a casualty, it can degrade the performance of normal duties. Slightly altered reaction times, attention, or motivation have important consequences across the entire range of military operations. Regardless of the situation, it must be emphasized that the most extreme psychological damage occurs when physiological symptoms from an unknown toxic exposure become manifested. Significant degradation in performance may occur as military personnel become concerned about the material they were exposed to, the dose, and the long-term effects of that exposure.

RADIATION DISPERSAL DEVICES AND NUCLEAR INCIDENTS

6-2. Although RDDs and nuclear incidents lack the destructive power of a nuclear detonation, the psychological impact of these events might impede military operations by denying key terrain or installations and by degrading unit morale and cohesiveness. If an incident occurs in a civilian setting, psychological stress is expected to increase. Material in this paragraph is an estimate of the problems likely to be encountered, since an RDD has not yet been employed against U.S. forces or civilians.

PSYCHOLOGICAL EFFECTS OF RADIOLOGICAL DISPERSAL DEVICES, RADIOLOGICAL EXPOSURE DEVICES, AND NUCLEAR INCIDENTS

6-3. The use of an RDD, radiological exposure device or a nuclear incident would be expected to produce acute anxiety effects, including psychosomatic effects such as nausea and vomiting. Symptoms of acute radiation sickness in just a few personnel might trigger an outbreak of similar symptoms in the unit and/or in the civilian populace. Emergency personnel responding to the incident may have a false perception of the threat that has little connection to the actual physical hazard present. Experience from industrial accidents shows that both real and imagined illnesses may be attributed to radiation exposure. The severity of the psychological effects of an RDD, radiological exposure device or a nuclear incident will depend on the nature of, and the extent of the physical effects. Malicious use of a sealed source of radioactivity left in an area of personnel traffic would pose only an external radiation hazard, which depending on the dose received, may lead to acute radiological injury. Similarly, an RDD that distributes radioactive material using passive means would likely generate a contamination hazard with little, if any acute physical injury. However, blast injuries, in addition to radiation effects, may be caused by an RDD that uses a conventional explosion, or if the high explosive component of a nuclear weapon detonates. The greater the number of casualties from the blast and a generally more chaotic situation will intensify the level of COSR on individuals and likely produce more psychological casualties.

INCIDENCE

6-4. Exposure or perceived exposure to radiation can be expected to increase the number of COSR casualties. The number of casualties will also depend on the level of leadership, cohesiveness, level of training, and morale in the unit. Long-term chronic psychological stress patterns could be expected to arise from the uncertainty about the effects of exposure to radiation. Some of the potential effects include phobias, depression, and posttraumatic stress disorder. An RDD, radiological exposure device or a nuclear incident within a civilian population center may produce more detrimental psychological effects to military personnel than if it occurred in a strictly military operations area. Recently, the military has seen increased stability and support operations where closer relationships may exist between civilians and military personnel. Requests for treatment of civilian casualties especially women and children after an incident, might markedly increase the psychological impact on military personnel. A civilian mass casualty situation could severely overload emergency medical operations and increase distress in military personnel. For more information regarding emergency management program planning and operations, refer to AFI 10-2501. Behaviors such as altruism, heroism, and loyalty to comrades typically seen in units with exceptional esprit de corps may alleviate some of the COSR.

NUCLEAR DETONATION

6-5. Personnel witnessing a nuclear detonation are likely to suffer sensory overload as well as the fear of injury or death. Depending upon the yield of the weapon and the distance, the Service member may see a brilliant flash that temporarily blinds him, hear a deafening explosion at incredible decibels, suffer thermal injury, feel the shock of blast winds, and then experience the ground shaking beneath his feet. At night, flash blindness could affect personnel miles beyond the range of any other acute effects. Some personnel may have immediate adverse psychological reactions, even in the absence of actual physical injury.

6-6. Contrary to media portrayals of disasters, mass panic is rare in disaster situations. It seems to occur primarily in situations where there are limited avenues of escape and possible entrapment, such as mine fires or mine collapses, sinking ships, or fires in crowded areas where exit routes are limited. The most frequent psychological effect after disasters is a temporary emotional disruption where people are stunned or dazed. This transient response may last minutes to days. Typically, such individuals will be able to respond to strong leadership and direction. Another psychological response is to become more efficient in the face of danger. This response is expected more likely in well-trained units with high morale. A third type of response would be that of a psychological casualty, where the transient emotional disruption is continued and more severe. Reactions include stunned, mute behavior, tearful helplessness, apathy, inappropriate activity, and preoccupation with somatic symptoms (often of emotional origin).

6-7. Somatic effects such as nausea, vomiting, diarrhea, and a feeling of weakness or fatigue would likely occur. These individuals may exhibit helpless, aimless, or disorganized behaviors. In the aftermath of the Hiroshima and Nagasaki bombings, some people were stunned into meaningless, repetitive behaviors with no obvious goal orientation or survival value. Some wandered uselessly in the debris, with no conscious effort to either escape or aid others. Many withdrew into an apathy approaching catatonia, apparently shutting themselves off from the outside world.

FALLOUT FIELD

6-8. The most stressful effects of a fallout field or contaminated area are likely to be the uncertainties of the levels of radiation present, lack of defined boundaries of the area, and the perceived acute and chronic effects of radiation. A chronic level of high stress will also exist when monitoring an area for radiation hazards. Stress in this situation resembles that of troops clearing an area of mines or patrolling a booby-trapped area. Military personnel may not know their individual exposure since only unit dosimetry may be available. They may fear that they are getting a much larger dose than deemed wise, especially if there is a lack of trust in the leadership. Stress levels can be decreased with positive identification that defines the contamination field and with proper training of military personnel as to the actual hazards and their effects.

PSYCHOSOCIAL SEQUELAE OF RADIATION EXPOSURE

6-9. Even in the absence of actual exposure, fear that one has been exposed to radiation may cause psychosocial sequelae. Since fear and anxiety are stressors, the person may experience psychosomatic symptoms, some of which may mimic early acute radiation syndrome symptoms. For example, in the accident at Three Mile Island in 1979, surveys of the surrounding population found an increase in such psychosomatic symptoms as nausea, anorexia, and skin rashes, even though there was no detectable radiation exposure in most of these areas. At Goiânia, Brazil, after scavengers opened a medical radiotherapy device containing radiocesium, approximately 5,000 of the first 60,000 persons (8 percent) to be screened for radioactive contamination showed symptoms of acute stress or allergies such as a rash around the neck and upper body, vomiting, and diarrhea. However, none of these individuals were contaminated. Thus, the perceptions and preconceptions about radiation may be just as important as the radiation itself in terms of subsequent pathology.

PSYCHOLOGICAL FACTORS AT CHERNOBYL

6-10. Many of the recovery team members (liquidators) called in to help with the cleanup of the reactor at Chernobyl were military personnel. A local study of Estonian liquidators found no increases in cancer, leukemia, or overall mortality, but they did find an increase in suicide. A study of Latvian liquidators found that almost half had psychosomatic disorders. The fear of radiation in the liquidators was probably enhanced by their lack of knowledge, the misinformation published in the media, and a distrust of the Red Army's record of the radiation doses. An epidemic of vegetative dystonia occurred in liquidators and people from the contaminated areas. The symptoms of vegetative dystonia resemble the medically unexplained physical symptoms seen in Agent Orange Syndrome and Gulf War Illness, as well as neurocirculatory asthenia or effort syndrome that was prevalent during and after both World Wars. The vegetative dystonia was more prevalent in liquidators who suffered acute radiation sickness, but was also seen in others who suffered no acute effects.

6-11. Many people living upwind of Chernobyl and hundreds of miles away received detectable doses of radiation equivalent to, or less than a doubling of the normal background radiation level. Some people became so afraid of the fallout that their whole lives began to revolve around avoidance. Whenever possible, they refused to go outside or eat locally grown produce. Some sank into deep despair and committed suicide rather than risk what they believed would be the inevitable and horrible effects of radiation. Such severe reactions were referred to as radiophobia by the media. However, those with social support were better able to handle the increased psychological stress.

TREATMENT

6-12. The treatment of psychological stress resulting from actual or perceived exposure to radiation is the same as that for COSR. Guidance on appropriate interventions can be accessed through the Department of Veterans Affairs/DOD Clinical Practice Guideline on Management of Post-Traumatic Stress Web site (link found in the reference section).

6-13. The principles of proximity, immediacy, expectancy, simplicity are the cornerstones of treatment—

- Proximity means to treat the psychological casualty as close as possible to the unit and the area from which the individual came, so as to prevent evacuating a casualty to a distant medical facility.
- Immediacy refers to initiating treatment as soon as possible to prevent the strengthening of maladaptive habits and the self-perception of illness or disability.
- Expectancy means that medical personnel should convey the positive expectation that the casualty will fully recover and be able to return to duty (RTD) after a short break from the operation.
- Simplicity refers to the use of simple, brief, and straightforward methods to restore physical well-being and self-confidence.

6-14. Generally, treatment modalities consist of the following—

- Reassurance and suggestion that the situation will improve. Psychological casualties are suggestible early in their disruptive phase and simple reassurance using a positive, direct approach is usually successful. Individuals should be made to feel that they have an excellent chance of recovery, which is true in most cases.
- Rest with removal from immediate danger. A short period of rest in a safe area is of great benefit.
- Elimination of negative emotions by expression of those emotions (catharsis). Retention of fear and anxiety by the more severely incapacitated frequently blocks effective communication. When the patient expresses his or her feelings, this tends to remove the block. This communication is essential before the individual can recover enough to rejoin the activities of his or her group or unit.

6-15. Sedatives or tranquilizers should be avoided unless they are essential to manage sleep or agitated behavior. Stress casualties should only be evacuated to the next higher echelon if their symptoms make them too disruptive to manage at a given echelon. Similarly, hospitalization should be avoided unless absolutely necessary, and those requiring hospitalization should be transferred to a nonhospital treatment setting as soon as their condition permits.

PREVENTION, RISK MITIGATION, AND COMMUNICATION

6-16. Prevention, when possible, is always preferred to treatment. Prior to deployment to an area where nuclear and radiological hazards are present, medical personnel can implement programs on behalf of the line commanders that instruct their units about radiation and its effects. For more information on medical readiness program management, refer to AFI 41-106.

Prevention

6-17. In general, troops who are psychologically prepared for specific stresses are better able to endure them and will suffer fewer and less severe adverse reactions. This same principle is widely used in preparing troops to cope with mission- oriented protective posture gear, chemical agent exposure, and other adverse environments. Postexposure training will be much less effective. Lack of information about the physical hazards of radiation increases the incidence of fear and anxiety in troops regardless of the actual physical hazard. Units responding to a nuclear incident should have operational RADIAC equipment and dosimeters. Dosimeters should be issued to each individual according to current doctrine. Individual dose information can therefore be provided to alleviate fears of receiving large doses. In fallout fields, COSR is reduced by positively identifying and assessing the radiation field, its boundaries, the exposure levels and the risks associated with continued exposure. Primary and backup personnel should be fully trained in proper equipment operation and in proper CBRN reporting procedures and formats.

Risk Mitigation and Communication

6-18. To effectively mitigate risks, the training should be tailored in layman's terms, it should be realistic and accurate, and it should highlight practical (not theoretical) measures on self-protection. Specific training in radiation effects, radiation protection, radiation risk communication and psychological casualty prevention should be given. For more information on risk communication, refer to Appendix D. The principles of minimizing time, increasing distance, and increasing shielding from a radiation source should be introduced as ways of decreasing radiation exposure. Service members should gain an understanding that exposure to natural sources of radiation is continuous throughout life. Normal background radiation levels, medical exposures, and exposures from expected missions should all be put in context with one another. Questions about increased cancer risks from potential mission exposures should be answered with relation to normal cancer incidence rates. For fallout fields, troops should understand that decontamination is the simple act of dusting oneself off (or changing clothes) and washing exposed skin areas with soap and water. In addition to training military units, radiation training must also be provided to deploying behavioral health personnel.

6-19. The credibility of leaders, and the trust on which that credibility is based, must be maintained. Leaders must keep troops informed on possible mission exposures, realistic risk estimates, unit dose

information from radiation, RADIAC equipment, and other information that removes ambiguities and uncertainties in any given situation. Leaders must address, and not dismiss, real concerns. Leaders should know the operational exposure guidance for their mission, the radiation exposure state of their unit, and the risks associated with their mission. They should have an understanding of acute radiation exposure hazards in comparison with the immediate dangers of conventional combat. They should also understand the potential for long-term health risks when troops receive radiation exposures. Leaders should also be knowledgeable on how to request assistance in interpreting risks associated with radiation exposures or with readings from RADIAC equipment.

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Appendix A

Medications

LIST OF MEDICATIONS

A-1. Table A-1 (pages A-1 through A-5) is a listing of medications available (not all inclusive) for use when treating nuclear and radiological casualties. Stockage levels of specific medications will be as authorized by unit assemblages and standing operating procedures.

CAUTION

The doses listed are guidelines and the manufactures' recommended dose and dose schedule should be reviewed prior to the administration of these medications; especially in the use of these medications for infants and children.

Table A-1. Medications

GENERIC NAME	CLASS	DOSE/ROUTE	INDICATION	NOTES
Systemic Antibiotics				
metronidazole	Antibiotic	7.5 mg/kg PO/IV q 6 hrs (maximum 4 grams qd)	Anaerobic infections	
gentamicin	Antibiotic	3-5 mg/kg/day IV in divided doses	Gram (–) infections	Monitor peak and trough levels
ciprofloxacin	Antibiotic	500 mg PO/IV qd	Bacterial prophylaxis when neutropenic	
ampicillin	Antibiotic	150-200 mg/kg/day in divided doses q 3-4 hrs	Gram (+) infections	
vancomycin	Antibiotic	1 gram IV q 12 hrs	Gram (+) infections	Monitor peak and trough levels
Topical Antibiotics				
mafenide acetate	Antibiotic	Apply 1/16" qd or bid	Gram (-) and gram (+) infections, including pseudomonas	Adjunctive therapy for patients with second-degree and third-degree burns
silver sulfadiazine	Antibiotic	Apply 1/16" qd or bid	Gram (-) and gram (+) infections, including pseudomonas	Adjunctive therapy for patients with second-degree and third-degree burns
Systemic Antifungal Agents				
amphotericin B, lipid complex	Antifungal	5 mg/kg/day IV	Invasive fungal infections	Use if refractory to or intolerant of amphotericin B
amphotericin B, liposome	Antifungal	3-5 mg/kg/day IV	Invasive fungal infections	Use if refractory to or intolerant of amphotericin B
fluconazole	Antifungal	400 mg PO/IV qd	Fungal prophylaxis when neutropenic	
amphotericin B	Antifungal	0.5-1.5 mg/kg/day IV	Invasive fungal infections	Slow IV, extreme side effects

Table A-1. Medications (continued)

GENERIC NAME	CLASS	DOSE/ROUTE	INDICATION	NOTES
Systemic Antiviral Agents				
gancylovir	Antiviral	5 mg/kg IV bid for 7 days then 5 mg/kg IV qd	Cytomegalovirus	
acyclovir	Antiviral	400 mg PO tid or 500 mg IV tid	Viral prophylaxis when neutropenic	
Colony Stimulating Factors (CSF)				
sargramostim	CSF	500 mcg SQ qd	Neutropenia	Hematopoietic Growth Factor
oprelvekin	CSF	50 mcg/kg SQ qd	Thrombocytopenia	Questionable efficacy
filgrastim	CSF	5 mcg/kg SQ/IV qd	Neutropenia	Hematopoietic Growth Factor
erythropoietin	CSF	150-300 units SQ/IV three times per week	Anemia	Questionable use for radiation casualties
General Comments: In order to achieve the maximum clinical response, G-CSF or GM-CSF should be started within 24 to 72 hours subsequent to the exposure. This provides the opportunity for maximum recovery. Colony stimulating factor administration should continue daily to reach the desired effect of an absolute neutrophil count of 1.0 x 10^9/l. The predominant side effect noted with administration of G-CSF (filgrastim) is medullary bone pain, which may be observed shortly after initiation of G-CSF treatment, and again just before onset of neutrophil recovery from nadir. Granulocyte-colony stimulating factor may also exacerbate preexisting inflammatory conditions. The most noted side effects with administration of GM-CSF (sargramostim) are fever, nausea, fatigue, headache, bone pain, and myalgia. Both G-CSF and GM-CSF patients should be monitored for splenic enlargement and risk of splenic rupture.				
Antidiarrheal Agents				
loperamide	Antidiarrheal	4 mg PO then 2 mg after each unformed stool (maximum 16 mg qd)	Diarrhea	Rule out infectious cause first
diphenoxylate	Antidiarrheal	2 tablets PO qid or 10 ml PO qid	Diarrhea	Rule out infectious cause first
Gastric Acid "Neutralizers"				
aluminum hydroxide	Antacid	10 ml q 4-6 hrs as needed	Hyperacidity	
sucralfate	Cytoprotectant	1 gram PO qid	Erosive esophagitis/gastritis	Another indication is gastroesophageal reflux disorder
(Histamine Receptor Antagonists)				
omeprazole	Gastric acid pump inhibitor	20 mg PO qd	Erosive esophagitis/gastritis	Another indication is gastroesophageal reflux disorder
cimetidine	H2 Blocker	800 mg bid for erosive esophagitis and gastritis or 300 mg 3-4 times/day for antiulcer usage	Erosive esophagitis and gastritis	Parenteral doses for erosive esophagitis and gastritis unestablished
ranitidine	H2 Blocker	150 mg PO bid or 50 mg IV q 8 hrs	Erosive esophagitis/gastritis	
General Comments: The term "neutralizer" is used here in general sense to refer to agents that decrease the effects of gastric acid on the lining of the GI tract, even though the mechanism may be different. Aluminum hydroxide directly neutralizes the effect of gastric acid; sucralfate forms a sucrafate-albumin film that provides a barrier to diffusion of hydrogen ions and protects the lining of the gastrointestinal tract; omeprazole suppresses gastric acid secretion by specific inhibition of the H^+/K^+ ATPase enzyme system at the secretory surface of the gastric parietal cell; and ranitidine and cimetidine inhibit basal gastric acid secretions by reversibly inhibiting the action of histamine at the histamine H_2-receptors, including those on the gastric cells.				
Antiemetics				
prochlorperazine	Antiemetic	5-10 mg PO/IV/IM q 6 hrs	Nausea/Anxiety	
granisetron	Antiemetic	10 mcg/kg IV qd or 1 mg PO bid	Nausea/Vomiting	
promethazine	Antiemetic	12.5-50 mg PO/IM/PR q 4-6 hrs	Nausea	
metoclopramide	Antiemetic/ Prokinetic	10 mg PO/IM/IV qid	Nausea	
ondansetron	Antiemetic	8 mg IV q 6-8 hrs or 8 mg PO q 8-12 hrs	Nausea/Vomiting	

Table A-1. Medications (continued)

GENERIC NAME	CLASS	DOSE/ROUTE	INDICATION	NOTES
Analgesics				
meperidine	Opioid Analgesic	50-150 mg PO/IV/IM q 3-4 hrs	Pain/Rigor	Consider as premed for amphotericin B
hydromorphone	Opioid Analgesic	2-4 mg PO q 4-6 hrs or 1-2 mg IV/IM q 4-6 hrs	Pain	
morphine sulfate	Opioid Analgesic	0.1-0.2 mg/kg (up to 15 mg) SQ/IV/IM q 4 hrs	Pain	
oxycodone and acetaminophen	Opioid Analgesic	1-2 tablets PO q 4-6 hrs	Pain	
acetaminophen	Analgesic/ Antipyretic	650-1000 mg PO q 6 hrs	Pain/Fevers	Use as premed for amphotericin B and blood products
acetaminophen and codeine	Opioid Analgesic	1-2 tablets PO q 4 hrs	Pain	
Selective Gut Decontamination				
norfloxacin	Antibiotic	400 mg bid PO	Selective Gut Decontamination	
cotrimoxazole (trimethoprim-sulfamethoxazole)	Antibiotic	2 tablets (160/800 mg) q 8 hrs PO (total of 6 tablets qd)	Selective Gut Decontamination	
nystatin	Antifungal Agent	6×10^6 International Units/day	Selective Gut Decontamination	
General Comments: Antibiotics and antifungal agents can be used to reduce the colonization of intestinal mucosa by opportunistic pathogens. Total intestinal decontamination is difficult to achieve and it creates further vulnerability to colonization by antibiotic-resistant pathogens. However, selective decontamination with oral antibiotics has already been tested clinically and it offers promise for the management of mass casualties who have been exposed to midlethal radiation. The oral administration of specific antibiotics eliminates opportunistic pathogens but leaves intact the relatively benign intestinal flora. These benign flora increase resistance to colonization by occupying binding sites and creating an environment that is inhospitable to pathogens. This approach eliminates the need for elaborate methods of isolation.				
Antihistamines				
fexofenadine HCL	Antihistamine	60 mg PO bid	Allergies	Used for bone pain due to filgrastim
diphenhydramine	Antihistamine	25-50 mg PO/IV/IM q 4-6 hrs	Nausea/Allergies	Use as premed for amphotericin B and blood products
loratadine	Antihistamine	10 mg qd	Allergies/Urticaria	Relief of itching in CRS
Therapeutic Agents for Cutaneous Radiation Syndrome (CRS)				
Topical Steroids (mometasone is an example of a medium-strength corticosteroid shown to be successful)		Apply topically bid	Erythema, inflammation	Rx of manifest stage of CRS
Linoleic Acid		Apply topically qd	Skin Dryness	Rx of manifest stage of CRS
tretinoin		Apply topically qd	Keratoses	Rx of chronic stage of CRS; causes skin irritation, dryness
acitretin	Retinoid	25-50 mg qd with the main meal	Keratoses	Rx of chronic stage of CRS; multiple side effects, administered only with physician supervision
interferon gamma		50 mcg SQ 3 x per week for 18 months	Severe radiation fibrosis	Rx of chronic stage of CRS
pentoxifylline and Vitamin E		Pentoxifylline 400 mg PO tid and Vitamin E 300 mg PO qd for a minimum of 6 months	Radiation fibrosis	Rx of chronic stage of CRS
General Comments: Experience in the management of the manifest stage of CRS is limited to radiotherapy patients. The treatment modalities for the chronic stage of CRS were developed from treatment of clinical sequelae in victims of the Chernobyl incident and from treatment of clinical sequelae in therapeutic irradiation patients.				

Table A-1. Medications (continued)

GENERIC NAME	CLASS	DOSE/ROUTE	INDICATION	NOTES
Medications for Treating Internal Contamination				
Prussian blue (ferrihexacyano-ferrate [II])	Absorption Reducer and Mobilizing Agent	1 gm in 100-200 ml of water PO tid for several days	Rx for internal contamination with cesium, rubidium, and thallium	Most effective when given early after ingestion and serially thereafter
General comments: Not absorbed by the GI tract. Decreases the absorption of radionuclides into the GI tract and removes some radionuclides from the capillary bed surrounding the intestine and prevents their absorption.				
potassium iodide	Blocking Agent	130 mg PO followed by 130 mg qd x 7 days if indicated. This dose is for adults. Consult FDA recommended doses for infants and children.	Rx for internal contamination with iodine	Decreases the uptake of iodine in the thyroid gland
General Comments: If given within 30 minutes of exposure to iodine-131, potassium iodide prevents the uptake of iodine-131 by the thyroid gland. If given within the first 6 hours, the blocking effectiveness is 50 percent. At 24 hours, its blocking effect is zero. Potassium perchlorate (200 milligrams by mouth daily) may be given to individuals who are sensitive to iodine.				
strontium lactate	Blocking Agent	500 to 1,500 mg PO qd for several weeks	Rx for internal contamination with strontium-85 and strontium-90	Decreases uptake in bone and testes
propylthiouracil, methimazole, and potassium thiocyanate	Blocking Agents	propylthiouracil: 100 mg PO q 8 hrs for 8 days methimazole: 10 mg PO q 8 hrs for 2 days; reduced to 5 mg PO q 8 hrs for 6 days	Rx for internal contamination with iodine	
General Comments: Propylthiouracil, methimazole, and potassium thiocyanate increase the rate of excretion of iodine. However, the toxicity of these three drugs and their relative ineffectiveness make them less appealing than potassium iodide.				
ammonium chloride	Mobilizing Agent/De-mineralizing Agent	3 gm tid PO	Rx for internal contamination with strontium	
General Comments: Ammonium chloride mobilizes strontium from body tissues and, if given with calcium gluconate intravenously, causes a 40 percent to 75 percent decrease in body stores of strontium over a period of 3 to 6 days. The combined treatment is most effective if given early after strontium deposition, but some effectiveness is still demonstrated if given as late as 2 weeks after deposition.				
water		Force fluids	Rx for internal contamination with tritium	Isotopic Dilution
sodium bicarbonate		Slow IV infusion of bicarbonated physiological solution (250 ml at 14%)	Rx for internal contamination with uranium	Alkalinizes the urine and reduces the chance of ATN from uranium toxicity
dimercaprol (British Anti-Lewisite)		One ampule (300 mg) IM q 4 hrs for 3 days (first test for sensitivity with ¼ ampule)	Rx for internal contamination with polonium, mercury, arsenic, bismuth, and gold	Promotes excretion May cause toxicity
calcium gluconate		20% solution, 10 ml given IV qd or bid may be tried	Rx for internal contamination with radium	Displaces the radium
barium sulfate		100 gm BaSO4 in 250 ml of water	Rx for internal contamination with strontium and radium	Inhibits absorption
sodium alginate		10 gm in a large glass of water	Rx for internal contamination with calcium and barium	Inhibits absorption

Table A-1. Medications (continued)

GENERIC NAME	CLASS	DOSE/ROUTE	INDICATION	NOTES
D-Penicillamine	Chelation Agent	1 gm IV qd or 0.9 mg PO q 4-6 hrs	Rx for internal contamination with copper, polonium, lead, mercury, and gold	
CaEDTA	Chelation Agent	75 mg/kg/day in 250-500 ml in 5% glucose in water; Maximum total dose not to exceed 550 mg/kg	Primarily recom-mended Rx for lead	
General Comments: CaEDTA (calcium ethylenediaminetetraacetate) was used extensively in the past. Given IV or IM, it is associated with a lot of local pain at the injection site and significant side effects including GI upset, bone marrow depression, and nephrotoxicity.				
DTPA	Chelation Agent	1 gm CaDTPA in 500 ml 5% dextrose in water IV over 60 minutes or 1 gm (4 ml) in 6 ml of 5% dextrose in water by slow IV injection (1 minute).	FDA specifically recommends Rx for plutonium, americium, and curium	
General Comments: The chelator DTPA (diethylenetriaminepentaacetic acid), in the zinc or calcium salt state, forms stable soluble complexes with a large number of metal ions. When DTPA releases its calcium or zinc, it binds to soluble plutonium, americium, or curium and carries it to the kidneys where it is then excreted in the urine. No accumulation of DTPA occurs in tissues or specific organs. Calcium DTPA (CaDTPA) is approximately ten times more effective than ZnDTPA (zinc DTPA) for initial chelation of transuranics. Therefore, CaDTPA should be used whenever larger body burdens of transuranics are involved. DTPA has been shown to greatly reduce the uptake of absorbed Pu-239 if given within an hour of contamination. With repeated dosing, CaDTPA can deplete the body of zinc and, to a lesser extent, manganese. Zinc replacement therapy is recommended when repeated dosing is done due to loss of the body's zinc stores. The most effective dose schedules have not been determined, but as with other therapies, it is more effective the earlier it is given.				

LEGEND:

ATN	acute tubular necrosis	kg	kilogram
bid	twice a day	mcg	micrograms
CRS	cutaneous radiation syndrome	mg	milligram
CSF	colony-stimulating factor	ml	milliliter
FDA	Food and Drug Administration	PO	by mouth
G-CSF	granulocyte colony-stimulating factor	PR	by rectum
GI	gastrointestinal	q	every
gm	gram	qd	every day
GM-CSF	granulocyte-macrophage colony-stimulating factor	qid	four times a day
hrs	hours	Rx	treatment
IM	intramuscular	SQ	subcutaneous
IV	intravenous	tid	three times a day

Note: For technical reachback regarding the medication table, contact or go to the Armed Forces Radiobiology Research Institute and the Radiation Emergency Assistance Center/Training Sites/Oak Ridge Institute for Science and Education Web sites.

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Appendix B

Levels of Identification

CHEMICAL, BIOLOGICAL, RADIOLOGICAL, AND NUCLEAR LEVELS OF IDENTIFICATION

B-1. The new four CBRN levels of identification are—presumptive; field confirmatory; theater validation; and definitive. For more information on CBRN levels of identification, refer to ATP 3-11.37, ATP 4-02.84 and Technical Information Paper 64-003-0310. This appendix will only concentrate on the nuclear/radiological levels of identification descriptors.

Note. The forward deployable preventive medicine units have field confirmatory radiological capabilities.

B-2. The higher the level of identification completed on a nuclear/radiological hazard—the higher the confidence the commander has that a nuclear/radiological attack or incident has occurred. Samples may not require analysis at all four levels of identification. An example of this is a presumptively identified radiological sample sent directly to a theater validation laboratory. An overview of the levels of identification is provided in Figure B-1.

Note. Samples may not require analysis at all four levels of identification depending on the agent and the decisions and actions taken after identification.

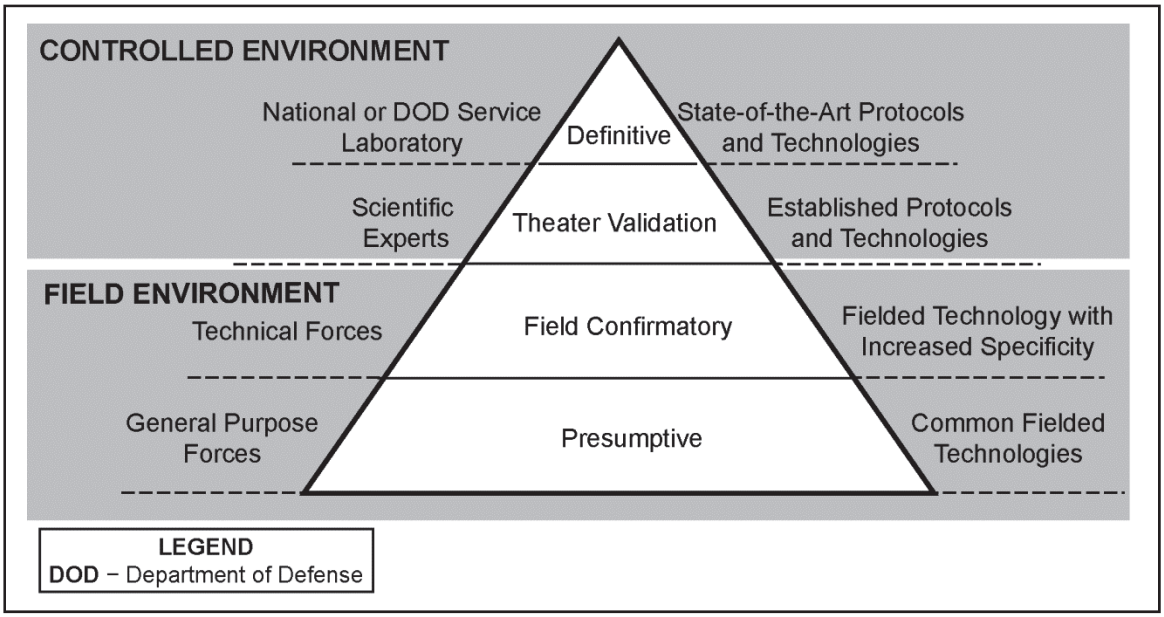

Figure B-1. Overview of the four CBRN levels of identification

Note. In Figure B-1, *Technical Forces* are those specially trained and equipped forces that possess a higher degree of CBRN detection and sampling capability compared to general purpose forces.

PRESUMPTIVE IDENTIFICATION

B-3. Definition: Presumptive Identification—The employment of technologies with limited specificity and sensitivity by general purpose forces in a field environment to determine the presence of a chemical, biological, radiological, and/or nuclear hazard with a low level of confidence and the degree of certainty necessary to support immediate tactical decisions.

B-4. Descriptor: Presumptive identification is obtained using commonly fielded devices/materials/ technologies available to general purpose forces to indicate/warn of the possible presence of a nuclear/radiological/target hazard. It provides important information to support warning decisions and actions, such as taking avoidance, protection, and decontamination measures. Table B-1 provides further presumptive identification descriptors.

Table B-1. Presumptive identification (radiological) descriptors

Who	General purpose forces.
Where	Field environment.
Capabilities	• Handheld RADIAC survey equipment for the detection of beta and gamma ionizing radiation. • Gamma and neutron dose detection and gamma dose rate detection.
Why	Determine presence/absence of radioactive hazards including toxic industrial radiologicals to support immediate tactical decision such as, avoidance, protection, or decontamination.
Example actions	• Assuming higher protection (shielding/distance). • Warning. • Reporting. • Further assessments/exploitation.
Legend: RADIAC Radiation Detection, Indication, and Computation	

FIELD CONFIRMATORY IDENTIFICATION

B-5. Definition: Field Confirmatory Identification—The employment of technologies with increased specificity and sensitivity by technical forces in a field environment to identify chemical, biological, radiological, and/or nuclear hazards with a moderate level of confidence and the degree of certainty necessary to support follow-on tactical decisions.

B-6. Descriptor: Field confirmatory identification is obtained using fielded devices/materials/ technologies available to specially trained personnel and units in a field environment that includes collection and analyses of samples to substantiate the presence and type of a nuclear/radiological/target hazard at a given area/location. Field confirmatory identification can be used to prove (or disprove) previous presumptive results. It results in higher confidence levels to support tactical decisions regarding avoidance, protection, and decontamination measures and immediate treatment. Table B-2 on page B-3 provides further field confirmatory identification descriptors.

Table B-2. Field confirmatory identification (radiological) descriptors

Field confirmatory	
Who	Technical forces.
Where	Field environment.
Additional capabilities not available at lower levels of identification	• Handheld RADIAC survey equipment for the detection of alpha ionizing radiation. • Handheld RADIAC survey equipment with increased sensitivity for the detection of beta and gamma ionizing radiation. • Handheld scintillation-based gamma spectrometry (low specificity and sensitivity). • Dose rate neutron and gamma detection devices. • Handheld survey equipment for the detection of nonionizing radiation.
Why	To substantiate the presence and type of radioactive hazards at a given area/location to support follow-on tactical decisions such as, avoidance, protection, or decontamination.
Example actions	• Reporting. • Further assessments/exploitation.
Legend: RADIAC Radiation Detection, Indication, and Computation	

THEATER VALIDATION IDENTIFICATION

B-7. Definition: Theater Validation Identification—The employment of multiple independent established protocols and technologies by scientific experts in the controlled environment of a fixed or mobile/transportable laboratory to characterize a chemical, biological, radiological, and/or nuclear hazard with a high level of confidence and the degree of certainty necessary to support operational-level decisions.

B-8. Descriptor: Using accepted quality assurance measures, theater validation quantifies the nuclear/radiological/target hazard. It provides additional critical information to support timely and effective decisions regarding avoidance, protection, and decontamination measures, and medical prophylaxis and treatment for affected units and personnel. It can also support preliminary attribution to implicate or support trace analytics for the source of the identified nuclear/radiological material. Table B-3 provides further theater validation identification descriptors.

Table B-3. Theater validation identification (radiological) descriptors

Theater validation		
Who	Radiological	Scientific experts applying multiple independent established protocols and technologies.
Where	Radiological	Controlled environment, fixed or mobile laboratory with constant temperature and humidity controls; stable power supply.
Additional capabilities not available at lower levels of identification	Radiological	• Liquid scintillation counting. • Nonshielded semiconductor-based gamma spectrometry (high specificity and low sensitivity). • Low background (shielded) scintillation-based gamma spectrometry (low specificity and high sensitivity).
Why	Radiological	To support timely and effective operational-level decisions regarding avoidance, protection, and decontamination measures.
Example actions	Radiological	• Reporting. • Further technical assessments/exploitation.

DEFINITIVE IDENTIFICATION

B-9. Definition: Definitive Identification—The employment of multiple state-of-the-art independent established protocols and technologies by scientific experts in a nationally recognized laboratory to determine the unambiguous identity of a chemical, biological, radiological, and/or nuclear hazard with the highest level of confidence and degree of certainty necessary to support strategic-level decisions.

B-10. Descriptor: Definitive identification supports attribution to implicate or point to the source of the identified material. It uses the highest level quality assurance measures. Table B-4 provides further definitive identification descriptors.

Table B-4. Definitive identification (radiological) descriptors

Definitive		
Who	Radiological	Scientific experts using multiple independent, state-of-the-art established protocols and technologies.
Where	Radiological	National or Department of Defense Service laboratories.
Additional capabilities not available at lower levels of identification	Radiological	• Gas proportional counting. • Low background (shielded) semiconductor-based gamma spectrometry (high specificity and high sensitivity). • Alpha spectrometry. • Inductively coupled plasma mass spectrometry.
Why	Radiological	To support strategic-level decisions. To support attribution; to implicate or point to the source of the identified material.
Example actions	Radiological	• Reporting. • Further technical assessments/exploitation.

Appendix C

Treatment Briefs (Clinical Guidelines)

TREATMENT BRIEFS

C-1. Patient categories involving a range of radiation doses are briefly described in this appendix. Several patient categories (Levels r1 through r6) involve radiation alone and others describe patients receiving radiation in combination with trauma and/or burns. These descriptions are termed Treatment Briefs and are derived from the work of the Defense Medical Materiel Program Office. Table C-1 below lists the eight Treatment Briefs in accordance with dose range and combined injury, if applicable. In addition to the assumptions specifically provided in each Treatment Brief, the assumptions and background information found in this appendix are applied to all Treatment Briefs.

Table C-1. List of treatment briefs

Treatment briefs	
1	Radiation injury at 0 to 125 cGy with closed fracture of the upper extremity and elbow dislocation.
2	Treatment brief for radiation exposure r1/r2 (0.00 to 1.25 Gy) with 1st and 2nd degree burns (not involving genitalia or eyes).
3	Treatment brief for radiation injury at level r2 (0.7 to 1.25 Gy) without other physical injury.
4	Treatment brief for radiation injury at level r3 (1.25 to 3.0 Gy) without other physical injury.
5	Treatment brief for radiation exposure level r3/r4 (1.25 to 5.0 Gy) with nonoperative trauma (simple laceration).
6	Treatment brief for radiation injury at level r4 (3.0 to 5.0 Gy) without other physical injury.
7	Treatment brief for radiation injury at level r5 (5.0 to 8.0 Gy) without other physical injury.
8	Treatment brief for radiation injury at level r6 (8.0 to 15 Gy) without other physical injury.
Legend: cGy centigray Gy gray	

ROLES OF MEDICAL CARE

C-2. A basic characteristic of organizing a modern Military Health System is the distribution of medical resources and capabilities to facilities at various levels of command, diverse locations, and progressive capabilities, which are referred to as roles of care. Refer to JP 4-02 and FM 4-02 for more information on roles of medical care. As a general rule, no role will be bypassed except on grounds of medical urgency, efficiency, or expediency. The rationale for this rule is to ensure the stabilization/survivability of the patient through trauma management and far forward resuscitative surgery prior to movement between medical treatment facilities (Roles 1 through 3). The roles of medical care are described in the following paragraphs.

Role 1

C-3. The first medical care a Service member receives is provided at Role 1 (also referred to as unit-level medical care). This care is rendered by self-aid/buddy aid/combat lifesaver/combat medic/corpsmen/Air Force Medics/medical personnel. This role of care includes—

- Immediate lifesaving measures.
- Disease and nonbattle injury prevention.
- Combat and operational stress control.
- Patient location and acquisition (collection).
- Medical evacuation from supported units (point of injury or wounding, company aid posts, or casualty/patient collection points) to supporting medical treatment facilities.

C-4. Treatment is provided by designated combat medics or treatment squads. Major emphasis is placed on those measures necessary for the patient to RTD or to stabilize him and allow for his evacuation to the next role of care. These measures include maintaining the airway, stopping bleeding, preventing shock, protecting wounds, immobilizing fractures, and other emergency measures, as indicated.

C-5. Nonmedical personnel performing first-aid procedures assist the combat medic in his duties. First aid is administered by an individual (self-aid/buddy aid) and enhanced first aid is provided by the combat lifesavers.

C-6. Role 1 medical treatment is provided by the combat medic/corpsmen/Air Force medics or by the physician or the physician assistant in the battalion aid station (BAS). Treatment is as follows:

- Emergency medical treatment (immediate far forward care) consists of those lifesaving steps that do not require the knowledge and skills of a physician. The combat medic/corpsmen/Air Force medics is the first individual in the medical chain who makes medically substantiated decisions based on medical military occupational specialty-specific training.
- At the BAS, the physician and the physician assistant are trained and equipped to provide trauma management to the combat casualty. This element also conducts routine sick call when the tactical situation permits. Like elements provide this role of medical care at brigade and echelons above brigade in the U.S. Army.

Role 2

C-7. Role 2 medical care may include forward surgical resuscitation, defined as surgery that focuses on specific lifesaving practices. These practices include management of severe bleeding, airway compromise, life-threatening chest injuries, and preparation of casualties for evacuation. Based on the concept of the *golden hour* of trauma treatment, Role 2 would receive some, but not all, of the patients that are acutely injured in combat requiring expeditious surgery to save life or limb. Role 2 medical care will usually provide resuscitative level care and surgical interventions to improve patient chances for transport to Role 3. However, if it is possible to provide Role 3 care at the Role 2 facilities without jeopardizing the mission, then Role 3 care may be done on a case-by-case basis. This may include holding patients up to 72 hours.

Note. An Army forward surgical team will only hold patients for recovery, then move them to the supported medical company for evacuation.

Role 3

C-8. Role 3 medical care is the first role of care at which patients are admitted into a hospital for medical treatment within the theater of operations. Patients that cannot receive definitive care and RTD within the time allocated by the theater medical evacuation policy are stabilized and evacuated out of the theater. Typical Role 3 facilities are combat support hospitals and USAF air transportable general hospitals.

Role 4

C-9. Role 4 medical care is found in Continental United States-base hospitals and other safe havens. Mobilization requires expansion of military hospital capacities and the inclusion of Department of Veterans Affairs and civilian hospital beds in the National Disaster Medical System to meet the increased demands created by the evacuation of patients from the area of operations. The support-base hospitals represent the most definitive medical care available within the Military Health System.

TECHNICAL REACHBACK

C-10. Technical reachback is the capability to contact technical subject-matter-experts when an issue exceeds the on-scene subject-matter-experts' capability. Reachback should be conducted using established unit protocols. Many of the reachback resources listed in Table C-2 have other primary missions.

Table C-2. Technical reachback points of contact

Organization	*Contact information*
Armed Forces Radiobiology Research Institute	1-301-295-0530 (24 hours)
Radiation Emergency Assistance Center	1-865 576-1005 (24 hours)
Defense Threat Reduction Agency	1-877-240-1187 or 1-703-767-2000
National Response Center	1-800-424-8802
United States Air Force Environment, Safety, and Occupational Health (ESOH) Service Center	1-703-697-9297
United States Army Public Health Command	1-410-436-4375 (24 hours)
20th Support Command	1-410-436-6200
Centers for Disease Control and Prevention Emergency Operations Center	1-770-488-7100

COMBINED INJURY

C-11. Combined injuries include thermal burn/blast trauma/radiation injuries. Human data sets regarding treatment of radiation combined injuries are scarce. General descriptions of trauma and burns assumed in the combined injury are provided below.

Nonoperative Blast Trauma

C-12. Examples include concussion (without intracranial hemorrhage), simple lacerations, closed fractures, ligamental injuries, and simple pneumothorax.

Operative Blast Trauma

C-13. Examples include open fractures, major lacerations, and hemopneumothorax.

Burns

C-14. Burns are classified on the basis of the depth of the injury as follows:

- Superficial or partial skin thickness burns are painful lesions which affect only the epidermis. These burns will heal readily if treated appropriately.
- Deep or full-thickness burns are burns that require extensive resuscitation and surgical intervention. They involve the full thickness of the skin and usually result in healing by scarring which causes contractions and loss of function.

C-15. All burns (including white phosphorus) will be treated with moist dressings and/or absorbent gel-type dressing materiel and antibacterial agents. This is due to the removal of cupric sulfate from the world market. The below percentages of BSA are approximations.

- Mild Burns: 1st degree—1 to 100 percent BSA; 2nd degree—1 to 15 percent BSA; 3rd degree—1 to 5 percent BSA.
- Moderate Burns: 2nd degree—16 to 30 percent BSA; 3rd degree—6 to 15 percent BSA.
- Severe Burns: 2nd degree— >30 percent BSA; 3rd degree—20 percent BSA.

WOUND CLOSURE

C-16. All Role 2 medical care operative procedures for trauma will be left open (irrigated, debrided, packed, and dressed only). An exception includes patients exposed to radiation with operative trauma. Wounds that are left open and allowed to heal by secondary intention will serve as a potentially fatal nidus

of infection in the radiologically injured patient. Wound healing is markedly compromised within hours of radiation injury. If at all possible, wounds should be closed primarily as soon as possible. Extensive debridement of wounds may be necessary in order to allow this closure.

C-17. Traditionally, combat wounds are not closed primarily due to the high level of contamination, devitalized tissue, and the subsequent morbidity and mortality of the closed-space contamination. In the case of the radiation/combined injury patient, aggressive therapy will be required to allow survival. The decision to amputate an extremity that in ordinary circumstances would be salvageable will rest with the surgeon in the first two days following the combined injury. No studies are available regarding the use of aggressive marrow resuscitation as described for the physically wounded patient.

C-18. All surgical procedures should be accomplished within 36 to 48 hours of radiation injury. However, clinical judgment may allow for surgery beyond this window in cases of low dose exposure, as wound healing will not necessarily be impaired. If surgery cannot be completed at far-forward locations, patients with moderate injury will need early evacuation to a medical treatment facility where surgical capabilities are immediately available.

RETURN TO SURGERY

C-19. If not evacuated within 72 hours, there will be a percentage of patients that will require a return to surgery. If there is radiation exposure, the return to surgery must be anticipated within 36 to 48 hours postirradiation.

PSYCHOLOGICAL EFFECTS CASUALTIES

C-20. Psychological and related COSR casualties associated with nuclear warfare information can be found in Chapter 6.

DECONTAMINATION

C-21. Not all casualties exposed to radiation will be contaminated. A quick survey of casualties with a RADIAC meter can determine if contamination is present. Decontamination is highly desirable prior to treatment of all casualties contaminated with radioactivity. Decontamination consists of removal of uniforms/clothes, washing the casualty with soap and water, and washing personal items with soap and water. See Chapter 4 of this manual, FM 3-11.5/MCWP 3-37.3/NTTP 3-11.26/AFTTP(I) 3-2.60, and FM 4-02.7/MCRP 4-11.1F/NTTP 4-02.7/AFTTP 3-42.3 for more information on patient decontamination.

INCIDENCE RATES

C-22. The Treatment Briefs assume that 100 percent of the force exposed to radiation will eventually enter the medical system. Therefore, the statistics in the Treatment Briefs for the incidence of symptoms, for example, nausea and vomiting, is based on doctrine that considers the total population exposed. The percentages for providing treatment, determining evacuation, and RTD are planning estimates. The mortality rates used for patient conditions are sequential and represent estimates of *middle of the road* patient expectations. Thus, 50 percent mortality at Role 1, with 50 percent mortality at Role 2, and 50 percent mortality at Role 3, may result in 88 percent mortality and 12 percent salvage rate for in-theater care.

BLOOD PRODUCTS

C-23. Blood products should be irradiated for nuclear casualties exposed to radiation levels of 300 cGy or greater and requiring transfusions. Blood products provided to radiation casualties should be irradiated at a dose of 2000 cGy prior to administration to diminish incidence of transfusion-related graft-versus-host diseases.

C-24. Irradiated blood products may not be available at Roles 2 and 3. Group O blood-packed cells and platelets may be available at Role 3. The Armed Services Blood Program Office's planning factor of 4 units per wounded in action/nonbattle injury casualty is intended for the entire continuum of care and not

identified on role of care. The need for blood products may exceed this planning factor during a nuclear and radiological incident. Additional amount will be necessary to treat burns, trauma, and radiation injuries (either single or as a combined injuries).

C-25. Pathogen Reduction Technology is scheduled to be approved for use in 2015. Pathogen reduction is a method where infectious pathogens in blood are inactivated when added with riboflavin and irradiated with ultraviolet light. Pathogen reduction inactivates donor white blood cells preventing the incidence of graft-versus-host diseases. When approved, pathogen reduction may be used in place of irradiation at Roles 2 and 3.

C-26. Irradiated blood products may likely be in short supply during a nuclear warfare or radiation incident and might be nonexistent within theater medical supply system.

TETANUS

C-27. Tetanus toxoid usage may be high. By definition, traumatic wounds are usually considered to be *dirty* wounds requiring consideration for tetanus prophylaxis. Although routine tetanus boosters should be administered every 10 years, traumatic wounds may require an emergency booster if 5 or more years have elapsed since the patient's last booster dose. Tetanus toxoid administration should be considered in cases where the dose interval cannot be determined (for example, no access to medical records, unconscious patients). Patients should receive tetanus toxoid booster at the point where they receive their in-theater surgical care, at Role 3, or at a point prior to transport out of theater. Tetanus toxoid may not be available at Role 2. It is assumed anyone deploying may have had at least one tetanus immunization in their lifetime. Up to a 72 hour delay between Role 2 and Role 3 should not present a risk of tetanus to previously immunized individuals.

NUTRITION AND DIET

C-28. Unless otherwise stated in the briefs—

- Intensive care unit patients may be given nothing by mouth. Special diets may be specified.
- Intermediate care ward (ICW) patients may advance to regular diet as tolerated.
- Minimal care ward (MCW) patients may advance to regular diet as tolerated.

TREATMENT BRIEFS (#1 - #8)

C-29. The Treatment Briefs are not designed or intended as medical protocols. Physicians and other medical staff may find much of the information in this appendix helpful as quick reference material for treatment of radiation casualties.

TREATMENT BRIEF (#1) FOR RADIATION INJURY AT 0 TO 125 CGY WITH CLOSED FRACTURE OF THE UPPER EXTREMITY AND ELBOW DISLOCATION

Classification

C-30. Radiological.

Exposure

C-31. Improvised nuclear device.

Signs and Symptoms

C-32. Patients exposed to 0 to 125 cGy of radiation with a closed fracture of the upper extremity and dislocation of the elbow may present with stable vital signs, severe pain in the upper extremity, no significant hemorrhage, and moderate deformity of the elbow. Patient may be alert and oriented. Radiation effects may include apprehension and agitation with mild headache. Five to thirty percent of patients may experience nausea and vomiting.

TREATMENT SUMMARY

C-33. Ninety percent of patients may require placing the arm in a posterior plaster long arm splint and sling; ten percent may have open reduction with possible fixation of fracture with plates and screws/K-wires; further definitive stabilization may be required at higher level with ten percent requiring fasciotomy of forearm, and under axillary block, application of long arm splint, and antibiotics; antiemetics may be administered to decrease vomiting; and fifty percent may require intramuscular (IM)/IV morphine with 100 percent requiring IV fluids.

Combat Medic/Corpsmen/Air Force Medic

C-34. Five to 30 percent of patients exposed to 0 to 125 cGy of radiation with a closed fracture of the upper extremity and dislocation of the elbow may receive antiemetics to decrease vomiting. Fifty percent of patients may be ambulatory. Fifty percent of patients may be litter borne and require the administration of morphine (IM). Injured extremities should be treated and patients reassured. One hundred percent of these casualties may be transported in the routine evacuation category. Radiation does not contribute to mortality at this level.

Battalion Aid Station

C-35. Thirty percent of patients exposed to 0 to 125 cGy of radiation with a closed fracture of the upper extremity and dislocation of the elbow may receive antiemetics (promethazine) (by mouth) to decrease vomiting. Fifty percent of patients may be ambulatory. Fifty percent of patients may be litter borne and require the administration of morphine (IM). Fifty percent of the casualties may require lactated ringer's IV solution. Injured extremities may be treated and patients reassured. One hundred percent of these casualties may be transported in the routine evacuation category. Radiation does not contribute to morbidity at this level.

Forward Resuscitative Care

C-36. Thirty percent of patients exposed to 0-125 cGy of radiation with a closed fracture of the upper extremity and dislocation of the elbow may receive antiemetics (promethazine) (by mouth) to decrease vomiting. Fifty percent of patients may be ambulatory. Fifty percent of patients may be litterborne. Eighty percent of patients may require the administration of lactated ringer's IV solution. Ten percent of patients may require axillary block and fasciotomy and/or attempted reduction for compartment syndrome and vascular compromise. Injured extremities may be treated and patients reassured. One hundred percent of these casualties may be transported in the routine evacuation category. Radiation may contribute to morbidity at this level.

Theater Hospital Care

C-37. Thirty percent of patients exposed to 0 to 125 cGy of radiation with a closed fracture of the upper extremity and dislocation of the elbow may require antiemetics (promethazine) (by mouth). Fifty percent of patients may be ambulatory and fifty percent litterborne. Fifty percent may require morphine sulfate (morphine) (IM/IV). Ninety percent may require affected arm in posterior plaster long arm splint and sling. Radiation may contribute to morbidity at this level.

Operating Room

C-38. Ten percent of patients may require admission to the operating room and may have open reduction with possible fixation of fracture with plates and screws/K-wires. Further definitive stabilization may be required at higher role of care. Fasciotomy of the forearm and application of long arm splint (under axillary block) may be required for 100 percent of these patients. The administration of antibiotic (ciprofloxacin) by IV may be required for 100 percent of these patients.

Intensive Care Ward

C-39. One hundred percent of patients from operating room may require lactated ringer's IV solution and vital signs check to include—

- Administer morphine (IM/IV).
- Elevate the affected limb.
- Perform neurological and circulatory checks using Doppler.
- Change dressings.
- Place patients in reverse isolation.
- Transport patients in the priority evacuation category by air.

TREATMENT BRIEF (#2) FOR RADIATION EXPOSURE R1/R2 (0.0 TO 1.25 GY) WITH 1ST & 2ND DEGREE BURNS (NOT INVOLVING GENITALIA OR EYES)

Classification

C-40. Radiation.

Routes of Exposure

C-41. Ionizing radiation and fallout exposure.

Signs and Symptoms

C-42. The severity of signs and symptoms of radiation sickness depend on the amount of radiation absorbed. The amount absorbed is dependent on the strength of the radiated energy, the distance between the casualty and the source, and the amount of time exposed. The initial signs and symptoms for a person who has absorbed mild levels of acute radiation (doses of 0.0 to 1.25 Gy) can range from nothing to mild nausea and headache, up to nausea and vomiting with an onset time ranging from 3 to 6 hours. Other signs and symptoms may include fever and anxiety. The amount of time between exposure and the onset of nausea and vomiting can serve as a relatively reliable indicator of how much radiation a person has absorbed. After the initial onset of signs and symptoms, a person with radiation sickness then experiences a brief period of a few days with no apparent illness. This period precedes the onset of signs and symptoms indicating more serious illness. Mild burns are classified as 1st degree (akin to sunburn) over 1 to 100 percent of the body; 2nd degree over 1 to 15 percent of the body surface area; and 3rd degree over 1 to 5 percent of the BSA.

TREATMENT SUMMARY

C-43. All burns (including white phosphorus) are treated with moist dressings and/or absorbent gel dressing material and antibacterial agents. Treatment at Role 1 includes the cleaning and dressing of burns, administering pain medication, reassurance, and 100 percent routine ground transport to the BAS. Patients may be ambulatory with stable vital signs, alert and oriented but radiation effects can include apprehension and agitation with 5 to 30 percent affected with nausea and vomiting and mild headache. Pretreatment with oral antiemetics decreases vomiting. Treatment at the BAS includes all treatment in the Role 1 with the addition of lactated ringer's IV solution. Treatment at forward resuscitative care (FRC) includes all treatment available at Roles 1 and 2 as well as moist cool compresses, reassurance and counseling, and one percent receive oxygen treatment for carbon dioxide poisoning. Laboratory tests at this level include CBC with differential twice daily until transferred via routine ground or air transport to the theater hospital level. The ICW may receive 30 percent of the patients arriving at the theater hospital. Treatment may include IV fluids, CBC differentials twice daily, and routine transport out of the theater. The MCW may receive the bulk of patients with this condition. Treatment includes supportive care, oral fluids push, advanced diet, application of topical burn agents, and wound dressings. Laboratory tests include CBCs with differential twice daily. Routine air transport may be needed for 90 percent of patients with 10 percent of patients being returned to duty. Radiation does not contribute to mortality at this level.

Combat Medic/Corpsmen/Air Force Medics

C-44. After the cleaning and bandaging of burn patients, they may need reassurance, and 100 percent routine ground support to the BAS. The patients may present with stable vital signs, alert and oriented but anxious, apprehensive, and agitated. Symptoms may include nausea and vomiting (5 to 30 percent) and mild headache. Pretreatment with oral antiemetics may help to block nausea. The administration of pain medication may help to deal pain associated with the burns.

Battalion Aid Station

C-45. Patients at the BAS may have stable vital signs and may be alert and oriented but radiation effects can include apprehension and agitation. Along with mild headache, 5 to 30 percent may have nausea and vomiting. Treatment includes administration of lactated ringer's IV solution, reassurance, pain medications, and 5 to 30 percent may be needing antiemetics to combat the nausea and vomiting. Routine ground transport to the FRC level is indicated for 100 percent of patients.

Forward Resuscitative Care

C-46. Patients at the FRC may also be ambulatory, alert, and oriented but radiation effects can include apprehension and agitation. The percentage of nausea and vomiting remains at 5 to 30 percent with headaches being another symptom. Treatment may consist of lactated ringer's IV solution (1 liter), rest, antiemetics, and oxygen therapy for carbon dioxide poisoning (one percent), reassurance, and counseling with combat and operational stress control unit. Laboratory tests may include 100 percent draw of one blood specimen per patient for biodosimetry for radiation exposure documentation, 100 percent CBC with differential for lymphocyte count every 12 hours for prognosis until transferred. Routine ground transport for 100 percent to the higher role of care may be needed.

Theater Hospital

C-47. Patients at the theater hospital may be ambulatory, alert, and oriented with radiation exposure effects of apprehension and agitation. Nausea and vomiting may affect 5 to 30 percent, along with headaches. Treatment in triage may include emergency medical treatment, vital signs, and primary assessment. Laboratory tests may include 100 percent draw of one blood specimen per patient for biodosimetry for radiation exposure documentation. Patients with this level of exposure may be admitted to the MCW (70 percent) and the ICW (30 percent). Patients in ICW may receive CBCs with differential every 12 hours until evacuated by routine air transport. Patients admitted to MCW may receive supportive care, by mouth, fluids push, and advance diet. Laboratory tests may include CBC with differential for lymphocyte count every 12 hours. Wound treatment includes topical burn agents and wound dressing. At this exposure and injury it is expected that 10 percent may be returned to duty and 90 percent routine air evacuated out of theater.

TREATMENT BRIEF (#3) FOR RADIATION INJURY AT LEVEL R2 (0.7 TO 1.25 GY) WITHOUT OTHER PHYSICAL INJURY

Classification

C-48. Radiation.

Routes of Exposure

C-49. Ionizing radiation.

Signs and Symptoms

C-50. The severity of signs and symptoms of radiation sickness depend on the amount of radiation absorbed. The amount absorbed is dependent on the strength of the radiated energy, the distance between the casualty and the source, and the amount of time exposed. The initial signs and symptoms for a person who has absorbed mild levels of acute radiation (doses of 0.75 to 1.25 Gy) are nausea and vomiting within

3 to 5 hours. Other signs and symptoms may include fever, headache, and anxiety. The amount of time between exposure and the onset of nausea and vomiting can serve as a relatively reliable indicator of how much radiation a person has absorbed. After the initial onset of signs and symptoms, a person with radiation sickness then experiences a brief period of a few days with no apparent illness. This period precedes the onset of signs and symptoms indicating more serious illness.

TREATMENT SUMMARY

C-51. Only 10 percent of Service members exposed to this level of radiation may require hospitalization. Reassurance and counseling may be the primary treatment with pretreatment of oral antiemetics to help the 5 to 30 percent of Service members presenting with nausea and vomiting at Role 1. One half of the patients forwarded to the BAS may be returned to duty.

C-52. Oral pain medication may help with the 10 percent who complain of headaches at FRC and theater hospital with IV fluids and antiemetics for 60 percent of the Service members suffering nausea and vomiting at these levels. Radiation exposure documentation may require 100 percent of those Service members transferred to the FRC and theater hospital to have blood drawn for CBC with differential for lymphocyte. Expect 100 percent of patients with exposure to radiation of 0.75 to 1.25 Gy to be returned to duty.

Combat Medic/Corpsmen/Air Force Medics

C-53. Patients at this role of care may primarily need reassurance and 100 percent routine ground support to the BAS. The patients may present with stable vital signs, alert, and oriented but anxious. Symptoms may include nausea and vomiting (5 to 30 percent) and mild headache. Pretreatment with oral antiemetics may help to block nausea.

Battalion Aid Station

C-54. Patients at the BAS may have stable vital signs with the possible exception of mild tachycardia. They may be alert and oriented but may be anxious. Along with mild headache, 5 to 30 percent may have nausea and vomiting. Treatment includes reassurance, consultation with the combat and operational stress control unit, with 10 percent needing oral pain medications and 30 percent needing antiemetics. One half of the patients reporting to the BAS may be returned to duty, while the remaining 50 percent may be transferred to FRC or theater hospital for further care via routine ground transport. Further nonmedical radiation exposure must be limited.

Forward Resuscitative Care

C-55. Patients at the FRC may also be ambulatory, alert, oriented, and anxious. The percentage of nausea and vomiting increased to 15 to 60 percent with headaches. Treatment may consist of lactated ringer's IV solution (60 percent), rest, IV antiemetics (60 percent), reassurance, and counseling with combat and operational stress control unit. Laboratory tests may include 100 percent draw of one blood specimen per patient for biodosimetry for radiation exposure documentation, and 100 percent CBC with differential for lymphocyte count every 12 hours for 48 hours for prognosis. Expect 80 percent to be returned to duty with the remaining 20 percent transported routine ground to a higher role of care.

Theater Hospital

C-56. Patients at the theater hospital may be ambulatory, alert, oriented, and anxious. Nausea and vomiting may affect 5 to 10 percent along with headaches. Only 10 percent of casualties reporting to the BAS may ultimately reach theater hospitals. Treatment may include emergency medical treatment, vital signs, primary assessment with 10 percent requiring IV antiemetics. Laboratory tests may include 100 percent draw of one blood specimen per patient for biodosimetry for radiation exposure documentation. Patients with this level of exposure may be admitted to the MCW and require supportive care along with pushing fluids by mouth and advanced diet. Laboratory tests may include a serial CBC with differential for lymphocyte count every 12 hours for 48 hours. At this exposure it is expected that 100 percent may be returned to duty.

TREATMENT BRIEF (#4) FOR RADIATION INJURY AT LEVEL R3 (1.25 TO 3.0 GY) WITHOUT OTHER PHYSICAL INJURY

Classification

C-57. Radiation.

Routes of Exposure

C-58. Ionizing Radiation and fallout.

Signs and Symptoms

C-59. The severity of signs and symptoms of radiation sickness depend on the amount of radiation absorbed. The amount absorbed is dependent on the strength of the radiated energy, the distance between the casualty and the source, and the amount of time exposed. The initial signs and symptoms for a person who has absorbed a significant level of acute radiation (doses of 1.25 to 3.0 Gy) are nausea and vomiting within 2 to 3 hours. Other signs and symptoms may include fever, headache, and anxiety. The amount of time between exposure and the onset of nausea and vomiting can serve as a relatively reliable indicator of how much radiation a person has absorbed. After the initial onset of signs and symptoms, a person with radiation sickness then experiences a brief period of a few days with no apparent illness. This period precedes the onset of signs and symptoms indicating more serious illness.

TREATMENT SUMMARY

C-60. Service members exposed to doses of 1.25 to 3.0 Gy have received a significant level of radiation. Patients may be ambulatory, alert, oriented, and anxious. Their vital signs may range from stable to tachycardia, headache, 20 to 70 percent suffering from nausea and vomiting, and 25 to 60 percent may complain of mild to moderate fatigability and weakness. Pretreatment with antiemetics may help in decreasing vomiting. Treatment includes fluids, rest, antiemetics, reassurance, and counseling. No patients exposed to doses of 1.25 to 3.0 Gy may be returned to duty and 100 percent may be transferred to the theater hospital and admitted to the MCW. If untreated within 30 days, exposure to this dose of radiation may have a 5 percent mortality rate.

Combat Medic/Corpsmen/Air Force Medics

C-61. The patient that has been exposed to 1.25 to 3.0 Gy is considered a significant exposure. Vital signs may range from stable to tachycardia. Patient may be ambulatory, alert, oriented, and anxious. Signs and symptoms include mild headache, nausea and vomiting (20 to 70 percent), and mild to moderate fatigability and weakness (25 to 60 percent). Pretreatment with antiemetics may help reduce vomiting. Treatment may consist mainly of reassurance and routine group transport for 100 percent of exposed patients.

Battalion Aid Station

C-62. Patients at the BAS may have vital signs ranging from stable to tachycardia. They may be alert and oriented but may be anxious. Along with mild headache, 20 to 70 percent may have nausea and vomiting and 25 to 60 percent may suffer from mild to moderate fatigability and weakness. Treatment includes vital signs, lactated ringer's IV solution in 20 percent of patients, pain medication in 10 percent of patients, and oral antiemetics in 50 percent of patients. Further radiation exposure must be strictly limited to medical diagnostic procedures. Patient may be transported routine ground to the next role of care.

Forward Resuscitative Care

C-63. Patients at the FRC may be ambulatory with vital signs ranging from stable to tachycardia. If left untreated, patients exposed to this level of radiation occur a 5 percent mortality rate. Patients may be alert, oriented, but may be anxious. Signs and symptoms may include mild headache, nausea and vomiting (20 to 70 percent), and mild to moderate fatigability and weakness (25 to 60 percent). Pretreatment with antiemetics may help reduce vomiting. Treatment may include IV fluids (50 percent), rest, 70 percent oral

antiemetics, reassurance, and counseling. Laboratory tests may include CBC with differential for lymphocyte count every 12 hours for prognosis. Routine ground transport for 100 percent patients. Biodosimetry should be performed as soon as possible.

Theater Hospital Care

C-64. Patients at the theater hospital may be ambulatory with vital signs ranging from stable to tachycardia. If left untreated, patients exposed to this level of radiation occur a 5 percent mortality rate. Patients may be alert, oriented, but may be anxious. Signs and symptoms may include mild headache, nausea and vomiting (10 to 30 percent), and mild to moderate fatigability and weakness (25 to 60 percent). Pretreatment with antiemetics may help reduce vomiting. Treatment may include emergency medical treatment, vital signs, primary assessment, and oral antiemetics. For radiation exposure documentation, 100 percent of patients may require one blood draw specimen for biodosimetry. Laboratory tests may include CBC with differential for lymphocyte count every 12 hours. Consider cytokines (G-CSF 480 micrograms subcutaneous daily) in 10 percent of patients. Patient may be transported routine air transport with 100 percent being admitted to MCW.

TREATMENT BRIEF (#5) FOR RADIATION EXPOSURE R3/R4 (1.25- TO 5.0 GY) WITH NONOPERATIVE TRAUMA (SIMPLE LACERATION)

Classification

C-65. Radiation.

Routes of Exposure

C-66. Ionizing radiation and fallout exposure.

Signs and Symptoms

C-67. Nonoperative trauma, even a simple laceration combined with significant radiation exposure, increases the mortality and morbidity at this level of injury. The signs and symptoms of radiation sickness depend on the amount of radiation absorbed. The amount absorbed is dependent on the strength of the radiated energy, the distance between the casualty and the source, and the amount of time exposed. The initial signs and symptoms for a person who has absorbed moderate levels of acute radiation (doses of 1.25 to 5.0 Gy) can range from headache, mild nausea and headache to nausea and vomiting with an onset time ranging from 2 to 6 hours, onset of diarrhea within 6 hours. Other signs and symptoms may include fever and anxiety. The amount of time between exposure and the onset of nausea and vomiting can serve as a relatively reliable indicator of how much radiation a person has absorbed. Radiation effects at this level include apprehension and agitation and fatigue and weakness.

TREATMENT SUMMARY

C-68. Information regarding treatment of radiation combined injuries is scarce. Treatment may vary depending on the trauma injury. Patients with nonoperative trauma, along with this significant radiation exposure, may require wound management, lactated ringer's IV solution, pain management, reassurance, treatment with antiemetics, and routine ground transport to the next role of care.

C-69. Traditionally, combat wounds are not closed primarily due to the high level of contamination, devitalized tissue, and the subsequent morbidity and mortality of the closed-space contamination. However, in the case of radiation exposure, wounds should be closed as soon as possible as wound healing is markedly compromised within hours of a radiation injury. In the case of the radiation/combined injury patient, aggressive therapy may be required to allow survival. Extensive debridement of wounds may be necessary in order to allow wound closure.

Combat Medic/Corpsmen/Air Force Medics

C-70. After stabilizing and dressing all wounds, patients at this role of care may need reassurance, pain management (75 percent IM morphine), and 100 percent priority ground support to the BAS. Vital signs may be stable dependent upon the severity of laceration involved. The patients may be alert and oriented but anxious, apprehensive, and agitated. Roughly 75 percent of patients may be litterborne. Radiation exposure symptoms may include nausea and vomiting (50 to 90 percent), mild headache, and mild fatigability and weakness (25 to 60 percent). Pretreatment with oral antiemetics may decrease vomiting. Radiation does not contribute to mortality at this role of care.

Battalion Aid Station

C-71. Patients at the BAS may be alert and oriented but radiation effects can include apprehension and agitation. Vital signs may be stable dependent upon the severity of the laceration involved. Along with mild headache, 50 to 90 percent may have nausea and vomiting, and 25 to 60 percent may complain of mild fatigability and weakness. Treatment includes administration of lactated ringer's IV solution (90 percent), reassurance, pain management (100 percent IM morphine) and 90 percent needing by mouth/IV antiemetics. Further exposure may be strictly limited to medical diagnostic procedures. Routine transport for 100 percent is recommended to the next role of care.

Forward Resuscitative Care

C-72. Patients presenting at the FRC are considered to have received a significant and potentially lethal radiation exposure. Patients may be alert, cooperative, and oriented, but radiation effects can include apprehension and agitation. Along with headache, the percentage of nausea and vomiting ranges from 50 to 90 percent and mild fatigability and weakness from 25 to 60 percent. Treatment at this role of care may include IM/IV morphine for pain management and lactated ringer's IV solution (100 percent), rest, by mouth antiemetics (90 percent), x-ray, neurovascular check, and 100 percent routine ground transport to the theater hospital. Complete blood count with differential twice daily until transferred. This level of radiation exposure, combine with the laceration, does contribute to an increase in the morbidity and mortality rates.

Theater Hospital Care

C-73. Radiation at the theater hospital, combined with trauma, markedly contributes to mortality and morbidity due to immunosuppression. Patients are considered to have received a significant and potentially lethal radiation exposure. Radiation effects for patients (alert and oriented with apprehension and agitation) may include nausea and vomiting (50 to 90 percent), mild headaches, and mild fatigability and weakness (25 to 60 percent). Treatment at triage may include emergency medical treatment, vital signs, primary assessment, lactated ringer's IV solution, 75 percent IM/IV morphine, wound management, and CBC with differential for biodosimetry for radiation exposure prognosis. Wounds may be closed as soon as possible as wound healing is markedly compromised within hours of a radiation injury. In the case of the radiation/combined injury patient, aggressive therapy may be required to allow survival. Extensive debridement of wounds may be necessary in order to allow wound closure.

Intermediate Care Ward

C-74. One hundred percent of patients arriving at Role 3 may be admitted to the ICW. Treatment includes vital signs, lactated ringer's IV solution (100 percent), IV antibiotics (10 percent), pain medications (IM/IV morphine), wound dressing, supportive care, and reverse isolation. Patients admitted to ICW suffer 10 percent early mortality due to combination of the laceration and high-dose radiation. Ninety percent are air transported (priority) out of theater.

TREATMENT BRIEF (#6) FOR RADIATION INJURY AT LEVEL R4 (3.0 TO 5.0 GY) WITHOUT OTHER PHYSICAL INJURY

Classification

C-75. Radiation.

Routes of Exposure

C-76. Ionizing radiation and fallout exposure.

Signs and Symptoms

C-77. The severity of signs and symptoms of radiation sickness depend on the amount of radiation absorbed. The amount absorbed is dependent on the strength of the radiated energy, the distance between the casualty and the source, and the amount of time exposed. The initial signs and symptoms for a person who has absorbed dangerous levels of acute radiation (doses of 3.0 to 5.0 Gy) are onset of nausea and vomiting within 2 hours and onset of diarrhea within 2 to 6 hours. Other signs and symptoms may include fever, headache, and anxiety. The amount of time between exposure and the onset of nausea and vomiting can serve as a relatively reliable indicator of how much radiation a person has absorbed. After the initial onset of signs and symptoms, a person with radiation sickness then experiences a brief period with no apparent illness. This period precedes the onset of signs and symptoms indicating more serious illness.

TREATMENT SUMMARY

C-78. Patients who have received a radiation exposure ranging from 3.0 Gy to 5.0 Gy are considered to have received a dangerous level of exposure. If left untreated, the mortality rate is 5 to 50 percent of patients exposed to this level. While ambulatory, vital signs may range from stable to tachycardic. Patients may be alert and oriented, but anxious. Nausea and vomiting may affect 50 to 90 percent and 60 to 90 percent may be suffering from fatigability and weakness. At Role 1, treatment may consist of recording vital signs, as well as pretreatment of oral antiemetics to help decrease vomiting, and 100 percent requiring routine ground transport to the next higher role of care. At the BAS, treatment may include taking of vital signs with 80 percent requiring lactated ringer's IV solution and 90 percent requiring oral antiemetics. No further radiation exposure is allowable and 100 percent of patients reporting to this role of care may be transported routine ground to the next higher role of care. At the FRC, treatment may include rest, 100 percent receiving lactated ringer's IV solution, and 25 percent requiring electrolyte replacement once daily for two days. Other medication may include antiemetics for 90 percent with an equal split of one half being administered orally and the remaining administered intravenously. Theater hospital treatment may comprise of any emergency medical treatment required, along with 60 percent of patients requiring antiemetics (30 percent by mouth and 30 percent IV), and 100 percent are to have one blood specimen drawn for biodosimetry for radiation exposure documentation. A majority (90 percent) of patients may be admitted to the MCW while 10 percent may be admitted to the ICW. Patients may need fluids, antiemetics, and electrolyte replacement. Patients admitted to ICW may require priority air transport.

Combat Medic/Corpsmen/Air Force Medics

C-79. Treatment may consist of recording vital signs as well as pretreatment of oral antiemetics to help to decrease vomiting and 100 percent requiring routine ground transport to the next higher role of care.

Battalion Aid Station

C-80. Treatment may include taking of vital signs with 80 percent requiring lactated ringer's IV solution and 90 percent requiring oral antiemetics. Further radiation exposure is ill-advised. One hundred percent of patients reporting to this role of care may be transported by routine ground to the next higher role of care.

Forward Resuscitative Care

C-81. Treatment may include rest, 100 percent receiving lactated ringer's IV solution, and 25 percent requiring electrolyte replacement once daily for two days. Other medication may include antiemetics (90 percent) with an equal split of one half being administered orally and the remaining administered intravenously.

Theater Hospital Care

C-82. Theater Hospital treatment may comprise of any emergency medical treatment required, along with 60 percent of patients requiring antiemetics (30 percent by mouth and 30 percent IV), and 100 percent are to have one blood specimen drawn for biodosimetry for radiation exposure documentation. A majority (90 percent) of patients may be admitted to the MCW while 10 percent may be admitted to the ICW.

Intermediate Care Ward

C-83. Ten percent of patients arriving at the theater hospital may be admitted to ICW. Treatment consists of recording vital signs four times a day, supportive care, 100 percent of these patients may require lactated ringer's IV solution (4 liters/day) with 60 percent of patients requiring antiemetics (30 percent by mouth and 30 percent IV), and clear liquids. Laboratory requirements are 100 percent electrolytes once daily and serial CBCs with differential every 12 hours daily, consider cytokines (G-CSF 480 micrograms subcutaneous daily) in 100 percent of patients, blood specimens drawn for HLA typing (three yellow-top tubes), and reverse isolation. Patients (100 percent) admitted to ICW require priority air transport. For more information regarding antibiotic prophylaxis/therapy, refer to Chapter 3.

Minimal Care Ward

C-84. Ninety percent of patients arriving at the theater hospital may be admitted to MCW. Treatment may include vital signs, supportive care, push by mouth fluids, advance diet, and reverse isolation. Laboratory requirements are serial CBCs with differential every 12 hours, consider cytokines (G-CSF 480 micrograms subcutaneous daily) in 100 percent of patients, and blood specimens drawn for HLA typing (three yellow-top tubes). Patients (100 percent) admitted to MCW may need routine air transport.

TREATMENT BRIEF (#7) FOR RADIATION INJURY AT LEVEL R5 (5.0 TO 8.0 GY) WITHOUT OTHER PHYSICAL INJURY

Classification

C-85. Radiation.

Routes of Exposure

C-86. Ionizing radiation and fallout exposure.

Signs and Symptoms

C-87. The severity of signs and symptoms of radiation sickness depend on the amount of radiation absorbed. The amount absorbed is dependent on the strength of the radiated energy, the distance between the casualty and the source, and the amount of time exposed. The initial signs and symptoms for a person who has absorbed critical levels of acute radiation (doses of 5.0 to 8.0 Gy) are onset of nausea and vomiting within one hour and onset of diarrhea within 1 to 8 hours. Other signs and symptoms may include fever, headache, and anxiety. The amount of time between exposure and the onset of nausea and vomiting can serve as a relatively reliable indicator of how much radiation a person has absorbed. After the initial onset of signs and symptoms, a person with radiation sickness then experiences a brief period with no apparent illness. This period precedes the onset of signs and symptoms indicating more serious illness.

Treatment Summary

C-88. Patients who have received a radiation exposure ranging from 5.0 Gy to 8.0 Gy are considered to have received a critical level of exposure. If left untreated for 30 days the mortality rate is 50 to 95 percent. While 50 percent of patients may be ambulatory, the remaining may be litter borne, vital signs include tachycardia. Patients may be alert and oriented but anxious. Nausea and vomiting may affect 80 to 100 percent and 90 to 100 percent may be suffering from extreme fatigability and weakness. Depending on how long it takes to move the patient up the levels of care, the onset of diarrhea may occur before reaching the theater hospital. At Role 1, treatment may consist of recording vital signs and 100 percent of patients may require urgent ground transport to the next higher role of care. Pretreatment with antiemetics for nausea and vomiting is ineffective. At the BAS treatment may include taking of vital signs with 100 percent requiring lactated ringer's IV solution and 100 percent requiring injectable antiemetics, and 10 percent may require pain medication. Patient should be isolated from communicable diseases, no further radiation exposure is allowed, and 30 percent of patients reporting to this role of care may be transported urgent ground to the next higher role of care with 70 percent receiving urgent air transport with overflight to the theater hospital if possible.

C-89. If at all possible, patients may skip the FRC and be transported directly to the theater hospital. However, patient treatment at the FRC may include lactated ringer's IV solution (100 percent), injectable antiemetics, reverse isolations, no further radiation exposure, and 100 percent urgent transport to the theater hospital. Theater hospital treatment may comprise of any emergency medical treatment required, vital signs, primary assessment, along with 60 percent of patients requiring antiemetics (30 percent by mouth and 30 percent IV), and 100 percent are to have one blood specimen drawn for biodosimetry for radiation exposure documentation. A majority (90 percent) of patients may be admitted to the MCW while 10 percent may be admitted to the ICW. Patients may need fluids, antiemetics, and electrolyte replacement. Patients admitted to ICW may require priority air transport.

Combat Medic/Corpsmen/Air Force Medics

C-90. Treatment at Role 1 is limited to urgent ground transport to the next higher role of care (BAS). This level of radiation is considered a critical exposure. Vital signs may include tachycardia. One half of the patients may be litterborne with all patients being alert and oriented but anxious. Nausea and vomiting may be present in 80 to 100 percent with 10 percent already affected by diarrhea. Moderate to extreme fatigability and weakness may be experienced by 90 to 100 percent. Pretreatment with oral antiemetics is ineffective.

Battalion Aid Station

C-91. Treatment at BAS includes recording base line vital signs, lactated ringer's IV solution (100 percent), injectable antiemetics for the nausea and vomiting, pain medication for 10 percent, isolation from communicable diseases, and no further radiation exposure. Urgent ground transport may be acceptable for 30 percent of patients but 70 percent need urgent air transport with overflight to the theater hospital if possible. If not treated within 30 days, there is a 50 to 95 percent mortality rate.

Forward Resuscitative Care

C-92. If possible, overflight of this role of care is recommended. Patients presenting for treatment at FRC may receive lactated ringer's IV solution, vital signs, injectable antiemetics, reverse isolation, no further exposure to radiation, and urgent transport to the theater hospital.

Theater Hospitalization Care

C-93. With this critical level of exposure, if untreated, the mortality rate is 50 to 95 percent. Patient may be air evacuated by day four. If unable to evacuate patients by day four, postexposure treatment may include antibiotic and antivirals along with surveillance cultures. In triage, patient's vital signs should be recorded, primary assessment made, and patient should be given any emergency medical treatment needed. All patients may be admitted to the ICW.

Intermediate Care Ward

C-94. All patients with this level of exposure may be admitted to this ward. Treatment may require vital signs four times daily, supportive care, lactated ringer's IV solution (4 liters/day), and 50 percent may be nothing by mouth, while the remaining may be limited to clear liquids. Laboratory tests may include CBCs with differential every 12 hours for the first four days, consider cytokines (G-SCF 480 micrograms subcutaneous daily) in 100 percent of patients. Patients require reverse isolation. Antidiarrheal medication may be needed by 10 percent. Draw blood specimens for HLA typing (three yellow-top tubes). Patients admitted to ICW may require urgent air transport to a Role 4.

TREATMENT BRIEF (#8) FOR RADIATION INJURY AT LEVEL R6 (8.0 TO 15 GY) WITHOUT OTHER PHYSICAL INJURY

Classification

C-95. Radiation.

Routes of Exposure

C-96. Ionizing radiation and fallout exposure.

Signs and Symptoms

C-97. The severity of signs and symptoms of radiation sickness depend on the amount of radiation absorbed. The amount absorbed is dependent on the strength of the radiated energy, the distance between the casualty and the source, and the amount of time exposed. The initial signs and symptoms for a person who has absorbed critical levels of acute radiation (doses of 8.0 to 15 Gy) are onset of nausea and vomiting within 3 to 10 minutes and onset of disorientation within the same time frame. Other signs and symptoms may include fever, headache, and anxiety. The amount of time between exposure and the onset of nausea and vomiting can serve as a relatively reliable indicator of how much radiation a person has absorbed.

TREATMENT SUMMARY

C-98. Exposure to 8.0 to 15 Gy of radiation is considered a critical exposure. Without prompt treatment, mortality rate will be 100 percent. Nausea and vomiting and extreme fatigability and weakness may affect 100 percent of patients. Treatment is limited to lactated ringer's IV solution, injectable antiemetics, and antidiarrheal medication to the 10 percent afflicted with diarrhea. No further radiation exposure is advised. Morphine pain medication may be required in 25 percent of the patients. Patients should be evacuated by urgent air transport within four days to a Role 4 treatment facility. If unable to evacuate patient, irradiated blood products (2000 cGy), antibiotics, antivirals, antifungals, and surveillance cultures may be needed.

Combat Medic/Corpsmen/Air Force Medics

C-99. Treatment at Role 1 is limited to urgent ground transport for 100 percent patients exposed to this level of radiation. Patients (100 percent) may be nonambulatory, disoriented, with immediate onset of extreme fatigability and weakness and nausea and vomiting, 10 percent may have diarrhea.

Battalion Aid Station

C-100. Treatment at this role of care consists of 100 percent lactated ringer's IV solution, 100 percent injectable antiemetics, and 25 percent IM/IV morphine. No further radiation exposure is advised. Recommend urgent ground transport to the next role of care for 100 percent of patients.

Forward Resuscitative Care

C-101. Mortality rate for this level of exposure is 100 percent if left untreated. Treatment for critical level of exposure at the FRC includes vital signs, 100 percent lactated ringer's IV solution, 100 percent

injectable antiemetics, 10 percent antidiarrheal medication, CBC with differential every 12 hours, attempt reverse isolation, and urgent ground transport for all patients.

Theater Hospitalization Care

C-102. One hundred percent of patients arriving at the theater hospital may be admitted to the ICW.

Intermediate Care Ward

C-103. At the ICW, treatment includes supportive care with 100 percent receiving lactated ringer's IV solution (4 liters/day), nothing by mouth 50 percent, clear liquids 50 percent, laboratory tests to include 100 percent serial CBCs with differential every 12 hours daily, and electrolytes every 24 hours. Consider cytokines (G-CSF 480 micrograms subcutaneous daily) in 100 percent of patients, 10 percent antidiarrheal medications, reverse isolation, and 100 percent drawn blood specimens for HLA typing (three yellow-top tubes, acid-citrate dextrose [keep refrigerated]). One hundred percent urgent air transport to a Role 4 treatment facility. If unable to evacuate by day four postexposure, blood products (preferably irradiated to 2000 cGy), antibiotics, antivirals, antifungals, and surveillance cultures may be needed. Almost all individuals who demonstrate obvious signs of damage to the CNS will have symptoms that include seizures, increased cranial pressure, mental confusion, and maybe coma. Without aggressive medical support and management, these patients succumb to a complex of gross CNS dysfunction leading to a relatively prompt and inevitable death.

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Appendix D

Radiation and Risk Communication

EFFECTIVE COMMUNICATION

D-1. Communicating effectively when *concerns are high and/or trust is low* is challenging for even the most skilled communicator. These challenges can be complicated even further when the topic to be addressed is radiation. For example, radiation cannot be seen, touched or smelled, lending further mystery and unfamiliarity. The public's overall lack of knowledge about scientific concepts—particularly radiation, only heightens their fear of its potential harmful effects. Although media coverage of major radiation events (for example, Chernobyl and Japan) has had some degree of influence over public perceptions, this coverage has often resulted from poor risk communication efforts on the part of the organization involved (for example, Three Mile Island). Communicating effectively about radiation issues related to military activities can be even more challenging, due in part to—

- Distrust of the military dating back several decades (for example, veteran exposures to Agent Orange during the Vietnam War).
- Classified nature of many military operations.
- Transiency of the military culture, which can further complicate realization of consistent and effective risk communication efforts related to radiation issues.
- Multiple communication channels and numerous chains of command.

D-2. In addition, today's U.S. population experiences and participates in real time as they unfold; demands nearly instantaneous access to information; and, at times, demands a voice in decisions they believe directly affect them. Although accurate, relevant, and timely information is a critical element of effective risk communication, it is rarely sufficient in decreasing a layperson's concerns about radiation when *concern is high and/or trust is low*. Good risk communication will not guarantee mission success, but poor risk communication will surely increase potential negative outcomes; such as—

- Decreased trust in the communicator, the organization, and Military Health System.
- Increased—
  - Skepticism.
  - Political scrutiny.
  - Negative media coverage.
  - Need for personnel, resources, and time to repeatedly explain and in some cases, defend the military's decisions associated with radiation issues.
  - Hostile court of public opinion.
  - Negative change in organizational reputation.
  - Legal action against the organization or individuals.
  - Adverse mission impacts.

RISK COMMUNICATION DEFINED

D-3. According to the National Research Council published document (Improving Risk Communication), the most widely accepted definition of risk communication is the exchange of information about the nature, magnitude, significance, and control of a risk. Although messages/information are critical elements, the most effective risk communication efforts combine words with actions and interactions that integrate and respect the stakeholder's perceptions of those receiving the information, so that these individuals can make informed decisions about a potential or real risk. Regardless of the definition used, the most effective risk communication efforts encompass what an organization does, as well as what it says indicating that most effective communication about risks is an ongoing process, not a single event.

D-4. This approach is vital in risk communication situations which typically involve some level of concern, conflict, disagreement, mistrust, skepticism, anger, misperception or other form of negative emotion. In these situations, the effectiveness of communications can play a critical role in how well information is received, and whether trust in the leadership and the organization can be maintained. Highly charged situations demand a higher level of communication efforts, often making routine information dissemination inadequate.

D-5. The success or failure of risk communication efforts is so critical to organizational success that it has become a standard field of academic study. Over the past 40 years, researchers have identified information tools and communication processes proven to be successful when *concern is high and/or trust is low*. One key finding that has proven successful to Army radiation and other public health issues is that two-way dialogue opportunities between leaders, experts, and nonexperts, coupled with clear and simple information, is the most effective communication response in these situations. So instead of being used only in response to a crisis, effective risk communication can be a preventive tool when integrated early, such as when issues—both real or perceived, are first identified; when people are overtly concerned, or when it is suspected they might be.

D-6. It is known that radiation issues have a high potential for being misunderstood or misperceived. Radiation experts within the Services must possess excellent risk communication skills in order to minimize the potential for negative outcomes to—

- Increase the likelihood that information will be received and understood by stakeholders.
- Help address the audience's communication needs, perceptions and/or outrage associated with a real or perceived radiation risk.
- Help build the trust necessary to communicate successfully.

D-7. Additional risk communication tools and references, to include tips on how to communicate more effectively with command, Service members, and others, can be found on the Risk and Crisis Communication Resources within Army Knowledge Online Web site (see reference section of this publication). Additional risk communication tools can also be found at the following Web sites (see reference section of this publication):

- Navy and Marine Corps Public Health Center.
- International Atomic Energy Commission.
- United States Department of Health and Human Services.
- Agency for Toxic Substances and Disease Registry.

GENERAL RISK COMMUNICATION PRINCIPLES

D-8. The overall principles related to effective risk communication have been identified through years of evidence-based research, and can provide the context in which productive risk communication can take place. Due to the recent explosion in risk communication research, many such lists are available; but the following principles speak to radiation risk communication, specifically the—

- Need for trust and credibility.
- Importance of perceptions.
- Nonstandard meaning and inferences of language.

The Need for Trust and Credibility

D-9. Research clearly indicates that trust, credibility, confidence, and respect are the foundation of productive risk discussions. Effective risk communication efforts cannot take place without mutual trust and respect, and mutual trust and respect cannot be built without successful risk communication efforts. According to a Centers for Disease Control and Prevention publication (Crisis and Emergency Risk Communication), the key elements necessary to build or strengthen trust and credibility within the organization are:

- Openness and transparency.
- Dedication and commitment.
- Expertise.

- Competence.
- Timeliness of information.
- Accountability.

D-10. Mutual trust and respect is particularly important because, in the absence of adequate knowledge and understanding about a risk, nonexperts tend to rely on trust in the institution or leadership to determine what is risky. Trust is so critical to effective risk communication (and vice versa) that it is worth emphasizing the need to consider trust-building actions over the long term. Examples of trust-building actions include:

- Demonstrating empathy when dealing with someone concerned about radiation.
- Dedicating efforts to ensure full understanding of nonexpert concerns or complaints.
- Offering open dialogue opportunities to reinforce information provided versus providing information alone.
- Helping receivers decide for themselves if a radiation risk warrants concern (versus telling them not to worry).
- Demonstrating transparent decision-making processes by describing the steps involved, the rationale behind decisions, experts consulted, and where possible, inviting nonexperts into the decision-making process.
- Increasing accountability (where possible) to reinforce transparency.
- Ensuring timeliness of information.
- Committing to follow-up actions.

Importance of Perceptions

D-11. Communicating technical information about a radiation issue by itself can be difficult enough, but risk communication efforts can be clouded even further by psychological factors that determine how a nonexpert evaluates risks. Perceptions of risk are reality for most people, and even though the scientific or medical data may indicate no risk or impact, the layperson makes a determination of risk based on an equally detailed and complex process. (See Table D-1.)

Table D-1. Perception of risks

Risks perceived to—	*Are perceived to be more risky than those that—*
Impact a specific group (for example, children; a specific Army unit).	Impact everyone equally.
Be under someone else's control (for example, irradiated foods).	Can be personally controlled (for example, radon).
Be unfamiliar (for example, depleted uranium; nuclear power).	Are more familiar (for example, medical x-rays).

D-12. Disregarding or downplaying stakeholder perceptions or concerns can have detrimental effects, to include—

- Increased outrage toward the organization.
- Loss of credibility.
- The need for a crisis communication response.
- Increased belief that protective actions will be ignored.

D-13. Dedicating efforts to better understand and integrate audience perceptions and knowledge about radiation issues, designing communication methods to increase familiarity, and engaging in frank risk discussions can positively impact those perceptions over time.

D-14. Consider and develop methods to identify and address community emotions or outrage related to the radiation issue. Communication research in recent years indicates that, until emotions are verbally acknowledged and addressed adequately, effective communication cannot take place. This means that, when outrage is high, the primary communication goal should be to decrease emotions or outrage. Until

that occurs, productive communication cannot take place. Understanding and addressing any outrage related to radiation issues is crucial in defining the most appropriate messages and communication approaches, and can help avoid a crisis situation. Unfortunately, social science research and the Army's own experience and history suggest this does not always happen. For example, when members of the U.S. armed forces serving in Iraq returned early for medical reasons, the Service members reported that their repeated requests to be tested for depleted uranium exposure were denied. Service member's concerns, suspicions, and outrage escalated significantly, ultimately resulting in extensive—

- Negative media coverage.
- Congressional scrutiny.
- Depleted uranium testing provided by a non-Army source.
- Public health team response.

D-15. The team's first action was to hold open discussion sessions with redeployed Service members and their Families, medical support staff, and unit leadership to address the outrage and obtain a fuller understanding of concerns. Only after this took place could Service members cognitively process information the team wanted to provide. Over time (between 3 to 5 months), Service member's concerns decreased because accurate, relevant, and timely information about depleted uranium exposure was provided, and their concerns were taken seriously.

Nonstandard Meaning and Inferences of Language

D-16. Scientific and medical experts rely heavily on technical terminology to represent specific ideas or concepts, such as—

- Health risks.
- Environmental risks.
- Hazard.
- Severity.
- Probability.

D-17. This is particularly true for radiation issues which can involve extremely complex terms (for example, *picocuries*- which describes a unit of radioactivity or *half-life*- which is associated with the rate of nuclear decay) and concepts that may be difficult for nonexperts to comprehend (for example, some forms of radiation can be stopped by clothing attire). Research clearly suggests, however, that in risk communication situations, the meaning of words is processed very differently by nonexperts. For example, is *below the standard* a good message? Or does it suggest that the work is substandard? When the risk issue involves highly complex terms or concepts, and *concern is high and/or trust is low*, nonexperts often infer the intent of the speaker or communicator (for example, the U.S. Armed Forces do not care about me or they would talk in more understandable language). This phenomenon further underscores the need for simple, consistent and clear information. The key points should include language that is succinct, memorable, and understandable (avoid jargon), and provide a balance between what the experts want the audience to remember with what will resonate with them. When possible, key messages should be pretested with members of the intended audience to ensure the choice of language is appropriate, and that syntax interpretation is the same.

BASIC RULES FOR EFFECTIVE RISK COMMUNICATION

D-18. The successful completion of risk communication is not self-explanatory or guaranteed because fact sheets are distributed or information is posted to a Web page. Risk communication effectiveness is often based on quantitative data (for example, the number of press releases or public meetings held), experience acquired in practice, and occasionally on nonexpert feedback. Although many summaries are in circulation that offer pointers, guidelines, and rules related to good risk communication skills, the rules below provide a good starting point for focusing radiation risk communication efforts.

Accept and Involve the Receiver of Risk Information as a Legitimate Partner

D-19. People expect the right to participate in decisions that affect their lives, especially when they believe a risk issue directly affects them. When people feel disenfranchised or that concerns have been ignored or discounted, they will take actions to ensure they are heard and engaged (through the media or through their politicians). Take nonexperts' outcry and concern seriously by—

- Listening actively.
- Acknowledging fears and concerns.
- Displaying a willingness for public involvement in decision-making at an early stage.
- Communicating clearly through channels preferred by those concerned.

Plan And Tailor Risk Communication Strategies

D-20. Different communication goals, audiences, and channels require different risk communication strategies. For example, workers who believe that radiation in the workplace is making them sick may respond more positively to one-on-one interactions, while other employees in the same building may respond positively to email updates. The most effective risk communication strategies are based on the needs and preferences of those directly impacted by the risk or who believe they are. These strategies include a combination of information dissemination and two-way discussions which are proactively updated at regular intervals and as the situation changes.

Listen to The Audience

D-21. To identify real concerns, a risk communicator must be willing to listen carefully to the audience regardless of how difficult it may be and integrate these concerns into the overall communication strategy. Opportunities for listening include—

- One-on-one interactions.
- Small-group meetings.
- Web-based surveys.
- Feedback links on the organization's homepage.
- Information fairs.
- Town hall meetings.

D-22. In order for risk communications to be successful, it is necessary to understand the range of available methods and choices to appropriately collect and measure audience feedback.

Be Honest, Frank, and Open

D-23. One of the mantras of public affairs training is that *bad news does not get better with age*. Communicating honestly, frankly, and openly can be difficult at times, but is necessary to demonstrate commitment to transparency, and over time, strengthen the most valuable assets of an effective risk communicator- public trust and credibility.

Coordinate and Collaborate With Other Credible Sources

D-24. Communication about risks are enhanced when accompanied by referrals to credible, neutral sources of information. Doing so provides recommended sources for nonexperts interested in learning more or in verifying the information. Determining the most appropriate credible sources will be issue- and site-dependent (national, state, local), but can be helpful in increasing awareness/understanding, and in reinforcing the Army's commitment to communication transparency.

Plan for Media Influence

D-25. Handling media interactions successfully is one of the strengths of public affairs officers. The media play a major role in transmitting risk information, whether through response to inquiries, during a crisis, or through interactions with media at town hall meetings. Media interactions require adequate preparation (with the public affairs officer); clear, consistent, and simple risk communication messages; trained media

spokespersons who possess the skills to deliver information effectively; background about the media outlet/ reporter; and when necessary, broader strategies to mitigate the potential impact of negative media coverage. For example, engaging with political leaders and key stakeholders (such as, special interest groups) prior to expected negative media coverage can minimize its impact.

Speak Clearly and With Compassion

D-26. Preparing to communicate requires as much or more attention and thought than the act of communicating. While it may be tempting to rely on technical language, acronyms, and jargon that is so familiar to radiation experts, doing so poses major barriers to effective risk communication. Abstract, complicated, unfeeling language can offend people, particularly when they are upset. Devote time and attention to the selected presentation method (for example, town hall meeting, small-group meeting) and content (provide bottom line upfront and avoid jargon), and balance what needs to be communicated versus what the audience wants. If possible, pretest messages or briefings to ensure clarity before presenting them.

CHARACTERISTICS OF EFFECTIVE RISK COMMUNICATORS

D-27. Effective risk communication is no easy task. No one is born knowing what to say, how to respond, or when to begin communicating. Becoming a skilled risk communicator requires among other things the willingness to—

- Seek training to hone skills and increase confidence to communicate successfully in situations where mistrust, skepticism, and scrutiny are high, and understanding or trust may be low.
- Commit to communicate more effectively based on what science tells us, and to integrate proven risk communication methods. Although a relatively new field of research, risk communication findings and recommendations are based on decades of academic research. Adopting proven risk communication methods when *concerns are high and/or trust is low* will ultimately support mission success.
- Consider the risks and benefits of not addressing concerns (perceptions) at the time they are identified and not sharing information when it becomes available.
- Acknowledge and explain bad news, inconsistencies, and uncertainties and benefits of a risk, regardless of how much work or discomfort it may involve. Waiting to release information to avoid media coverage, political scrutiny, increased concern, agency embarrassment, or increased work or stress for the staff and organization are not valid reasons to avoid communicating.
- Commit to communicate with integrity, humility, and a focus on strengthening or building trust. When concerns are high, the most effective communicators are those who are confident and credible, yet not condescending, and those who—
  - Honor agreements.
  - Demonstrate empathy.
  - Share the communication role with other experts.
  - Listen.
  - Provide ongoing opportunities for audience feedback to continually improve future risk communication efforts.
- Improve future risk communication efforts. Evaluating the effectiveness of risk communication efforts (through feedback mechanisms or meeting evaluations) will help strengthen social trust, demonstrate that communication improvement is important, and that public input to communication success is valued.

D-28. Service personnel who deal with radiation issues face some of the most challenging risk communication situations possible. Even one wrong word or poor response can adversely impact someone's perception of radiation risk, or hurt the organization's reputation, credibility, and the overall mission. Risk communication situations can and will be challenging. Adopting the proven tools and strategies discussed in this appendix and referencing available risk communication tools will lead to successful interactions and more effective communications about radiation risks. When done well, timely and effective risk communication can reduce stress; alleviate anxiety; strengthen Service member, family,

beneficiary, and public trust in support for the Military Health System mission; and help ensure that deployed forces focus their physical and mental abilities on mission accomplishment. Successful communication when *concern is high and/or trust is low* requires very specialized skills gained by practice and refined over time.

D-29. In conclusion, communicating complex radiation concepts can be very difficult- the presence of outrage further underscores the need for radiation experts who are highly skilled in risk communication; and for a command environment that supports a transparent, cyclical, and collaborative communication approach. Effective risk communication cannot take place without mutual trust and respect; and mutual trust and respect cannot be built without successful risk communication efforts. Risk communication principles can help increase audience understanding and decrease unnecessary concerns after an event, but the most effective approach is to adopt risk communication as a preventive tool. When integrated early (for example, when issues—both real or perceived are first identified, when people are overtly concerned, or when it is suspected they might be), risk communication tools can and will avert the need for crisis communication. Personnel who deal with radiation issues face some of the most challenging risk communication situations possible. But adopting the proven tools and strategies discussed in this appendix and referencing additional risk communication tools will increase audience understanding, reduce stress, and alleviate anxiety. This will also strengthen Service member, family, beneficiary, and public trust and support for the Military Health System mission; and help ensure that deployed forces can focus on mission accomplishment.

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Glossary

This glossary lists acronyms and terms with Army or joint definitions. This publication is not the proponent for any terms. The proponent publication for other terms is listed in parentheses after the definition.

SECTION I – ACRONYMS AND ABBREVIATIONS

AFI	Air Force instruction
AFMAN	Air Force manual
AFTTP	Air Force tactics, techniques, and procedures
ALARA	as low as reasonably achievable
ATP	Army techniques publication
BAS	battalion aid station
Bq	becquerel
BSA	body surface area
BUMEDINST	Bureau of Medicine and Surgery instruction
CAC	common access card
Ca-DTPA	calcium-diethylenetriaminepentaacetic acid
CBC	complete blood count
CBRN	chemical, biological, radiological, and nuclear
cGy	centigray
Ci	curie
CNS	central nervous system
COSR	combat and operational stress reaction
DIME	delayed, immediate, minimal, and expectant
DOD	Department of Defense
DODI	Department of Defense instruction
EMEDS	expeditionary medical support
EPR	Electron Paramagnetic Resonance
FDA	Food and Drug Administration
FM	field manual
FRC	forward resuscitative care
G-CSF	granulocyte colony-stimulating factor
GI	gastrointestinal
Gy	gray
HLA	human leukocyte antigen
ICW	intermediate care ward
IM	intramuscular
IV	intravenous
JP	joint publication
KI	potassium iodide

KT	kiloton
LD	lethal dose
LET	linear energy transfer
MCM	memorandum for the chairman
MCRP	Marine Corps reference publication
MCW	minimal care ward
mg	milligram
NATO	North Atlantic Treaty Organization
NAVMED P	Bureau of Medicine and Surgery publication
NAVSUP P	Naval Supply Systems Command publication
NBC	nuclear, biological, and chemical
NTRP	Navy technical reference publication
NTTP	Navy tactics, techniques, and procedures
OPNAVINST	Office of the Chief of Naval Operations instruction
QF	quality factor
rad	radiation absorbed dose
RADIAC	Radiation, Detection, Indication, and Computation
RED	radiological exposure device
RC	response category
RDD	radiological dispersal device
rem	roentgen equivalent in man
RTD	return to duty
SI	International System of Units
STANAG	Standardization Agreement
Sv	sievert
Td	Tetanus-Diptheria
Tdap	Tetanus-Diptheria-Pertussis
U.S.	United States
USAF	United States Air Force
USAMEDDC&S	United States Army Medical Department Center and School
USMC	United States Marine Corps
USN	United States Navy
Zn-DTPA	Zinc-diethylenetriaminepentaacetic acid

SECTION II – TERMS

acute radiation syndrome

An acute illness caused by irradiation of the body by a high dose of penetrating radiation in a very short period of time. Also called ARS. (JP 3-11)

centigray

A unit of absorbed dose of radiation (one centigray equals one rad). (JP 3-11)

decontamination

The process of making any person, object, or area safe by absorbing, destroying, neutralizing, making harmless, or removing chemical or biological agents, or by removing radioactive material clinging to or around it. (JP 3-11)

initial radiation

The radiation, essentially neutrons and gamma rays, resulting from a nuclear burst and emitted from the fireball within one minute after burst. (JP 3-11)

ionizing radiation

Particulate (alpha, beta, and neutron) and electromagnetic (x ray and gamma) radiation of sufficient energy to displace electrons from atoms, producing ions. (JP 3-11)

radiation dose

The total amount of ionizing radiation absorbed by material or tissues. (JP 3-11)

radiological dispersal device

An improvised assembly or process, other than a nuclear explosive device, designed to disseminate radioactive material in order to cause destruction, damage, or injury. Also called RDD. (JP 3-11)

radiological exposure device

A radioactive source placed to cause injury or death. Also called RED. (JP 3-11)

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