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TREATMENT OF NUCLEAR AND RADIOLOGICAL CASUALTIES

HEADQUARTERS, DEPARTMENTS OF THE ARMY, THE NAVY, AND THE AIR FORCE, AND COMMANDANT, MARINE CORPS

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HEADQUARTERS
DEPARTMENTS OF THE ARMY, THE
NAVY, AND THE AIR FORCE, AND
COMMANDANT, MARINE CORPS
Washington, DC 20 December 2001

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PREFACE

Purpose

This publication serves as a guide and a reference for trained members of the Armed Forces Medical Services and other medically qualified personnel on the recognition and treatment of nuclear and radiological casualties.

Scope

a. This publication—

(1) Classifies and describes potential nuclear and radiological threats and hazards.

(2) Describes the biological aspects of blast, thermal radiation, and ionizing radiation and its effects on organs and systems of the body.

(3) Describes procedures for first aid, medical diagnosing, treating, and management of nuclear and radiological casualties.

b. The material in this publication is applicable to both the nuclear battlefield and to other operations where a high- or low-level radiation hazard exists; this includes military support to United States (US) civilian agencies during weapons of mass destruction (WMD) consequence management operations.

c. 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), Ratification Draft; the Medical Management of Radiological Casualties Handbook, First Edition, and the recently approved Treatment Briefs.

d. The use of the term "level of care" in this publication is synonymous with "echelon of care" and "role of care." The term "echelon of care" is the old NATO term. The term "role of care" is the new NATO and American, British, Canadian, and Australian (ABCA) term.

Standardization Agreements

This manual is in consonance with NATO Standardization Agreements (STANAGs) and ABCA Quadripartite Standardization Agreements (QSTAGs):

NATO STANAG	ABCA QSTAG	TITLE
2068		Emergency War Surgery.
2083		Commanders' Guide on Nuclear Radiation Exposure of Groups, Edition 6.

NATO STANAG	ABCA QSTAG	TITLE
2461		NATO Handbook on the Medical Aspects of NBC Defensive Operations, AMedP-6(C). Volume I-Nuclear Ratification Draft.
2473		Commanders' Guide on Low-Level Radiation (LLR) Exposure in Military Operations, Edition 1.
2475		Planning Guide for the Estimation of NBC Battle Casualties (Nuclear), AMedP-8 (A). Volume I.
	1263	Common Principles and Procedures for Critical Aspects of the Medical and Dental Treatment of Personnel.

Implementation Plan

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

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

b. Marine Corps. The Marine Corps will incorporate the procedures in this publication in US Marine Corps training and doctrinal publications as directed by the Commanding general, US Marine Corps Combat Development Command. Distribution is in accordance with Marine Corps Publication Distribution System.

c. Navy. The Navy will incorporate these procedures in US Navy training and doctrinal publications as directed by the Commander, Navy Warfare Development Command. Distribution is in accordance with MILSTRIP Desk Guide and NAVSOP Publication 409.

d. Air Force. The Air Force will validate and incorporate appropriate procedures in accordance with applicable governing directives. Distribution is in accordance with AFI 33-360.

e. Coast Guard. The Coast Guard will validate and refer to appropriate procedures when applicable. No material contained herein should conflict with Coast Guard regulations or other directives from higher authority, or supersede, or replace any order or directive issued by higher authority.

User Information

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

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

c. 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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Gender Statement

Unless this publication states otherwise, masculine nouns and pronouns do not refer exclusively to men.

Use of Trade Names/Trademarks

Use of trade names/trademarks in this publication is for illustrative purposes only. Their use does not constitute endorsement by the Department of Defense (DOD).

References

References listed should be consulted for details beyond the scope of this publication.

Acknowledgments

The Armed Forces Radiobiology Research Institute for allowing use of portions of the Medical Effects of Ionizing Radiation Course (CD-ROM).

The National Academy of Sciences for use of portions of Potential Radiation Exposure in Military Operations, Protecting the Soldier Before, During, and After, published 1999.

The National Council on Radiation Protection (NCRP) and Measurements for allowing use of portions of NCRP Report No. 65, *Management of Persons Accidentally Contaminated With Radionuclides,* 1979.

To RAND, working jointly with the Advisory Panel, for allowing use of portions of the *First Annual Report to The President and The Congress* of the *Advisory Panel To Assess Domestic Response Capabilities For Terrorism Involving Weapons of Mass Destruction, Part I. Assessing the Threat,* December 1999. Also, RAND is to be acknowledged for allowing use of portions of *A Review of the Scientific Literature As It Pertains to Gulf War Illnesses, Volume 7, Depleted Uranium,* 1999.

CHAPTER 1

INTRODUCTION

1-1. Purpose and Scope

a. This publication serves as a guide and a reference for trained members of the Armed Forces Medical Services on the recognition and treatment of nuclear warfare casualties and medical management of persons exposed to high and low-level radiation. 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 now effective, practical and possible, and must be part of US 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 US forces and civilians. The least likely threats are theater and strategic nuclear war (see Figure 1-1).

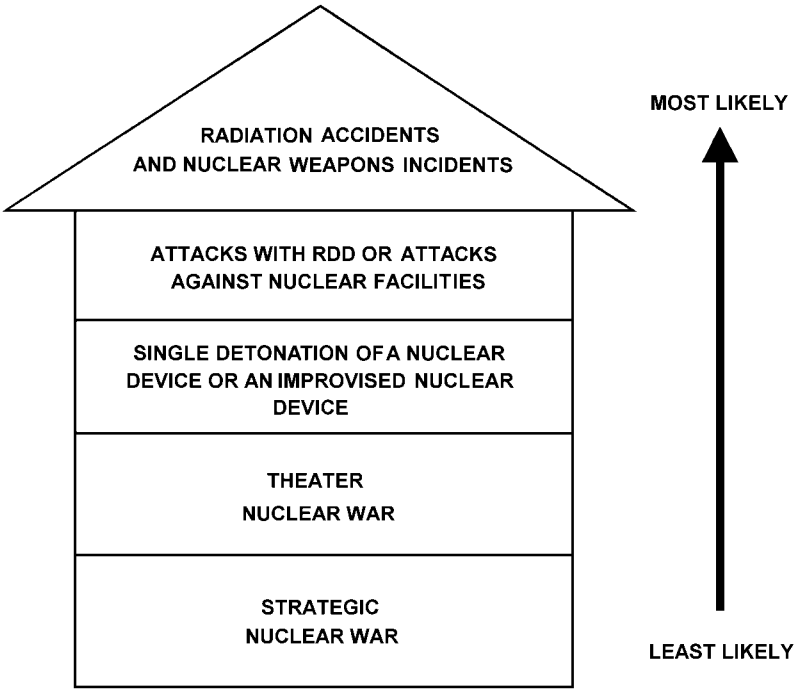


Figure 1-1. Likelihood of radiation threat.

b. Throughout the manual, both existing and the International System of Units (*systeme international d'unites*, abbreviated internationally as SI), are used to measure ionizing radiation. The

existing and new units of measurement are discussed in detail in Chapter 2. For comparison purposes, a radiation unit conversion table is shown below.

Table 1-1. Conversion Table

EXISTING UNITS					SI UNITS				
0.001	rem	=	1	mrem	= 0.01	mSv			
0.01	rem	=	10	mrem	= 0.1	mSv			
0.1	rem	=	100	mrem	= 1	mSv	=	0.001	Sv
1	rem	=	1,000	mrem	= 10	mSv	=	0.01	Sv
10	rem				= 100	mSv	=	0.1	Sv
100	rem				= 1,000	mSv	=	1	Sv
1000	rem						=	10	Sv
0.001	rad	=	1	mrad	= 0.01	mGy			
0.01	rad	=	10	mrad	= 0.1	mGy			
0.1	rad	=	100	mrad	= 1	mGy	=	0.001	Gy
1	rad	=	1,000	mrad	= 10	mGy	=	0.01	Gy
10	rad				= 100	mGy	=	0.1	Gy
100	rad				= 1,000	mGy	=	1	Gy
1000	rad						=	10	Gy
2.7×10^{-11}	Ci				= 1	Bq			
0.001	Ci	=	1	mCi	= 37	MBq			
1	Ci	=	1000	mCi	= 3.7×10^{10}	Bq			

1-2. Radiation Accidents

a. General. Radiation accidents are the most likely events that threaten US forces and civilians. A radiation accident is a situation in which there is a real or suspected unintentional exposure to ionizing radiation or radioactive contamination. According to the (Department Of Energy/Radiation Emergency Assistance Center/Training Site) Radiation Accident Registry, from 1944 to 2000, there have been 417 radiation accidents worldwide. These accidents involved radiation devices (74 percent), radioisotopes (21 percent), and criticality incidents (5 percent). 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 (ARS), acute local radiation injury, combined injuries (radiation, thermal, or blast injuries), psychological consequences, and long-term stochastic effects. This paragraph will discuss the most prevalent radiation sources and accidents associated with these sources. Examples will be included where appropriate. For a detailed discussion of radiation sources and hazards, see US Army Center for Health Promotion and Preventative Medicine (USACHPPM) Technical Guide (TG) 238, *Radiological Sources of Potential Exposure and/or Contamination*, Draft, June 1999.

b. Industrial Radiation Sources and Accidents.

(1) Radiation devices and radioactive materials are used in industrial processes involved with agricultural practices, scientific research, manufacturing, sterilization, and radiography. In fact, most radiation accidents have involved industrial gamma and x-ray radiography (nondestructive inspection) devices and sources. These industrial and radiography sources are summarized in 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. US personnel must always be aware of the possible dangers from these sources, especially when conducting operations in areas previously subjected to ground and/or air combat.

Table 1-2. Industrial Sources of Radiation

LOCATIONS AND MATERIALS	RADIATION SOURCES	SOURCE STRENGTH	COMMENTS
Gauges, Sources, Static Eliminators.	Iridium-192, Cesium-137, Cobalt-60, Radium-226, Neutrons, Americium-241, Polonium-210.	Greater than about 4 TBq.	Sealed sources, and if leaking, presents surface contamination.
X-ray Machine Sterilizers, Processors, and Particle Accelerators.	X-rays, Protons, 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 Radioactive 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.
Power Sources.	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 contamination.

(2) In February 1989, a radiation accident occurred at an industrial irradiation facility near San Salvador, El Salvador. Prepackaged medical products were sterilized at this facility by irradiation using an intensely radioactive Cobalt-60 source in a movable source rack. The accident happened when the source rack became stuck in the irradiation position, and the operator and two other workers entered the radiation room and attempted to free the source rack manually. The three workers were exposed to high radiation doses and developed ARS. Their initial hospital treatment and consequent specialized treatment

were effective in countering the acute effects. However, the legs and feet of two of the three men were so seriously injured that amputation was required. The worker who had received the most exposure died six and a half months post-exposure due to residual lung damage exacerbated by injury sustained during treatment.

c. Biomedical Sources. Biomedical sources of radiation are those devices or materials that are readily available at hospitals and some laboratories. They include sealed or encapsulated sources, unsealed sources, and machine-produced radiation. Of particular concern are teletherapy units, brachytherapy sources, and radionuclide generators. Cobalt-60 teletherapy units are currently used for the treatment of cancer throughout the world and may contain up to a 15,000 curie encapsulated source capable of delivering a dose rate of 350 cGy/min at 80 centimeters (cm). A life-threatening dose could be received in only a few minutes of exposure to unshielded source of this strength. For example, an explosion near a radiation therapy facility's Cobalt-60 unit could result in destruction of the shielding surrounding the source and 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 would be at high risk for exposure to the dispersed radioactive material. Medical sources of radiation are summarized in Table 1-3.

Table 1-3. Medical Sources of Radiation

LOCATIONS AND MATERIALS	RADIATION SOURCES	SOURCE STRENGTH	COMMENTS
Radiation Therapy Facility	Cobalt-60 and Cesium-137	80 cGy/min to 350 cGy/min at 80 cm when the source is unshielded.	Found in therapy rooms.
Sources and Applicators	Cesium-137, Iridium-192, Radium-226, Phosphorous-32, Strontium-90, Iodine-125.	Tens of MBq	Therapy and nuclear medicine areas.
Radiopharmaceuticals	Iodine-123, Phosphorous-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.

d. The Nuclear Fuel Cycle and Nuclear Reactors (Power Plants). 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. US 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 US Forces could occur if an accident in one of these facilities dispersed radiation into the surrounding environment. Of equal importance is that intentional exposure could occur if an enemy commander 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 and thus incapacitation of large numbers of US military personnel operating in the vicinity of the facility. 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.
Conversion and Enrichment; Fuel Fabrication	Liquid	Protactinium-234; Radium-226; Thorium-234; Uranium-238.
	Liquid and Solid	Plutonium; Thorium; Uranium.
Reactor Operations	Gaseous	Argon-41; Krypton-87, 89; Nitrogen-13; Xenon-138.
	Liquid and Solid	Cobalt-58, 60; Chromium-51; Iron-59; Hydrogen-3.
Waste Reprocessing	Gaseous	Hydrogen-3; Iodine-129, 131; Krypton-85; Xenon-133.
	Liquid and Solid	Fission products; Americium, Curium, Plutonium.

(1) *Nuclear fuel processing.*

(*a*) 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 uranium dioxide produces liquid waste that contains chemical impurities, including fluorides. The fuel enrichment process leads to the production of material enriched in Uranium-235 for use in nuclear power reactors and weapons. Depleted uranium (DU) is a waste product of the uranium enrichment process which has found use in military aircraft as a counterweight and in armored vehicles and antiarmor munitions (see Appendix A).

(*b*) 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. 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 spewed from the lake, affecting an estimated 41,000 people in an area of more than 40,000 square kilometers (kms). By 1990, radiation levels near the lakeshore were still high enough to provide a lethal dose within 60 minutes of exposure. Today, Lake Karachai remains the most contaminated spot on the earth's surface.

(2) *Nuclear reactors (power plants)*. As of 1999, there were 433 nuclear power plants in operation worldwide. The pressurized water reactor (PWR) is the most common type of nuclear power plant in the world. 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 -133, which can be taken up by the thyroid. The fission process also produces significant amounts of Cesium-134 and -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 dose from a plume overhead (cloud shine) or radioactive material on the ground (ground shine).
- Internal dose due to inhaling materials directly from the plume or from stirred up dust.
- Ingestion of contaminated materials in or on food or water.

(3) *Examples of nuclear reactor accidents*. There are three specific examples of accidents involving nuclear reactors that resulted in varying degrees of exposure.

(*a*) In October 1957, a plume of radioactive contamination was carried into the atmosphere from a nuclear reactor fire at Windscale in Great Britain. Because of the inadequacy of the temperature measuring instrumentation, the control room staff mistakenly thought the reactor was cooling down too much and needed an extra boost of heating. Thus, temperatures were abnormally high when the control rods were withdrawn for a routine start to the reactor's chain reaction. The uranium and graphite ignited and sent temperatures soaring to 1,300 degrees centigrade. As the fire raged, radioactivity was carried aloft. Blue flames shot out of the back face of the reactor and the filters on the top of the chimneys could only hold back a small proportion of the radioactivity. An estimated 20,000 curies of radioactive iodine escaped along with other isotopes such as plutonium, cesium, and polonium. Eventually, the reactor was flooded with cooling water which put out the fire, and gradually the reactor was brought under control.

(*b*) The Three Mile Island incident on March 28, 1979 in Pennsylvania, was due to a failure in an auxiliary component in the secondary system, which led to loss of the water supply to the steam generators. This resulted in lack of adequate cooling capability to remove the heat produced within the reactor. Part of the fuel melted, carrying fission products through the primary system into the pressurizer

relief tank. This tank burst open under the rising pressure and fission gases were released into the containment, actuating all of the radioactivity alarms. After several confusing hours, the operator finally restored cooling to the reactor and reflooded the core. Before the operator finally isolated the containment, fission gases such as xenon and krypton escaped through the ventilation filters. However, there was no uncontrolled release of iodines or other aerosols since they were all trapped in the water and the filters. No biological effects were observed as a result of the radioactive materials released in the accident.

(*c*) On April 26, 1986 a reactor at the Chernobyl power station located in the Ukraine, about 90 miles from Kiev, was destroyed in a catastrophic accident. The accident occurred during the running of safety test, not during the normal operation of the reactor. The test carried out at Chernobyl-4 was designed to demonstrate that during an external electrical grid failure, a "coasting" turbine would provide sufficient electrical power to pump coolant through the reactor core while waiting for electricity from the back-up diesel generators. Poor test design and violation of safety regulations ultimately resulted in two explosions. One was a steam explosion; the other was an explosion of the fuel vapor. The explosions lifted the nuclear pile cap, allowing the entry of air, which reacted with the graphite moderator blocks to form carbon monoxide. This gas ignited and a reactor fire resulted. The end result was that about eight tons of fuel and highly radioactive fission products were ejected from the reactor along with a portion of the graphite moderator, which was also radioactive. These materials were scattered around the site, while cesium and iodine vapors were released into the atmosphere.

e. Sources from United States Forces Commodities and Foreign Material.

(1) United States forces use many radioactive commodities in equipment, vehicles, ships, aircraft, weapons systems, and so forth. Depleted Uranium is discussed separately in Appendix A. Depleted Uranium is not a chemical or a radiological threat. However, DU is a low-level radioactive material and, as such, it is discussed in this manual for convenient reference by medical professionals. Some of the most common radioactive sources in US material are:

- Tritium (Hydrogen-3). Tritium is the heaviest isotope of hydrogen and is a low energy beta emitter with a physical half-life of 12 years. 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. Nickel-63 is a pure beta emitter with a radiological half-life of 92 years, and is used in the chemical agent monitor (CAM). 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. Cesium-137 is used in the soil density and moisture tester (Campbell Pacific Model MC-1). 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 since the radioactive source is shielded in double encapsulated stainless steel. However, placing the source close to the body (such as in a pocket) for an extended period of time can cause clinical injury.

- Thorium-232. Thorium-232 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 radiac sets AN/VDR-2, AN/PDR-54, and the AN/PDR-77 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. Americium-241 is used as a sealed source in the M43A1 Chemical Agent Detector that is a component of the M8A1 alarm. 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.

(2) Similar to US forces commodities, some foreign materiel contains radioactive sources. Although these sources do not present a hazard to personnel working close to them, it is important to be aware of their presence, as they could be dangerous if the equipment has been damaged or tampered with. See USACHPPM TG 238 for detailed descriptions of radioactive sources in foreign materiel.

1-3. Nuclear Weapons Incidents

a. 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 fissile materials in nuclear weapons (Uranium-235 and Plutonium-239) are basically 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, and the intensity is reduced by approximately one-half for every 5.0 millimeter (mm) of tissue or water. Actual nuclear detonations due to accidents and/or mishandling are considered to be highly unlikely.

b. A few very serious incidents involving nuclear weapons have occurred throughout the world. However, the Palomares incident remains today the most severe accident in US 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 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 cm 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.

1-4. Terrorism and Radiological Dispersal Devices

a. Another threat facing US Armed Forces and civilians today are terrorists and organized crime groups who could potentially use Radiological Dispersal Devices (RDD). An RDD, as defined by a 1979 US DOD report to a US/Soviet committee on disarmament, is *any device, including any weapon or equipment other than a nuclear explosive device, that is specifically designed to employ radioactive material by disseminating it to cause destruction, damage, fear, or injury by means of the radiation produced by the decay of such material.* They are ideal weapons for terrorism and can be used to intimidate and deny access to an area by spreading radioactive material. Environmental radiological problems are of special concern since at very low levels of radiation there will not be any immediate outward signs of exposure. Note that RDDs may have a strong psychological impact on troops as well as the civilian population.

b. RDDs are low-technology devices that may use biomedical sources, industrial radioactive material, and/or radioactive waste as its core element in the device. Potential radioactive material for RDDs include medical radiation therapy 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. Overall, RDDs could involve—

- Radioactive material combined perhaps with conventional high explosive.
- Medical and/or industrial isotopes.
- Cobalt, cesium, iodine, plutonium, and spent nuclear fuels.
- Unsophisticated delivery systems.

c. Another type of RDD would be the malicious distribution of sealed radioactive sources. This is simply spreading the radioactive material by abandoning the material in a populated or sensitive area. In one of the few recorded incidents of terrorists actually using radioactive materials, Chechen rebels placed Cesium-137 in a busy Moscow park in November 1995. The material was packed in a protective canister, and thus posed a minimal health threat. However, the incident embarrassed the Russian government, which was probably the Chechens' ultimate goal.

1-5. Terrorism and a Single Nuclear Detonation

a. The reasons that terrorists may perpetrate a WMD attack include a desire "to annihilate their enemies," to instill fear and panic in order to undermine a governmental regime, to create a means of negotiating from a position of strength, or to cause a great social and economic impact.[1] A single nuclear

1. First Annual Report to The President and The Congress of the Advisory Panel to Assess Domestic Response Capabilities for Terrorism Involving Weapons of Mass Destruction, I. Assessing the Threat (The Rand Corporation, 1999).

detonation could achieve all of these objectives. State-sponsored terrorism is regarded as a form of surrogate warfare and is a critical intelligence collection objective since more than 20 countries are suspected of proliferating NBC weapons technology (see Table 1-5).

b. Terrorists who are able to acquire nuclear weapons and/or special nuclear material (SNM) represent a major potential threat to US security and that of other nations. After the collapse of the Soviet Union, Western fears about the security of Russian strategic and nonstrategic nuclear weapons were heightened. However, it now appears that the weapons are more secure than had been initially feared. Where there may be particular concern is during their transportation for maintenance or dismantling, when the Russian weapons apparently are not subject to the same strict security measures.[2]

c. Terrorists who were either unable or unwilling to steal a nuclear device, or were unsuccessful in obtaining one on the putative black market, might attempt to build one themselves. Acquiring or processing SNM, that is, either highly enriched uranium (HEU) or plutonium is extremely difficult. Although much of the information about nuclear weapons design and production has become public knowledge during the past 50 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. Also, the device must also be small and light enough to be carried by a given delivery vehicle. If stringent conditions are not met, the terrorist ends up with a device that cannot produce any significant nuclear yield, but will instead function as an RDD.[3] (Terrorists may also develop weapons known as improvised nuclear devices [IND]. Such devices may be fabricated in a completely improvised manner, or may be a modification to a US or foreign nuclear weapon.) Finally, any nuclear weapons program will, by nature, involve a number of people, and significant resources, equipment, and facilities. This activity will increase the risk of exposure of the terrorist group to detection by intelligence and law enforcement agencies.[4]

1-6. Nuclear Warfare

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 on a theater battlefield.

a. Strategic Nuclear War. Strategic nuclear war would use weapons that generally range in yield from hundreds of kilotons (KT) to multiples of megatons (MT). They are designed to destroy large population centers, destroy or disrupt national and strategic nuclear forces and their command and control (C2), and to destroy or disrupt national infrastructure, logistics, and warfighting 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

2. Ibid.
3. Ibid.
4. Ibid.

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.

b. Theater Nuclear War. In the cold war environment, theater nuclear war planning envisioned the use of both small, low-yield tactical nuclear weapons and larger yield theater-level weapons. Low-yield tactical nuclear weapons (delivered by tube artillery or medium battlefield rockets) were planned for use against specific enemy units, key terrain on the battlefield, nuclear capable enemy units, or for shock value against specific troop concentrations. Generally, these would rarely exceed 10 KT. Also, there were a number of atomic demolition munitions (ADM) present on both sides during the cold war. Since low-yield tactical weapons have been removed from the inventory, it is no longer appropriate to use the term "tactical." The term "nonstrategic" is now used to describe the US theater-level capability. Current US theater-level nuclear weapons include gravity bombs, air launched cruise missiles (ALCM), and Tomahawk land attack missile/nuclear (TLAM/N). 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, and theater level logistic bases. They would also provide a deterrence and response to either the enemy's use, or threat of use, of any WMD. 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 (MTFs).

1-7. Global and Regional Threats

Certain countries have embarked on extensive efforts to acquire and develop nuclear, biological, and chemical weapons. Depending on their delivery systems, these weapons can pose a regional and a global threat (see Table 1-5). The Defense Intelligence Agency (DIA) has estimated that the Middle East will become the region of greatest concern in terms of nuclear weapons over the next 10 to 20 years. They judge certain states in this region will be able to begin stockpiling nuclear weapons in the next two decades; much sooner if they are successful in purchasing fissile material, or if they are successful in purchasing complete weapons.

Table 1-5. Summary of Nuclear Weaponry/Material and Delivery Systems by Country

COUNTRY	WEAPON/ MATERIAL ACQUIRED	DELIVERY SYSTEMS (does not include dual use aircraft)	PRIMARY SUPPLIERS
Iran	1000 MW reactor under construction; seeks to establish a complete nuclear fuel cycle capability.	SCUD SRBM Shahab-3 MRBM (prototype)	Russia China

Table 1-5. Summary of Nuclear Weaponry/Material and Delivery Systems by Country (Continued)

COUNTRY	WEAPON/ MATERIAL ACQUIRED	DELIVERY SYSTEMS (does not include dual use aircraft)	PRIMARY SUPPLIERS
Iraq	Unknown	Al-Samoud SRBM Ababil-100 SRBM	Unknown; under United Nations restrictions.
North Korea	1 to 2 nuclear weapons; enough plutonium for several more.	SCUD SRBM Nodong MRBM Taepodong LRBM	China
Libya	Unknown	Ballistic missiles still under development.	Russia Eastern Europe Iran
India	Unknown number of nuclear weapons; underground tests in May of 1998.	Agni-2 MRBM	Russia Western Europe
Israel	Estimated 100 -200 nuclear weapons; several reactors, fuel processing sites, and storage areas.	Jericho-1,-2 MRBM	France
Pakistan	Unknown number of nuclear weapons; tested in late May of 1998.	Ghauri MRBM	Russia China Western Europe
China	450 nuclear weapons; numerous reactors, fuel processing sites, and storage facilities.	DF-5, -31, -41 LRBM DF -3, -4, -21 MRBM JL-1 SLBM (LRBM)	N/A
Former Soviet Union (FSU)	21,000 nuclear weapons; numerous reactors, fuel processing sites, and storage areas.	Over 800 strategic LRBM Over 250 SLBMs	N/A

CHAPTER 2

HAZARDS OF NUCLEAR AND RADIOLOGICAL EVENTS

2-1. General

This chapter covers 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 manual. It must be emphasized that when dealing with an actual nuclear detonation, blast and thermal injuries in most cases will far outnumber radiation injuries. However, radiation effects are considerably more complex and varied than are blast or thermal effects, and are also subject to considerable misunderstanding. Also, radiation effects will predominate in RDD events and nuclear accidents. Since data from human experience are limited, much of the information in this chapter is based upon experimental information from animal studies.

2-2. Types of Ionizing Radiation

Ionizing radiation is simply nuclear radiation in the form of particles or electromagnetic waves (photons) that, as it passes through matter, causes atoms to become electrically charged or ionized. In living tissues, these electrically charged ions produced by radiation may effect normal biological processes. There are only four types of ionizing radiation of biological significance. These four types of radiation are classified into two categories—particulate and nonparticulate. Particulate ionizing radiation types are alpha particles, beta particles, and neutrons. The nonparticulate radiation type is electromagnetic radiation (photons of x-rays and gamma rays). Certain aspects of their mechanisms of interaction with living tissue are discussed below.

a. Particulate Ionizing Radiation.

(1) *Alpha radiation.* 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 particles is important in terms of causing long-term radiation injury. Many alpha-emitting materials also emit gamma radiation, and this more penetrating gamma radiation may irradiate tissues far from the areas of deposition.

(2) *Beta radiation.* Beta particles are identical to atomic electrons but, 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. Beta

particles can only penetrate a few millimeters of tissue. If the beta-emitting material is on the surface of the skin, the resulting beta irradiation causes damage to the epithelial basal stratum. 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 quickly 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 (see Chapter 5).

(3) *Neutron radiation*. Neutrons are electrically neutral, yet because of their relatively large mass, they can severely disrupt atomic structures. Neutrons are produced in the processes of nuclear fission and fusion. Compared to gamma rays, neutrons can cause much more damage to tissue. Collisions with atomic nuclei slow down a neutron so it may undergo nuclear capture. In nuclear capture, the neutron is actually absorbed into the target nucleus making the nucleus unstable and, therefore, radioactive.

b. Electromagnetic (Nonparticulate "Photon") Ionizing Radiation. 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 only difference between the gamma and x-ray photons is that gamma rays originate from the nucleus of an atom while x-rays are produced whenever high-velocity electrons strike a material object or when an orbital electron moves from an outer to inner shell. 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 because of 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.

2-3. Units of Measure

There are several different, but interrelated, methods of measuring and quantifying ionizing radiation. For comparison purposes, existing and new units of measurement are discussed in this paragraph (also, see Table 1-1).

a. Exposure. Exposure is defined for gamma and x-rays in terms of the amount of ionization they produce in air. The unit of exposure is called the roentgen (R) and is defined as: $1\ R = 2.58 \times 10^{-4}$ Coulombs per kilogram in air (C/kg-air). From a clinical standpoint, it must be remembered that some radiation passes through a volume of material or tissue without interacting and, therefore, does no damage. Therefore, while exposure measurements are a key element in making a diagnosis, they are only a part of the overall analysis.

b. Absorbed Dose. Although the concept of exposure provides a measurement standard for electromagnetic radiation in air, additional concepts are needed for all types of radiation and its interaction

with other materials, especially living tissue. Absorbed dose is defined as the radiation energy absorbed per unit mass. The traditional unit of absorbed dose is the rad (radiation absorbed dose), 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

Gray
1 Gy = 1 joule/kilogram = 100 rads

Figure 2-1. Units of absorbed dose.

c. Dose Equivalent.

(1) 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 rates, 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 they more randomly interact with molecules along their path. Conversely, 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-rays (see Table 2-1). The QF is then used to determine the equivalent dose.

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	3–20 *

* Values of quality factors for neutrons are dependent upon the energy of the neutron.

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

Rem = QF x Rad

Sievert = QF x Gy

1 Sv = 1 joule/kilogram = 100 rem

Figure 2-2. Units of equivalent dose.

d. Dose Rate. Dose rate is the dose of radiation per unit of time. An example would be centiGray per hour (cGy/hr).

e. Activity. The activity level of a radioactive material is simply a measure of how many atoms disintegrate (decay) per a unit of time. The existing unit for this is the Ci. The Ci 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
1 Ci = 3.7×10^{10} nuclear transformations per second

Becquerel
1 Bq = 1 nuclear transformation per second
1 Bq = 2.7×10^{-11} Ci

Figure 2-3. Units of activity.

f. Half-life. Activity is tied to a physical property of a radionuclide known as the half-life. The half-life of a radionuclide is the amount of time it takes one-half of the nuclei to decay. Thus, after 1 half-life, $^1/_2$ of the original amount remains. After 2 half-lives, $^1/_4$ remains, and after 3 half-lives, $^1/_8$ remains, and so forth. 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).

2-4. Penetration and Shielding

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).

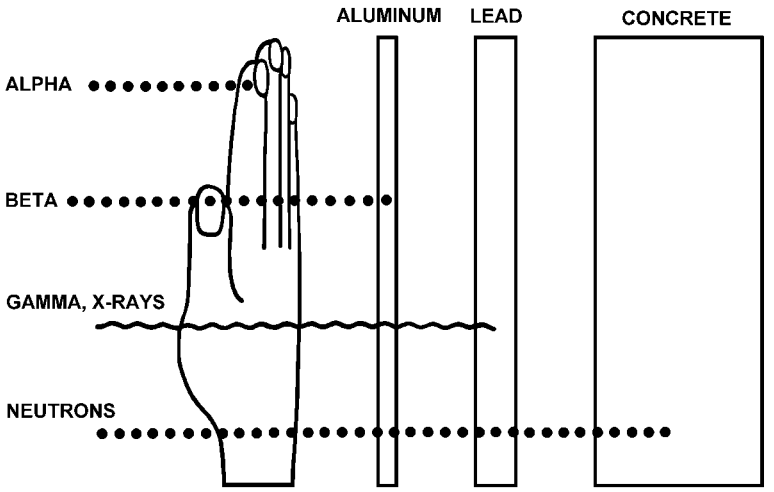


Figure 2-4. Radiation penetration and shielding.

a. Alpha Shielding. 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.

b. Beta Shielding. Beta emitters present two potential external radiation hazards: the beta particles themselves, and the x-rays they can produce when they strike certain materials such as lead. Although beta particles can travel significant distances in air, materials such as aluminum, plastic, or glass can provide appropriate shielding. However, these emitters should be handled with care. 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.

c. Gamma Shielding. Gamma rays and x-rays are more difficult to shield as they are typically 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, steel, and concrete 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.

d. Neutron Shielding. 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 or paraffin make efficient neutron shields.

2-5. Nuclear Detonation

A nuclear detonation results from the formation of a supercritical mass of fissile 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 fissile 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.

a. Basic Detonation Characteristics. 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 roughly as follows (see Figure 2-5):

- 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.

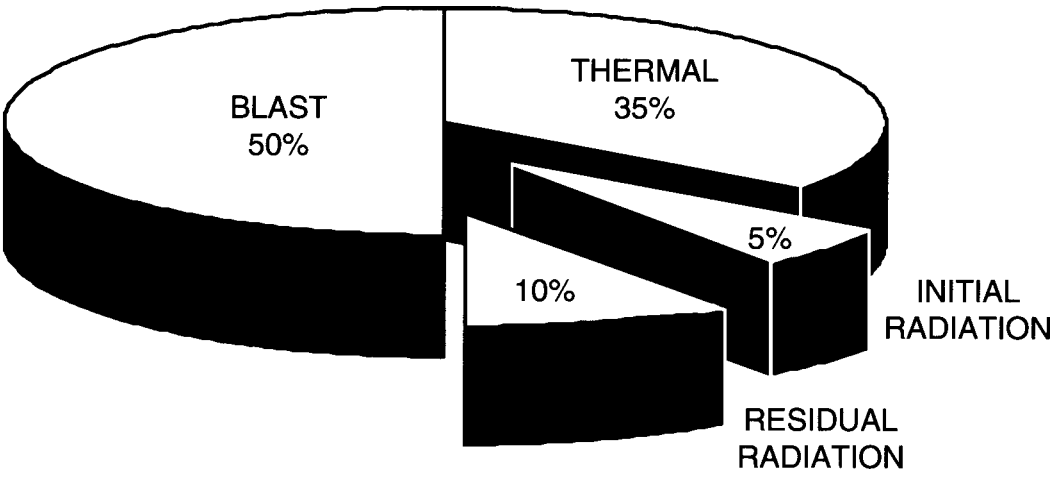


Figure 2-5. Energy partition from a nuclear detonation.

- 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).

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.

b. Types of Bursts. 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 airbursts, surface bursts, subsurface bursts, or high altitude bursts.

(1) *Airburst*. 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 (NIGA) that could be hazardous to troops required to pass through the area. The NIGA hazard is temporary, lasting only a few days to a few weeks.

(2) *Surface burst*. 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.

(3) *Subsurface burst*. 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, but will be less than for a surface burst of comparable yield. Local fallout will be very heavy if surface penetration occurs.

(4) *High altitude burst*. A high altitude burst is one in which the weapon is exploded at a high altitude (typically above 50 km) so that it generates an intense electromagnetic pulse (EMP) 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 national command, control, communications, computers,

and intelligence systems. There are no known adverse biological effects of EMP at exposure levels below the established protection standards.

2-6. Nuclear Detonation Blast Hazards

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, insofar as production of casualties requiring medical treatment is concerned, will be those due to the blast wind drag forces (see paragraph 2-9, Range of Damage). However, 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.

a. Direct Blast Injury. 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, but a minor blast injury. **However, direct blast injuries will not occur by themselves; in general, other effects, such as indirect blast wind drag injuries and thermal injuries are so severe at the ranges associated with these overpressures 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 (kPa) (1.9 atmospheres [atm]) can be lethal, but that survival is possible with overpressures as high as 262 kPa (2.5 atm). 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.

b. Indirect Blast Wind Drag Forces. The drag forces of blast winds are proportional to the velocities and duration times of those 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 km per hour. Indirect blast injuries will occur as crush and translational injuries, and as missile injuries. Casualties will be thrown against immobile objects and impaled by flying debris; therefore, solid organ, extremity, and head injuries will be commonplace. The distance from the point of detonation at which severe indirect injury will occur is considerably greater than that for serious direct blast injuries.

(1) *Crush and translational injuries*. 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 and at variable velocities 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.

(2) *Missile injury*. 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 increases with increasing velocity, particularly for small, sharp missiles such as glass fragments. Heavier objects require higher kinetic energies to penetrate, therefore, heavy blunt missiles will not ordinarily penetrate the body, but can result in significant injury, particularly fractures.

2-7. Nuclear Detonation Thermal Radiation Hazards

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.

NOTE

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 medical service.

a. Flash (Thermal Pulse) Burns. Since the 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; however, clothing significantly reduces the effective range producing partial thickness burns. It must be remembered that close to the fireball, the thermal output is so great 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.

b. Flame Burns. 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. Therefore, it is recommended that clothing made of natural fibers, or flame resistant clothing (for example, Nomex) 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. For example, the respiratory system may be exposed to the effects of hot gases, and respiratory system burns are associated with severe morbidity and high mortality rates.

c. Eye Injuries. 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. Direct vision optical equipment such as binoculars will increase the likelihood of damage. Night vision devices (NVDs) electronically amplify the ambient light, and they also detect infrared energy, the major component of the thermal pulse. However, most NVDs automatically shutdown when an intense burst of energy hits the device. Eye injury is due not only to thermal energy but also to photochemical reactions that occur within the retina with light wavelengths in the range of 400 to 500 nanometers (nm), in addition to thermal and blast effects.

(1) *Flash blindness*. 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 afterimage that lasts for several minutes. At night, flash blindness can last for up to 30 minutes and may occur up to 100 km from the blast (see Figure 2-6).

(2) *Retinal burns*. Direct observation of a brilliant flash of light in the wavelengths of 400 to 1,400 nm 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).

2-8. Nuclear Detonation Radiation Hazards

a. Initial Radiation. About 5 percent of the energy released in a nuclear airburst is transmitted in the form of initial neutron and gamma radiation. The neutrons result almost exclusively from the energy produced 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. Therefore, 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 (see paragraph 2-9).

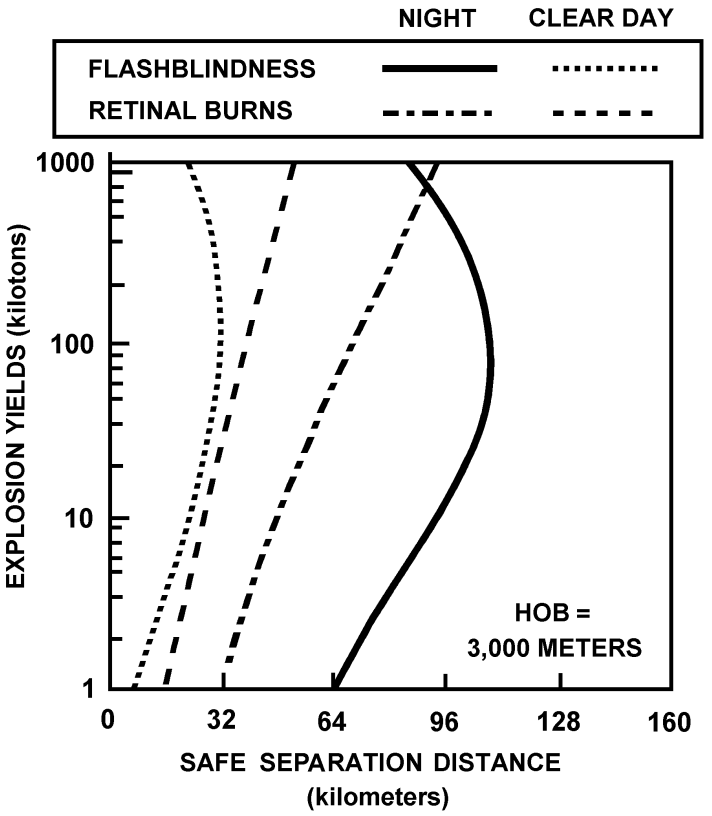


Figure 2-6. Flash blindness and retinal burn safe separation.

b. Residual Radiation. Residual ionizing radiation from a nuclear explosion arises from a variety of sources but is primarily in the form of NIGA and radioactive fallout.

(1) *Fission products.* 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.

(2) *Unfissioned nuclear material*. Nuclear weapons are relatively inefficient in their use of fissile 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. Also, the neutrons that are emitted as part of the initial nuclear radiation will cause activation of the weapon residues.

(3) *Neutron induced ground activity*. If atomic nuclei in soil, air, and water are exposed to neutron radiation and capture neutrons, they will, as a rule, become radioactive (NIGA) depending on their composition and distance from the burst. They then decay by emission of beta and gamma radiation over an extended period of time. For example, a small area around ground zero may become hazardous as a result of exposure of the minerals in the soil to initial neutron radiation. This is normally a negligible hazard because of the limited area involved.

(4) *Fallout*.

(*a*) 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 (and shallow underwater) bursts, 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.

(*b*) *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.

2-9. Range of Damage

Table 2-2 shows the ranges in kilometers of biological damage for the hazards discussed above. The ranges noted are for weapons of various yields including very low yield INDs. 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 by Yield in Kilometers

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/cm^2)	0.13	0.37	1.2	3.4	8.3	17
50% Second degree (4–5 cal/cm^2)	0.089	0.24	0.86	2.5	6.5	14
50% Third degree (6–8 cal/cm^2)	0.073	0.18	0.71	2.1	5.6	12
Retinal burns (0.0001 cal/cm^2)	10	20	33	49	66	84
Flash blindness (0.16 cal/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.

2-10. Radioactive Contamination Hazards

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, and 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.

a. External Contamination. Significant amounts of radioactive material may be deposited on personnel and ground surfaces after the use of nuclear weapons and/or RDD; and after the destruction of nuclear reactors; nuclear accidents; or improper radiological waste disposal. In severe cases of fallout contamination, lethal doses (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 remediation. In general, the external contamination hazard to both the patient and attending medical personnel will be so negligible that NECESSARY MEDICAL OR SURGICAL TREATMENT MUST NOT BE DELAYED BECAUSE OF POSSIBLE CONTAMINATION. If external contamination is detected, internal contamination may also be present.

b. Internal Contamination. In a nuclear explosion, more than 300 radioactive isotopes are released into the biosphere, of which about 40 are produced in sufficient abundance and with sufficiently long half-life to be of significance. 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 misadministration and the internalization of radioactive materials from an RDD.

CHAPTER 3

TREATMENT OF HIGH-DOSE RADIOLOGICAL AND COMBINED INJURY CASUALTIES

3-1. General

This chapter discusses the treatment of casualties who have suffered high-dose radiological injuries and/or combined injuries. In a nuclear detonation roughly 15 percent of the casualties can result from radiation exposure alone. Only a small percentage of the physical trauma casualties will not have some form of radiation injury that will complicate their recovery (see Table 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. However, in the more likely scenarios involving RDD or nuclear incidents, high dose radiological casualties without some form of trauma may be encountered. Because of this, and because of the complexities involved with treating ionizing radiation injuries, management of radiological casualties will be discussed first. Treatment of combined injuries follows in a later section. A detailed list of medications used in treatment is presented in Appendix B. Also, Appendix C contains patient descriptions involving radiation doses and combined injuries. These descriptions are termed Treatment Briefs (TBs). They may help physicians and other medical staff as quick reference material for the treatment of radiation and combined injury casualties.

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
Irradiation, Burns, and Wounds	17
Irradiation and Burns	40
Irradiation and Wounds	5
Wounds and Burns	5
Combined Injury Total	67

Section I. IONIZING RADIATION EFFECTS ON CELLS AND TISSUES

3-2. General

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 animal species and age, as well

as radiological factors, such as the type of radiation, dose, and dose rate (see Chapter 2), produce variations of response in biological systems.

3-3. Cellular Effects of Ionizing Radiation

a. General. 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 [DNA]) 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.

b. Relative Cellular Radiosensitivity. Cellular radiosensitivity tends to vary inversely with the degree of cell differentiation. In fact, cells may be classified in decreasing order of sensitivity into four categories—vegetative cells, differentiating cells, totally differentiated cells, and fixed nonreplicating cells.

(1) *Vegetative cells*. These cells are generally the most radiosensitive. Examples include—

- Free stem cells of hematopoietic tissue (hemocytoblasts, primitive lymphoblasts, primitive erythroblasts, and primitive myeloblasts).
- Dividing cells deep in the intestinal crypts.
- Primitive spermatogonia in the epithelium of the seminiferous tubules.
- Granulosa cells of developing and mature ovarian follicles.
- Basal germinal cells of the epidermis.
- Germinal cells of the gastric glands.
- Lymphocytes.
- Mesenchymal cells.

(2) *Differentiating cells*. These cells are somewhat less sensitive to radiation. They are relatively short-lived and include the first generation produced by division of the vegetative mitotic cells. They usually continue to divide a limited number of times and differentiate to some degree between divisions. As differentiation occurs, radiosensitivity decreases. The best examples of this type of cell are the dividing and differentiating cells of the granulocytic and erythrocytic series in the bone marrow.

(3) *Totally differentiated cells*. These cells are relatively radioresistant. They normally have relatively long life spans and do not undergo regular or periodic division in the adult stage, except under

abnormal conditions such as following damage to, or destruction of a large number of these cells. This class includes hepatocytes, cells of interstitial gland tissue of the gonads, smooth muscle cells, and vascular endothelial cells.

(4) *Fixed nonreplicating cells*. This group of cells is the most radioresistant and includes the long-lived neurons, striated muscle cells, short-lived polymorphonuclear granulocytes and erythrocytes, spermatids and spermatozoa, and the superficial epithelial cells of the alimentary tract. They are highly differentiated morphologically and highly specialized in function. They do not normally divide, and some types, such as neurons, do not divide under any circumstances.

3-4. Relative Tissue Radiosensitivity

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 Based on Parenchymal Hypoplasia

ORGANS	RELATIVE RADIOSENSITIVITY	CHIEF MECHANISM OF PARENCHYMAL HYPOPLASIA
Lymphoid organs; bone marrow, testes and ovaries; small intestines; embryonic tissue	High	Destruction of parenchymal cells, especially the vegetative or differentiating cells
Skin; cornea and lens of eyes; gastrointestinal organs: cavity, esophagus, stomach, rectum	Fairly high	Destruction of vegetative and differentiating cells of the stratified epithelium
Growing cartilage; the 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

a. The Hematopoietic System.

(1) 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 (lymphocytes, granulocytes, monocytes, and so forth), or platelets; a specific compartment for dividing and differentiating erythrocytes, leukocytes, or platelets; a specific compartment for maturing (nondividing) erythrocytes, leukocytes, or platelets; and a specific compartment for mature, functional erythrocytes, leukocytes, and platelets. 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.

(2) Radiation exposure at an LD_{50} level will deplete the hematological stem cell population drastically. As the functional, mature cells die, they cannot be replaced, and 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.

b. The Gastrointestinal System.

(1) 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, the maturation compartment, the functional compartment, and the extrusion zone compartment. Stem cells and proliferating cells move from crypts in the villi into a maturation compartment at the neck of the crypts. Then, 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.

(2) 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 mid-lethal 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 slowed. 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.

c. Cardiovascular/Central Nervous Systems.

(1) At extremely high doses (2000 cGy–3000 cGy and higher), damage to the central nervous system and cardiovascular systems are 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, body temperature, and so forth. However, the visible morphological changes at the cell level of the central nervous system (CNS) are limited to a few tissues, including the granule cell layer of the cerebellum and the meningeal lining of the brain. Also, there is a breakdown of the blood-brain barrier that leads to cerebral edema.

(2) Also, 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 with resulting changes in vessel wall permeability, but also activates a reparative molecular cascade in an attempt to correct the vascular defect. The major molecular players in this cascade include von Willenbrand 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 finally, 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, fully functional vessel.

Section II. SYSTEMIC EFFECTS OF HIGH-DOSE RADIATION

3-5. General

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 special weapon accident.
- When weapons or fuel-grade nuclear material is allowed to form a critical mass ("a criticality incident").
- Or 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.

Whole body irradiation is potentially the most damaging radiation. However, partial body irradiation is most likely to occur in both tactical scenarios and in radiological incidents since terrain, obstacles, shielding, and

so forth would preclude whole body exposure. Therefore, partial exposure would limit the amount of radiation actually transmitted to the body. Specific organ irradiation due to internal and external contamination is discussed in Chapter 4, Radioactive Contamination.

3-6. Acute Radiation Syndrome

a. General. 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, after industrial radiation accidents, after planned radiotherapy, and so forth. There are three phases to the acute radiation syndrome: A prodromal or initial phase occurring during the first few hours after exposure; a latent phase, which becomes shorter with increasing dose of radiation exposure; and a manifest phase in which the clinical illness appears.

(1) *Prodromal or initial phase.* 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, but are not diagnostic of the degree of radiation injury. An early onset of symptoms in the absence of associated trauma does suggest a large radiation exposure.

(2) *Latent phase.* 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 or injury, or by medical intervention.

(3) *Manifest phase.* 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 three subsyndromes. The details of each of the three subsyndromes are described in paragraph 3-6*c*.

b. Lethality/Lethal Dose.

(1) *Without medical intervention.* In the following sections, the term *lethal dose* may be used. For example, 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 450 cGy, as measured in free air. Medically, other figures of interest are the dose that will kill virtually no one (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.

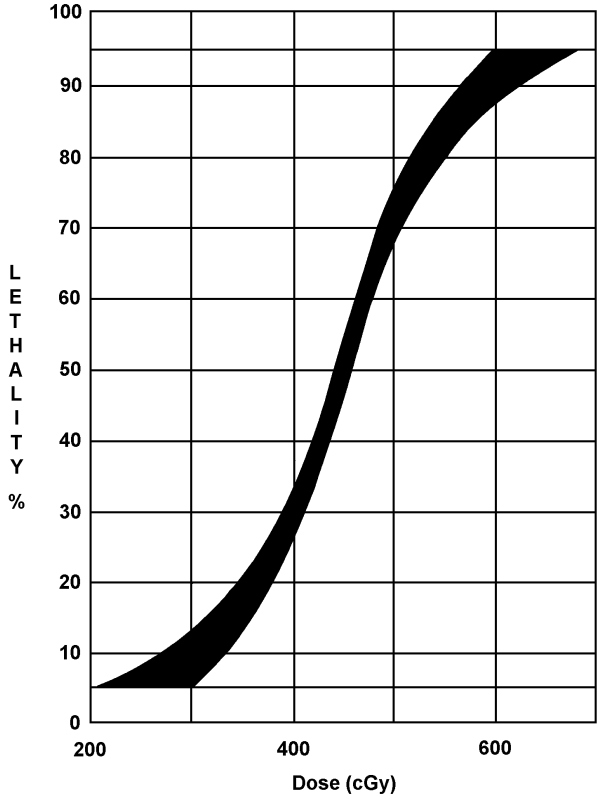


Figure 3-1. Lethality as a function of dose.

(2) *With medical intervention*. Adequate medical intervention significantly increases the LD_{50} and markedly diminishes mortality. Figure 3-2 shows the impact of medical intervention on lethal doses (adapted from the U.S. Army Human Response Dose Committee Meeting minutes, 10 October 2000). The LD_{50} for radiation moves from approximately 400 cGy to approximately 600 cGy if the exposed service member receives **timely medical treatment** that is generally available within a theater of operations.

c. *Acute Radiation Subsyndromes*. The subsyndromes of acute radiation syndrome include the hematopoietic, gastrointestinal, and cardiovascular/CNS syndromes. The syndromes are dose dependent, interrelated and cumulative. As dose is increased, the hematopoietic system, gastrointestinal system and cardiovascular/central nervous systems are each affected in turn, based largely on the radiosensitivity of the underlying cell and tissue system. Clearly, a dose sufficient to impact the gastrointestinal system will also

impact the hematopoietic system. Doses sufficient to impact the CNS system result in lethality before expression of the lower dose syndromes. The syndromes are discussed in turn below.

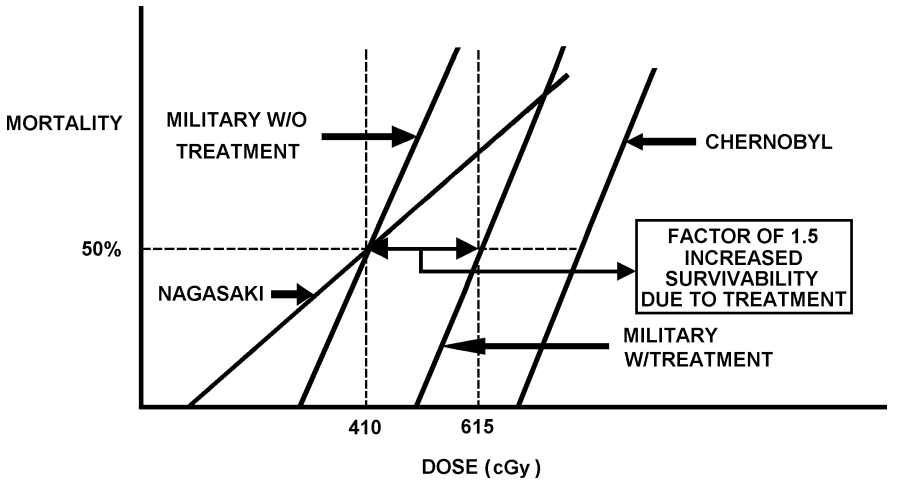


Figure 3-2. Estimates of medical intervention on dose effect models.

(1) *Hematopoietic syndrome*. Patients who received doses of radiation in the range of 200 to 600 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 3-3). 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.

(*a*) *Erythropoiesis*. 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. Death 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.

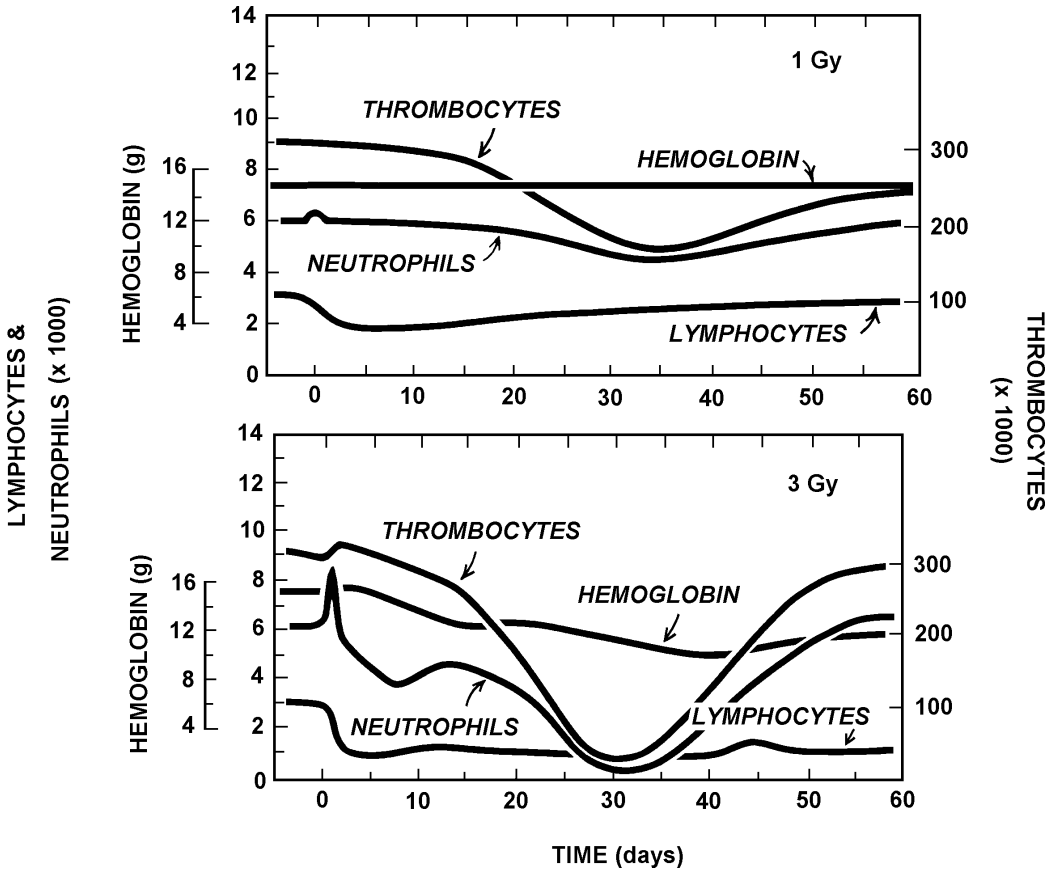


Figure 3-3. Hematological response to whole-body exposure of 1 Gy (100 cGy) and 3 Gy (300 cGy).

(*b*) *Lymphopoiesis*. 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 leukopenia will begin within hours and proceed to its nadir within 48 to 72 hours. 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 (see paragraph 3-10).

(*c*) *Leukopoiesis*. 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 are 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. Three to seven days are normally 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.

(*d*) *Thrombopoiesis*. 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 of 200–600 cGy, 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.

(2) *Gastrointestinal syndrome.*

(*a*) The gamma 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. Conversely, exposures to high doses at low dose rates or as fractionated exposures (multiple individual exposures totaling a specific dose) may not cause it. Regardless of the dose involved, the GI syndrome has a very serious prognosis, because it will almost always be accompanied by bone marrow suppression.

(*b*) 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*, in which nausea, vomiting, and diarrhea occur minutes to hours after exposure.

- *The Latent Phase*, which lasts a few days to a week.

- *The Manifest Phase*, in which the patient experiences 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 Chronic Phase*, in which survivors may develop fibrosis, bleeding, and fistulas months to years after exposure.

(3) *Cardiovascular/central nervous system syndrome*. 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 to receive such high doses would generally be located well within the range of 100 percent lethality due to blast and thermal effects (see paragraph 3-7).

(*a*) 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 among other damage.

(*b*) 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, which are severe and may last more than 24 hours, also include 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 (CV) collapse, leading to a relatively prompt and inevitable death.

3-7. Radiation-Induced Early Transient Incapacitation

Early Transient Incapacitation (ETI) 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.

a. 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. They do not 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. Exposure to doses of ionizing

radiation of approximately 2000 cGy results in an immediate precipitous decline in cerebral blood flow (CBF), which is followed by a partial recovery at 20 to 30 minutes, and subsequent slower secondary decrease in CBF, thereafter, accompanied by parallel changes in systemic blood pressure. The activity of certain brain enzymes involved in neurotransmitter metabolism is also considerably affected during ETI.

b. 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 ETI, uncomplicated by blast or thermal injury. Also, personnel protected from blast and thermal effects in shielded areas could also sustain doses that might manifest as ETI. Doses in this range could also 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 ETI 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.

Section III. DIAGNOSIS, SEVERITY, AND TRIAGE OF RADIATION CASUALTIES

3-8. Clinical Findings

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. One of the sources of information available to the medical staff is the medical military physicist (that is, the Army 72A, Air Force 43EX, 43YX, or Navy 0847 officers). Also, unit NBC personnel and chemical defense unit personnel can provide unit operational history information and perhaps collective unit exposure data. However, an accurate and prompt diagnosis of radiation sickness is based **primarily** 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. Some of these signs and symptoms, along with the information provided in Table 3-3, can help the clinician to estimate the approximate severity of the potential exposure.

a. Nausea and Vomiting. 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 that 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.

NOTE

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 use of this drug.

b. Hyperthermia. Casualties who have received a potentially lethal radiation injury show a significant rise in body temperature within the first few hours postexposure. Although the number of cases is few and is frequently overlooked, this condition appears to be a consistent finding. 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).

c. Erythema. 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 more).

d. Hypotension. A noticeable and sometimes clinically significant decline in systemic blood pressure has been recorded in victims who have received a supralethal whole body radiation dose. A severe hypotensive episode was recorded in one person who had received several thousand cGy. In persons who received several hundred cGy, a drop in systemic blood pressure of more than 10 percent has been 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.

e. Neurologic Dysfunction. 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. Without aggressive medical support, these patients succumb within 48 hours.

Table 3-3. Dose, Onset, and Duration of Symptoms

DOSE (cGy)	SYMPTOMS	ONSET	DURATION
0–35	None	N/A	N/A
35–75	Mild Nausea, Headache	6 Hours	12 Hours
75–125	Nausea/Vomiting (30%)	3–5 Hours	24 Hours
125–300	Nausea/Vomiting (70%)	2–3 Hours	3–4 Days
300–530	Nausea/Vomiting (90%) Diarrhea (10%)	2 Hours 2–6 Hours	3–4 Days 2–3 Weeks
530–830	Severe Nausea/Vomiting (90%) Diarrhea (10%)	1 Hour 1–8 Hours	Direct Transit into GI Syndrome
830–3000	Severe Nausea/Vomiting (90%) Disorientation (100%)	3–10 Min 3–10 Min	Persists Until Death 30 Min–10 Hours

3-9. Dosimetry

Dosimetry, at the present time, is useful in that it can help determine that an exposure has occurred, but it 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. Generally, they may not differentiate between single exposures and multiple exposures unless they are read at regular intervals. However, in a mass casualty situation in an operational theater where time is critical, decisions based only on dosimetric data may be all that is practical.

3-10. Laboratory Testing

a. 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 the severity of radiation injury only (see Figure 3-4). 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 2 weeks. More frequent sampling will increase the reliability of dose estimates. A useful rule of thumb: if lymphocytes have decreased by 50 percent and are less than 1.0 x 10^9/l within 24–48 hours, the patient has received at least a moderate dose of radiation. However, all personnel with lymphocyte levels of less than 2000/mm^3 at 24 hours postirradiation are candidates for treatment.

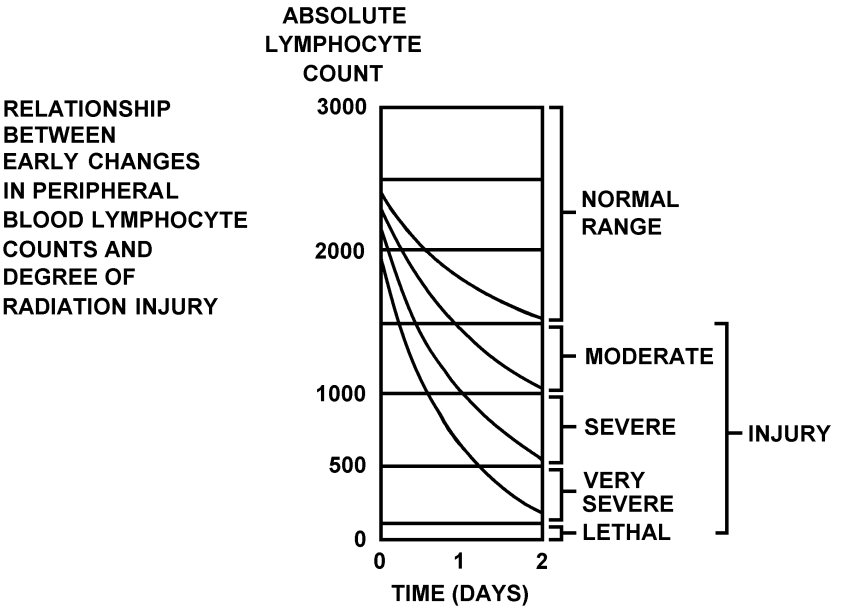


Figure 3-4. Lymphocyte nomogram.

b. Other medical assays can be used to determine the severity of exposure. Table 3-4 (adapted from AMedP-6(C), *NATO Handbook on Medical Aspects of NBC Operations*, Ratification Draft) lists clinical laboratory test and the treatment level where they should be performed.

Table 3-4. Medical Assay of the Radiological Patient

TEST	LOCATION/FACILITY			
	DECONTAMINATION POINT	MEDICAL TREATMENT UNIT (LEVEL 2)	HOSPITAL (LEVEL 3)	TERTIARY CARE (LEVEL 4)
Nasal swabs 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 4–12 hours for 3 days	Every 4–12 hours	
Human Leukocyte Antigen (HLA) subtyping		Draw sample	Draw sample before lymphocyte count falls	Draw sample before lymphocyte count falls
Cytomegalovirus (CMV)			+	+
Hemoglobin Agglutinin			+	+
Human Syncytial Cell Virus Antibodies				+
Human Immunovirus			+	+
Vesiculovirus				+
Lymphocyte Cytogenetics		Draw sample	Draw sample before lymphocyte count falls	+

+ Indicates test should be performed at this location/level of care.

3-11. Triage of Nuclear and Radiological Casualties

Casualty diagnosis and triage are linked in that diagnosis is an individual casualty determination, while triage takes that individual casualty information and applies it to a medical unit operational priority. This is

especially the case in a mass casualty situation in times of nuclear war or during consequence management of a catastrophic nuclear incident. A mass casualty situation is one where the number of patients requiring care exceeds the capabilities of treatment personnel and facilities. For example, the detonation of the high explosive (HE) component of a nuclear weapon (such as at Palomares, Spain) in a densely populated area can result in 50 patients requiring immediate care, yet the closest treatment facility can only provide for 10 patients. Thus, correct triage and evacuation procedures are essential.

a. Triage classifications for nuclear patients differ from conventionally injured patients. 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. That is, triage and care of any life-threatening injuries should be rendered without regard for the probability of radiation exposure or contamination. The physician should make a preliminary diagnosis of radiation injury only for those patients who display the appropriate radiation exposure symptoms, such as nausea, vomiting, diarrhea, hyperthermia, and so forth. The DIME method of triage codes is used for patient classification. That is, D = Delayed, I = Immediate, M = Minimal, and E = Expectant. Nuclear patient triage classifications are as follows:

(1) *Delayed treatment group* (*D*). Those needing surgery, but whose conditions permit delay without unduly endangering safety. Life-sustaining treatment such as intravenous fluids, antibiotics, splinting, catheterization, and relief of pain may be required in this group. Examples are fractured limbs, spinal injuries, and uncomplicated burns, and all casualties with only radiation injury who do not exhibit gross neurological symptoms. In the face of trauma combined with radiation injury, all surgical procedures must be completed within 36–48 hours of radiation exposure, or delayed until at least two months after the injury. Consequently, combined injury patients become the highest priority immediately after those requiring life or limb-saving surgery.

(2) *Immediate treatment group* (*I*). Those requiring immediate lifesaving surgery. Procedures should not be time-consuming and should concern only those with a high chance of survival, such as respiratory obstruction and accessible hemorrhage. Pure radiation injury is not acutely life-threatening unless the irradiation is massive. If a massive dose has been received, then the patient is classified as expectant (E).

(3) *Minimal treatment group* (*M*). Those with relatively minor injuries who can be helped by untrained personnel, or who can look after themselves, such those who have minor fractures or lacerations. Buddy care is particularly important in this situation. Patients with radiological injury should have all wounds and lacerations cleaned meticulously and then closed.

(4) *Expectant treatment group* (*E*). Those with serious or multiple injuries requiring intensive treatment, or with a poor chance of survival. These patients receive appropriate supportive treatment compatible with resources, which will include large doses of analgesics as applicable. Examples are severe head and spinal injuries, widespread burns, or neurological symptoms from massive doses of radiation. These casualties may be removed from this category as additional medical assets become available.

b. Table 3-5 provides radiation dosage, degradation of treatment, and treatment priorities for radiation and combined injuries.

Table 3-5. Radiation Dosage 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 he does not need immediate specialized care. Marrow resuscitative therapy should begin as soon as practical.

Section IV. TREATMENT OF RADIATION SUBSYNDROMES

3-12. First Aid

There is no direct first aid for radiological casualties. 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 21-11, *First Aid for Soldiers*.

3-13. Management of the Hematopoietic Syndrome

The primary goal of treating the hematopoietic patient is a reduction in both the depth and duration of leukopenia. 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 10 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.

a. Conventional Therapy of Neutropenia and Infection. 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/ml) 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 B) for prophylaxis are Ciprofloxacin as an antibiotic, Acyclovir as an antiviral agent, and Fluconazole (Diflucan) as an antifungal agent.

b. Prevention of Infection. 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 and H_2 blockers) 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 intravenous 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, but meticulous attention to proper care is necessary to reduce catheter associated infections.

c. Management of Infection.

(1) 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. First, 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 (ANC) is greater than or equal to 0.5×10^9 cells/l (500 cells/μl). 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 B).

(2) 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) 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, 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, that is, look for the reason the patient is infected, and eliminate it.

Overall recommendations for managing infections are summarized as follows:

- A standardized plan for 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.

d. Immune Globulin Administration. 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 (Ig) 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.

e. Hematopoietic Growth Factors (*Cytokines*). Hematopoietic growth factors, such as granulocyte-colony stimulating factor (G-CSF) (filgrastim [Neupogen®]) and granulocyte macrophage-CSF (GM-CSF) (sargramostim [Leukine®]), 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 GM-CSF, 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.

f. Thrombocytopenia and Anemia.

(1) *Conventional therapy of thrombocytopenia.* 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 x 10^9/l. Analysis of platelet counts versus hemorrhage suggests that 10 x 10^9/l is adequate in the absence of any indication of accompanying frank hemorrhage. If surgery is needed, the platelet count should be greater than 50 x 10^9/l. 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 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.

(2) *Growth factor/cytokine therapy for thrombocytopenia.* 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.

(3) *Conventional therapy of anemia.* Transfusion of packed red blood cells (PRBCs) remains the primary therapy to maintain hemoglobin above 8 gm/dl. 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 PRBC transfusion may include CMV transmission and alloimmunization. Gamma irradiation of blood products with 2000 cGy will diminish graft versus host reactions common in radiation casualties.

(4) *Erythropoietin therapy of anemia.* Use of erythropoietin (Epo) after radiation injury is not recommended even though it is likely to be safe. Endogenous Epo 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.

g. Bone Marrow/Stem Cell Transplantation. Stem cell transplantation usually has a limited role in the management of radiation casualties and can only be applied at select Level 5, fixed Continental United

States (CONUS) facilities. If possible, HLA typing should be done early. Also, 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.

3-14. Management of the Gastrointestinal Syndrome

a. 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 subacute 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 the early prodromal and subacute phases of diarrhea, agents directed against, or counteracting the effects of neurohumoral factors on GI cells should be considered. These include antidiarrheal/antisecretory agents such as anticholinergics, Metamucil, Amphojel, and Loperamide. Loperamide may offer distinct advantages as the drug affects both intestinal cell transport and motility, each of which may contribute to diarrhea. Antisecretory agents, however, will be of limited effectiveness against the acute phase of GI injury, during which the loss of epithelial cell lining has progressed to denudation of the intestine (See Appendix B).

b. 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.

c. 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.

d. The bactericidal effect of gastric acid on intestinal flora is well known. However, 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.

e. 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 (TPN) is inferior to direct enteric feedings. These data have not been replicated in trauma combined with radiation injury.

3-15. Management of the Cardiovascular/Central Nervous System Syndrome

As mentioned earlier, this syndrome is associated with very high acute doses of radiation, probably within the 2000 to 4000 cGy range. Shock accompanies these high doses, due to a massive loss of fluid into extravascular tissues through leaky vascular beds. 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. Therefore, aggressive medical support with pressors, fluids, steroids, and the like will bring only temporary improvement and may only serve to prolong suffering. Thus, therapy should include only palliative measures such as opiates or tranquilizers.

3-16. Recovery

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.

3-17. Summary of Medical Aspects of Acute Radiation Injury

Tables 3-6 through 3-9 summarize the current ideas on the treatment of radiation casualties at progressively increasing dose levels. The treatment modalities are meant as guidelines for medical officers during war conditions. Also, see Appendix C, Treatment Briefs.

Table 3-6. Medical Aspects of Radiation Injury (0 to 300 cGy)

DOSE (estimate)	INITIAL SYMPTOMS	INITIAL SYMPTOMS INTERVAL ONSET–END	ANTIEMETIC PRETREAT-MENT EFFECT	MEDICAL PROBLEMS	INDICATED MEDICAL TREATMENT	DISPOSITION WITHOUT MEDICAL CARE	DISPOSITION WITH MEDICAL CARE	CLINICAL REMARKS
0–35 cGy	None	N/A	Dry mouth. Headache.	Anxiety	Reassurance. Counsel at redeployment.	Duty	Duty	Potential for combat anxiety manifestation.
35–75 cGy	Nausea, mild headache.	ONSET 6 hrs. END 12 hrs.	Not determined	Anxiety	Reassurance. Counsel at redeployment.	Duty	Duty	Mild lymphocyte depression within 24 hrs.
75–125 cGy	Transient mild nausea, vomiting in 5–30% of personnel.	ONSET 3–5 hrs. END 24 hrs.	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 hrs. END 2 days.	Decreased vomiting. Possible increase of fatigability.	Significant medical care may be required at 3–5 wks 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 immunocom-promised 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 IAW command guidance.	Restricted duty. No further radiation exposure, elective surgery, or wounding.	If there are more than 1.7 X 10^9 lymphocytes per liter 48 hrs 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.

Table 3-7. Medical Aspects of Radiation Injury in Nuclear War (300 to 530 cGy)

DOSE (estimate)	INITIAL SYMPTOMS	INITIAL SYMPTOMS INTERVAL ONSET–END	ANTIEMETIC PRETREAT-MENT 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 hrs. END 3–4 days. Diarrhea ONSET at 10 days. END 2–3 wks.	Undetermined	Frequent diarrheal stools, anorexia, increased fluid loss, ulceration, death of crypt cells and Peyer's Patch lymphoid tissue. Increased infection susceptibility during immuno-compromised time frame. Bleeding diathesis at 3–4 wks due to megakaryocyte loss.	Fluid and electrolytes for GI losses. Consider cytokines for immunocom-promised 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 wks. No further radiation exposure. May require delayed evacuation from theater.	Increased percentage of survivors may be able to return to duty after 5 wks. No further radiation exposure. May require evacuation from theater for adequate therapy.	Moderate to severe loss of lymphocytes. Follow counts q6h in first few days if possible for prognosis. Moderate loss of granulocytes and platelets. Hair loss after 14 days. Thrombocytopenic purpura appears after 3 wks. 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 hrs after irradiation. Any additional surgery must be delayed until 6 wks postexposure.

Table 3-8. Medical Aspects of Radiation Injury in Nuclear War (530 to 830 cGy)

DOSE (estimate)	INITIAL SYMPTOMS	INITIAL SYMPTOMS INTERVAL ONSET–END	ANTIEMETIC PRETREAT-MENT 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 hr END indeterminate, may proceed directly to GI syndrome without a break.	None	At 10 days to 5 wks, 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 immunocom-promised 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 at 6 wks in more than 50% of personnel. At high end of exposure range, death may occur in 3–5 wks 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 hrs. 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 hrs after irradiation. Any additional surgery must be delayed until 6 wks postexposure. Partial marrow shielding may complicate bone marrow transplant. Steroid therapy is ineffective.

Table 3-9. Medical Aspects of Radiation Injury in Nuclear War (830 to 3000+ cGy)

DOSE (estimate)	INITIAL SYMPTOMS	INITIAL SYMPTOMS INTERVAL ONSET–END	ANTIEMETIC PRETREAT-MENT 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 at 2–3 wks. 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 dosage 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.

Section V. COMBINED INJURY—BLAST, THERMAL, AND RADIOLOGICAL INJURIES

3-18. General

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 NBC weapons.

3-19. Blast Injuries

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 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.

3-20. Treatment of Blast Injuries

Normally, treatment is divided into the following four basic phases—

a. Resuscitative Phase (*First Aid*). 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 advanced trauma life support standard therapies. Lifesaving resuscitative measures designed to prepare the patient for definitive surgical treatment come first. These include the establishment of the airway 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. That a wound is contaminated 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 21-11, *First Aid for Soldiers*.

b. Surgical Phase. 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, Part I, Volume 5, *Conventional Warfare, Ballistic, Blast and Burn Injuries* (Chapters 5-9). 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.

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

d. Convalescent Phase. 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 he can resume his duties. Both the convalescent and recovery phases will be more protracted with the addition of a radiation injury.

e. Orthopedic Injuries. 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. That is, 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.

f. Tetanus. All personnel receive mandatory immunization with tetanus toxoid when they enter active duty. However, members of today's professional military may serve many years after their initial immunizations; if they have not received a recent booster, they are at risk of developing tetanus if they are wounded. Therefore, all casualties, regardless of their injuries, will receive a tetanus toxoid booster (see Appendix C, paragraph C-15).

3-21. Thermal Injury

Thermal burns caused by fire, hot objects, hot liquids, and 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.

3-22. Determining Severity of Thermal Injuries

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: for example, the head and respiratory tract.
- Depth of burn: superficial (first- or second-degree), deep (second-degree), and full thickness (third-degree).

a. Area of burn. 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 3-10.

Table 3-10. Rule of Nines for Establishing Extent of Body Surface Burned

ANATOMIC SURFACE	% OF TOTAL SURFACE
Head and Neck	9 = 9
Anterior Trunk	2 x 9 = 18
Posterior Trunk	2 x 9 = 18
Upper Limbs	9 ea = 18
Lower Limbs	18 ea = 36
Genitalia and Perineum	1 = 1

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.

b. Involvement of critical organs. 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.

(1) *Head and neck burns.* Burns of the head and neck can be associated with upper respiratory tract edema, which can result in respiratory obstruction.

(*2*) *Burns of the deep respiratory tract*. These injuries may result in pulmonary edema with a resultant high probability of mortality.

c. *Depth of burn*. Burns are classified on the basis of the depth of the injury.

(1) *Superficial or partial skin thickness burns*. These are superficial and painful lesions which affect only the epidermis. These burns will heal readily if treated appropriately.

(2) *Deep or full-thickness burns*. These burns 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.

3-23. Treatment of Thermal Injuries

a. 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 field dressing to the burn. For a detailed discussion on first aid for burns, see FM 21-11, *First Aid for Soldiers*.

b. 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; and careful maintenance of medical records.

(1) *Maintenance of airway*. 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 have to 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. When only small numbers of patients require treatment, tracheotomies are rarely required.

(2) *Fluid therapy*. 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, Part I, Volume 5, *Conventional Warfare, Ballistic, Blast and Burn Injuries,* Chapter 11.

(3) *Input and output records*. It is extremely important to accurately follow the input 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. Combat medical records, however, must be simple and should be attached to the patient so that they accompany him during evacuation.

c. *Care of Burn Wound.* 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, after hospitalization, 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. Also, no data is available regarding the response to clostridial infection, but strong consideration should be given to the use of tetanus toxoid boosters as mentioned for wounds in paragraph 3-20. 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. Again, see Chapter 11, The Textbook of Military Medicine, Part I, Volume 5, *Conventional Warfare, Ballistic, Blast and Burn Injuries* for a detailed discussion of this issue.

3-24. Hematopoietic Effects of Combined Injury

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. Likewise, 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 3-11).

Table 3-11. Hematopoietic Effects of Combined Injury

RADIATION	TRAUMA
Anemia	Depletion of vascular reserves.
Bleeding	Abnormal clotting; increased viscosity.
Infection	Consumption of marrow progenitors.

3-25. Chemical Weapons and Radiation

Mustard agents and radiation can cause many similar effects at the cellular level. Therefore, 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. For example, little is known about the combined effect of

radiation and nerve agents. However, radiation will lower the threshold for seizure activity and thus may enhance the effects of nerve agents on the CNS.

3-26. Biological Weapons and Radiation

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 (BW) 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, since even 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.

3-27. Immunization and Radiation

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. However, the secondary response of the irradiated immune system to previously recognized antigens has not been thoroughly evaluated. Consequently, 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

4-1. General

As mentioned in Chapter 2, radioactive material released into the environment can pose both internal and external contamination hazards to personnel operating in either nuclear detonation or LLR environments. External hazards are generally associated with skin contamination, and include the biological effects of local tissue and 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.

4-2. Measuring Levels of Contamination

A number of methods are used to detect contamination and to estimate the extent of contamination. Direct methods include measuring skin contamination with hand-held radiation detection, identification, and computation (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.

a. Direct External Contamination Assessment. 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 Geiger-Muller probe contained as part of AN/VDR-2, AN/PDR-77, or ADM-300 RADIAC Sets. The use of these sets allows operational forces to survey patients for external contamination, determine whether decontamination efforts have been effective, or establish when forces have exceeded operational exposure guidance (OEG) levels. Specialized small probes may be used for deep wounds and can be cold sterilized for this purpose. Contaminated wounds 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.

b. Direct Internal Contamination Measurement. 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); also, measurements can 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 can either scan the whole body or "look at" the whole body to give total estimates of internal contamination.

c. Indirect Contamination Measurement.

(1) Skin and nasal swipes 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 swipes are sent to a laboratory where contamination can be measured, or dried and quick scanned locally. The detection of radioactive material in the nares usually indicates respiratory inhalation. However, under some situations inhalation exposures may not have an accompanying positive nasal result.

(2) 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 medical intervention and individual metabolic and clearance rates. Subsequent estimates of the amount of radioactive material initially inhaled and ingested are prone to significant variance.[5] However, 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, and 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. A detailed discussion of radiation measurement techniques including bioassay sampling can be found in Chapter 4 of NCRP Report No. 65, *Management of Persons Accidentally Contaminated With Radionuclides*.

Table 4-1. Guidelines for Bioassay Sampling

	OPTIMUM SAMPLE TIME AFTER EXPOSURE		
MATERIAL	**FECES**	**URINE**	**QUANTITY**
Plutonium	24 hours	2–3 weeks	24 hour total
Uranium	24 hours	24 hours	24 hour total
Tritium	N/A	12 hours	1 voiding

5. National Council on Radiation Protection (NCRP) and Measurements Report No. 65, 1979.

Section I. EXTERNAL CONTAMINATION, IRRADIATION, AND ACUTE LOCAL RADIATION INJURY

4-3. External Irradiation

The most serious injuries resulting from radiation accidents have been due to penetrating radiation from external sources.[6] External contamination by radionuclides can occur when an individual or unit traverses a contaminated area without appropriate protection, or remains in a hazardous downwind area when fallout occurs. If the individual is wounded while in the contaminated area, he may become internally contaminated. The radioactive contamination hazard of injured personnel to both the patient and attending medical personnel will be negligible, so necessary medical or surgical treatment must not be delayed because of possible contamination.

a. Medical personnel minimize the risk of exposure by following decontamination principles similar to those for BW and CW 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. Contain irrigation fluid in holding tanks and bag contaminated clothing and medical supplies and give them to radiation safety personnel. US medical personnel are subject to the same OEG as other military personnel. It should be noted that the highest actual dose recorded for a US health care worker was only 0.014 cGy, which occurred during the care of a radiation accident victim of a commercial nuclear power plant accident. That dose approximates the dose received during a single chest radiograph.

b. Use beta-gamma and alpha monitoring instruments for the initial radiation survey of the skin and clothing. If contamination is present on the clothing, remove it and repeat the monitoring over the patient's skin. 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 mm of skin. Skin on most areas of the body has a depth of 2 mm. The epidermis is approximately 0.1 mm 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 mm. Medical military 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 burns and scarring. However, it is highly improbable for a patient to be so contaminated that he is a radiation hazard to health care providers.

4-4. Decontamination

Decontamination is usually performed during the care of such patients by emergency service personnel and ideally, prior to the arrival at medical facilities. As this will not always be possible, decontamination

6. Ibid.

procedures 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 95% (military) and 90% (civilian) reduction in the patient's contamination. The presence of radiological contamination can be readily confirmed by slowly passing a radiation detector (RADIAC) over the entire body. Open wounds should be covered prior to decontamination of surrounding skin. Contaminated clothing should be carefully removed, placed in marked plastic bags, and removed to a secure location within a contaminated area. Bare skin and hair should be thoroughly washed, and if practical, the effluent should be sequestered and disposed of appropriately. See FM 8-10-7, *Health Service Support in a Nuclear, Biological, and Chemical Environment* for a detailed discussion on patient decontamination.

a. Skin Decontamination. 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 soap emulsifies and dissolves contamination. Gentle brushing or the use of an abrasive soap or abrasive granules dislodges some contamination physically held by skin protein, or removes a portion of the horny layer of the skin. 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.

b. Decontamination Techniques. Avoid unnecessary damage to the skin; cease washing before abrasion occurs. If washing will not remove stubborn hand and distal extremity skin contamination, wrap the contaminated area and, 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. Do not remove eyebrows without significant cause since they grow back slowly if at all. For skin and wound decontamination, use a cleaning solution. Suggested solutions are—

- Soap and water or normal saline.
- Betadine and water.
- Phisoderm and water.
- Hydrogen peroxide.
- Dakin solution (0.25 percent sodium hypochlorite).
- 0.05% chlorine solution (household bleach diluted with water at a ratio of 100 to 1).

4-5. Local Tissue Irradiation

Local irradiation of tissues occurs when highly radioactive material, such as an industrial radiography source, 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 dosage 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

DOSAGE (CGY)	SYMPTOM	TIME POST-EXPOSURE
>300	Epilation	2–3 weeks
~600	Erythema	Minutes to weeks
>600	Edema	Minutes to weeks
1000–2000	Blistering	2–3 weeks
~3000	Ulceration	1–2 months
5000–6000	Gangrene, necrosis, deep ulceration	Weeks

a. Initial skin changes will be similar to those of Cutaneous Radiation Syndrome (CRS) (see paragraph 4-6), 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.

b. Deep tissues respond in a similar fashion if the radioactive source is placed in their immediate proximity. Radiotherapy literature is the best source of information concerning injury to specific tissues and anatomic structures.

4-6. Cutaneous Radiation Syndrome

Acute skin injury occurs with radiation doses ranging from several hundred 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.

a. Cutaneous Radiation Effects. Effects follow a distinct clinical pattern that defines the CRS. The different steps of development, including the symptoms, are summarized in Table 4-3. 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 CRS 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 4-3. Clinical Stages of the Cutaneous Radiation Syndrome

STAGE	DEFINITION	SYMPTOMS	OCCURRENCE (POSTEXPOSURE TIME)	DURATION	SYNONYMS
1	Prodromal	Erythema itch	Minutes to hours	4 to 36 hours	Early erythema
2a	Manifest	Erythema	Days to 2 weeks	2 to 12 weeks	Main erythema
2b	Manifest	Blisters; Dry/moist desquamation Burn	Days to 2 weeks	2 to 12 weeks	Main erythema
2c	Manifest	Ulcers	Days to 2 weeks	2 to 12 weeks	Main erythema
3	Subacute	Erythema; Ulceration	6 to 9 weeks	2 to 4 months	Late erythema
4	Chronic Fibrosis	Keratosis; Ulceration Telangiectatic	Indefinite to 2 years	Progressive	
5	Late	Neoplasia; Ulceration Angiomas	Years to decades	Indefinite	

b. Chronic Cutaneous Radiation Syndrome. In the chronic stage of the CRS, three clinical manifestations dominate the course:

- Radiation keratoses can develop in any exposed area. These lesions must be considered precancerous 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 are a characteristic sign of the chronic stage of the CRS in humans. Apart from cosmetic disfiguring, they may cause a permanent itching sensation and a disturbing feeling of warmth.

4-7. Treatment of the Cutaneous Radiation Syndrome

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, dosages, and the therapeutic outcome are summarized in Table 4-4.

a. Experience in the management of the manifest stage of CRS 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 non-sedating 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 pilocarpine for prevention of mucositis. Heparinization and antibiotic prophylaxis for bacterial and viral infections may be beneficial.

Table 4-4. 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 X daily	Alleviation	None when used less than 3 weeks
Blisters	Steroids TCDO	Wet dressing	3 X daily	Alleviation	
Dryness	Linoleic acid cream	Topical	1 X daily	Inhibition of water loss	
Keratoses	Tretinoin Acitretin	Topical Oral	1 X daily 0.1-0.3 mg/kg	Clearance moderate	Irritation; dryness of lips
Inflammation	Mometasone	Topical	3–4 X week	Alleviation	
Fibrosis	IFN gamma PTX and Vitamin E	Subcutaneous Oral	50 mg 3 X week 400 mg 3 X daily + 300 mg 1 X daily	Reduction Reduction	Fever

b. Treatment modalities for the chronic stage of the CRS 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 (0.1–0.2 mg/kg daily) was used, analogous to the reported treatment of radiation-induced keratoacanthomas.

c. Subcutaneous administration of Interferon (IFN) has been beneficial to patients with severe and extensive radiation fibrosis (IFN 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 38.5°C after the first two injections. The

efficacy of IFN gamma may be explained in part by its antagonistic effect towards the cytokine TGF-beta, which is of importance for the induction of radiation fibrosis. Another therapeutic option for radiation fibrosis is the combined administration of PTX (400 mg three times daily) and vitamin E (400 mg once daily). This regimen, applied for a minimum of 6 months, ameliorated persistent radiation fibrosis that had been progressive for over 20 years. Topical dressings of TCDO induce considerable granulation and re-epithelization in erosive skin conditions. Radioprotective properties of TCDO have been reported in experimental models that also demonstrated regenerative capacities in complicated wounds.

d. 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. The surgical experience, derived from patients with skin fibrosis after deeply penetrating radiation therapy, was that skin grafts do not heal if the surrounding affected tissue is not completely removed.

Section II. INTERNAL CONTAMINATION AND IRRADIATION

4-8. General

Internal irradiation occurs when unprotected personnel ingest or inhale radioactive contaminants, or have contaminants become internalized via a traumatic wound. 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 (see Chapter 5). Contamination evaluation and therapy must never take precedence over treatment of conventional acute injuries. However, early recognition of internal contamination provides the greatest opportunity for removal of the contaminant, thus reducing the potential for further injury. See National Council on Radiation Protection and Measurements (NCRP) Report No. 65, *Management of Persons Accidentally Contaminated With Radionuclides,* for further detailed information on internal irradiation.

4-9. Internalization of Radioactive Materials

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.

a. Intake. In order of decreasing frequency, contaminants enter the body principally by the following four routes:

- Inhalation.

- Ingestion.
- Wound contamination.
- Skin absorption.

(1) *Inhalation*. 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. Those smaller than 1 micron will be naturally respired as the individual breathes out and those between 1 and 5 microns will be deposited 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. In addition, 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 (see Table 4-5).

Table 4-5. Clearance Times of Various Branches of the Human Respiratory Tract for Insoluble Particulates

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

(2) *Ingestion*. 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. However, most ingested heavy metal radionuclides will pass through the gastrointestinal 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 100 percent of tritium, iodine, and cesium that

are 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 4-6.

Table 4-6. 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	13–20	18
Lower Large Intestine	24	22

(3) *Wound contamination*. 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. For example, the more soluble the contaminant, the greater the absorption rate. In addition, comparatively smaller particles may be phagocytized in the tissues more rapidly and thus internalized more rapidly.

(4) *Skin absorption*. 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, overall, they constitute only a small surface area.

b. Distribution. Once a radionuclide is absorbed, it is distributed throughout the body via the circulatory and lymphatic systems. The rate of distribution to each organ is relative to the lymphatic or 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.

c. Metabolism and Excretion. 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 gastrointestinal 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. In general, compounds that are water soluble are excreted through the urine, while lipid-soluble compounds are excreted via the bile into the intestine.

4-10. Internal Contamination Treatment

a. Immediate Care. As discussed earlier, skin or wound contamination is almost never immediately life threatening to the patient or to medical personnel. Therefore, attending to conventional trauma injuries is the first priority. As soon as the patient's condition permits, steps should be taken to determine if internal contamination has occurred. Nasal swab samples for radioactivity should be obtained as early as possible. However, under some situations inhalation exposures may not have an accompanying positive nasal result. If contamination is present, especially in both nostrils, it is presumptive evidence that inhalation of a contaminant has occurred. A urine sample and feces sample should also be collected to help determine whether internal contamination has occurred.[7] Advice on collection procedures are discussed in detail in the NCRP Report No. 65, and may also be provided by a medical military physicist.

b. Treatment Procedures. 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: [8]

(1) Oral and nasopharyngeal irrigation.

(2) Stomach lavage until stomach washings are relatively free of radioactive material.

(3) Emetics to induce vomiting. Emetics are most effective when taken with 200–300 ml 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.

(4) Purgatives or laxatives to enhance intestinal motility.

(5) Enemas or colonic irrigations to reduce the time radioactive materials remain in the colon.

7. Ibid.

8. Ibid.

c. Therapeutic Agents. 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 B, and in NCRP Report No. 65.

(1) *Prussian blue*. The US Food and Drug Administration has removed earlier restrictions on the use of Prussian Blue (ferric ferrocyanide) in the US. It has been approved as an investigational new drug, and the Radiation Emergency Assistance Center/Training Site (REAC/TS) has the license for research use. Prussian blue is indicated for treatment of cesium, thallium, and rubidium contamination. This chemical is not absorbed by the GI tract and it works through two modes of action. It decreases the absorption of many radionuclides into the GI tract, and removes some radionuclides from the capillary bed surrounding the intestine and prevents their reabsorption. Prussian Blue is most effective when given early after ingestion and serially thereafter.

(2) *Blocking and diluting agents*. 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 is an excellent example of a blocking agent, and must be given before or within 6 hours of exposure to radioiodine (see Table 4-7).

Table 4-7. Recommended Prophylactic Single Doses of Stable Iodine

AGE GROUP	MASS OF TOTAL IODINE	MASS OF KI	MASS OF KIO^3	VOLUME OF LUGOLS SOLUTION
Adults/adolescents (over 12 yrs)	100 mg	130 mg	170 mg	0.8 ml
Children (3–12 yrs)	50 mg	65 mg	85 mg	0.4 ml
Infants (1 mo–3 yrs)	25 mg	32.5	42.5	0.2 ml
Neonates (birth–1 mo)	12.5 mg	16 mg	21 mg	0.1 ml

(3) *Mobilizing agents*. Mobilizing agents are compounds that increase the excretion of internal contaminants. Examples of mobilizing agents are the antithyroid medications—(propylthiouracil, methimazole, and potassium thiocyanate), ammonium chloride, and diuretics.

(4) *Chelating agents*. Chelators are a specific type of mobilizing agent that enhances the elimination of metals from the bloodstream before they reach target organs. For example, chelation is ineffective at removing plutonium already deposited in the bone. Chelators are organic compounds (ligands) that exchange less firmly bonded ions for metal ions. This stable complex, the chelator and the metal, is then excreted by the kidney. Chelation therapy has been used for enhanced elimination of lead, mercury, arsenic, and other heavy metals. In addition, chelation therapy has been used to treat internal radiation contamination on a limited basis. When used to treat internal radiation contamination, radioactivity levels

from samples of urine and feces must be followed as well as radioactivity levels based on total body and chest counts. Continuation of therapy is determined by assessing chelation yield in urine and feces with remaining body burden. No serious toxicity in humans has been reported when chelators are used in recommended doses. Examples of chelators include meso-2,3-dimercaptosuccinic acid (DMSA), 2,3-dimercapto-1-propanesulfonic acid (DMPS), calcium diethylenetriaminepentaacetic acid (CaDTPA), and DTPA.

CHAPTER 5

LOW-LEVEL RADIATION

5-1. Low-Level Radiation Characteristics and Hazards

a. For purposes of this manual, LLR patients are those who have received doses of 75 cGy or less. Low-level radiation may be present in 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 (alpha, beta, neutron, and gamma) may be emitted by the material present in LLR sources. Sources of LLR were discussed in detail in Chapter 1, and are generally radioactive material from nuclear facilities (power plants), industrial and medical commodities, RDDs, nuclear weapons incidents, and military commodities.

b. The current threat to US Forces involve primarily terrorist actions with improvised nuclear devices or RDDs, and hazards due to nuclear incidents. In contrast to the risks associated with nonstrategic or strategic 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 CBCs expected at the highest doses in this range. However, they could be above the US and host nation occupational dose limits that are applied to civilian workers and military personnel assigned to routine duties involving radiation exposure. Because of this, doctrine development goes beyond helping military personnel to survive acute radiation injuries. It now includes medical care and follow-up for delayed health effects from low-level radiation exposures (primarily the development of radiation induced cancer). This chapter will cover low-level radiation exposure guidance, delayed/late health effects, prevention, medical care for exposed personnel, long-term medical follow-up, and documentation of medical records. Further, these medical considerations will likely be a part of the commander's operational plan.

Section I. LOW-LEVEL RADIATION EXPOSURE

5-2. Exposure Guidance

a. In peacetime while not deployed, radiation exposures of service members whose normal operational duties include, for example, handling of military radioactive commodities, are governed by Department of Defense Instruction (DODI) 6055.8, *Occupational Radiation Protection Program*, federal regulations governing radiation protection, and service specific instructions and regulations. 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 ALARA (as low as reasonably achievable) still applies.

b. The occupational annual dose limit is 5 cGy, while 75 cGy is the threshold for the development of acute health affects that become a concern in nuclear war. The most current exposure guidance between

these two limits is found in Table 5-1 which is from NATO STANAG 2473, *Commanders Guide on Low-Level Radiation (LLR) Exposure in Military Operations*. 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 to 75 cGy are confined primarily to the risk of increased incidence of malignant diseases, including solid tumors and leukemias (see Section II, Delayed/Late Health Effects). Added to this table, are medical notes for each RES and the stochastic risk of long-term health effects as adapted from AMedP-6(C), *NATO Handbook on Medical Aspects of NBC Operations*, Ratification Draft. 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, Annexes C and D for exposure limits while operating in contaminated areas.

Table 5-1. Low-Level Radiation Guidance for Military Operations

TOTAL CUMULATIVE DOSE (SEE NOTES 1 AND 2)	RADIATION EXPOSURE STATE CATEGORY	RECOMMENDED ACTIONS	STOCHASTIC RISK	MEDICAL NOTES
0–0.05 cGy	0	–None	Normal Risk: < 0.004%	US baseline 20% lifetime risk of fatal cancer.
0.05-0.5 cGy	1A	–Record individual dose readings. –Initiate periodic monitoring (including air and water).	Up to 0.04% increased risk of lifetime fatal cancer.	None
0.5-5 cGy	1B	–Record individual dose readings. –Continue monitoring. –Initiate rad survey. –Prioritize tasks. –Establish dose control measures as part of operations.	0.04%–0.4% increased risk of lifetime cancer.	Reassurance
5-10 cGy	1C	–Record individual dose readings. –Continue monitoring. –Update survey. –Continue dose control measures. –Execute priority tasks only (see note 3).	0.4%–0.8% increased risk of lifetime fatal cancer.	Counsel regarding increased long-term risk; no live virus vaccines for 3 months.
10-25 cGy	1D	–Record individual dose readings. –Continue monitoring. –Update survey. –Continue dose control measures. –Execute critical tasks only (see note 4).	0.8%–2% increased risk of lifetime fatal cancer.	Potential for increased morbidity of other injuries or incidental disease.

Table 5-1. Low-Level Radiation Guidance for Military Operations (Continued)

TOTAL CUMULATIVE DOSE (SEE NOTES 1 AND 2)	RADIATION EXPOSURE STATE CATEGORY	RECOMMENDED ACTIONS	STOCHASTIC RISK	MEDICAL NOTES
25-75 cGy	1E	–Record individual dose readings. –Continue monitoring. –Update survey. –Continue dose control measures. –Execute critical tasks only (see note 4).	2%–6% increased risk of lifetime fatal cancer.	Increased morbidity of other injuries or incidental disease.

NOTES:

1. The use of the measurement multiple of Sv is preferred in all cases However, due to the fact that normally the military has only the capability to measure cGy, as long as the ability to measure in mSv is not possible, NATO forces will use cGy. For whole body irradiation, 1 cGy = 1 cSv.
2. All doses should be kept ALARA. This will reduce individual soldier risk as well as retain maximum operational flexibility for future employment of exposed soldiers.
3. Examples of *priority* tasks are those missions to avert danger to persons or to prevent damage from spreading.
4. Examples of *critical* tasks are those missions required to save lives.

Section II. DELAYED/LATE HEALTH EFFECTS

5-3. General

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 tends to be stochastic in nature, relating more to a stochastic response in exposed populations than 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.

5-4. Principles

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.

5-5. Types of Long-Term Effects

a. 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 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.

b. A stochastic effect is a consequence based on statistical probability. For radiation, tumor induction is the most important long-term sequelae 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.

5-6. Embryonic and Fetal Effects

Radiation-induced embryonic/fetal effects have been clearly documented by the increased mental retardation in Japanese children irradiated *in utero* as result of the nuclear bomb detonations over Hiroshima and Nagasaki. The direct military relevance of these fetal effects (as well as related ones, including microcephaly, microphthalmia, reduced growth, skeletal defects, neoplasias, and cataracts) is questionable. 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. No increase in this rate has ever been observed among radiation exposed humans.

5-7. Reproductive Cell Kinetics and Sterility

a. 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.

b. 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.

5-8. Carcinogenesis

Irradiation of almost 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.

a. 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.

b. It is difficult to address the radiation-induced cancer risk of an individual patient due to the already high background risk of developing cancer over a lifetime. Current National Academy of Sciences reports estimate that the *lifetime* risk of fatal cancer occurrence is increased by 770 cases per 100,000 persons/10 cGy for males and 810 cases per 100,000 persons/10 cGy for females. To illustrate this effect, the US 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 20,800 fatal cancers would occur. Deciding which 800 of these 20,800 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.

c. 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.

d. 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 nominal risks for radiation induced cancers and fatal cancers for the general population are given in Table 5-2. The information presented is an International Council on Radiation Protection (ICRP) summary of risks as presented in the reference manual for the Oak Ridge Institute for Science and Education course on Medical Planning and Care in Radiation Accidents. 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 Council on Radiation 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)

5-9. Cataract Formation

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 BEIR V, *Health Effects of Exposure to Low Levels of Ionizing Radiation,* 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.

Section III. PREVENTION, INITIAL ACTIONS AND MEDICAL CARE AND FOLLOW-UP

5-10. Prevention

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. 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 (MOPP) levels. For a detailed discussion of protective measures, see FM 3-4, *NBC Protection*, which is under revision as a multiservice manual. Medical personnel contribute to the prevention effort by providing input into the following staff actions:

- A risk assessment that includes analysis of intelligence 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. 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.

5-11. Initial Actions

If personnel encounter a radiological hazard, initial actions may include evacuation from the area, calling in the proper NBC reports, informing the local civil authorities, and requesting specialized monitoring and survey teams. At this time, medical personnel will provide input into staff estimates and plans that will establish control measures to contain the LLR hazard. This would include advice on modifying the commander's OEG 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.

5-12. Medical Care

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 stochastic effects, 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.

a. Early and Delayed Deterministic Effects. It is unlikely that symptoms of deterministic effects will appear due to acute whole or partial body radiation doses of less than 100 cGy. Early evidence of acute radiation-induced cellular injury, for example, structural changes in the chromosomes of some circulating lymphocytes, and falls in the absolute lymphocyte and sperm counts, is, however, clinically detectable in asymptomatic individuals who have received lower doses.[9]

b. Stochastic Effects. The primary stochastic late effect of exposure to radiation is the development of radiation-induced tumors and leukemia (see paragraph 5-8). Radiation-induced or radiogenic tumors are histologically and clinically indistinguishable from spontaneously occurring tumors. Their diagnosis, treatment, and management are the same as those for spontaneously occurring cancers of the same type.[10]

5-13. Medical Follow-Up

The low-level dose range (5 to 75 cGy) is unlikely to cause delayed acute or chronic deterministic effects. Therefore, this paragraph will address medical follow-up actions involved with the main long-term effect of radiation exposure—malignant disease.[11]

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9. Potential Radiation Exposure in Military Operations, Protecting the Soldier Before, During, and After (National Academy of Sciences, 1999).
10. Ibid.
11. Ibid.

a. Medical Assessment. 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.

b. Medical Monitoring.

(1) 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.

(2) 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 US 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.

(3) The Institute of Medicine in their committee report: *Potential Radiation Exposure in Military Operations* (1999), 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.

5-14. Documentation of Radiation Exposure Records

a. The OEG concept requires that all units maintain radiation exposure records. Currently, US Army records are based on platoon-level 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, usually two per squad in the US Army. Therefore, the US Army assumes that each soldier receives an individual dose equal to that of the average for the platoon. The records are usually kept by the unit chemical officer at battalion level. When a soldier transfers out of an exposed unit, the RES for that platoon is noted in the soldier's personnel file. When possible, soldiers are reassigned to platoons with the same RES category. Although this might create personnel strength management problems, it is intended to prevent personnel from incapacitation due to overexposure to radiation in future operations. The other services have 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.

b. In an LLR environment, STANAG 2473, *Commanders Guide on Low Level Radiation (LLR) Exposure in Military Operations*, 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 LLR exposure." Clearly, the intent is to equip all service members in the unit with appropriate dosimeters if the unit anticipates conducting operations in a radiologically hazardous area. The NATO NBC Medical Working Group is currently developing STANAG 2474, *Low-Level Radiation Dose Recording* in order to clarify record-keeping requirements.

CHAPTER 6

PSYCHOLOGICAL EFFECTS AND TREATMENT OF PSYCHOLOGICAL CASUALTIES

6-1. General

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 psychiatric casualties were 23 percent of all nonfatal casualties. Complicating matters further, psychological stress 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 *battle fatigue* in World War II. In RDD or nuclear incident scenarios, psychological stress 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 spectrum 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 manifest. 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.

6-2. Radiation Dispersal Devices and Nuclear Incidents

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 US forces or civilians, and approximately 35 years have passed since US forces have dealt with a major nuclear incident (Palomares, Spain).

a. Psychological Effects of RDDs and Nuclear Incidents. The use of an RDD 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 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 stress on military personnel and likely produce more psychological casualties.

b. Incidence. Exposure, or perceived exposure to radiation can be expected to increase the number of psychological stress casualties. The number of casualties will also depend on the level of leadership, cohesiveness, 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 post traumatic stress disorder. An RDD 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. Behaviors such as altruism, heroism, and loyalty to comrades typically seen in units with exceptional *esprit de corps*, may alleviate some of the psychological stress.

6-3. Nuclear Detonation

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 quaking 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.

a. 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 is 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).

b. Somatic effects such as nausea, vomiting, diarrhea, and a feeling of weakness or fatigue would be likely to 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.

6-4. Fallout Field

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.

6-5. Psychosocial Sequelae of Radiation Exposure

a. Psychosocial Sequelae. 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 ARS 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.

b. Psychological Factors at Chernobyl.

(1) Many of the recovery team members, *liquidators*, called in to help with the cleanup of the reactor at Chernobyl were military personnel. A 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 (MUPS) 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.

(2) 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.

6-6. Treatment

a. The treatment of psychological stress resulting from actual or perceived exposure to radiation is the same as that for battle fatigue. The principles of proximity, immediacy, expectancy, simplicity (PIES) are the cornerstones of treatment—

- Proximity means to treat the psychological casualty as close as possible to the unit and the area from which he 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 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.

b. Generally, treatment modalities consist of the following—

(1) 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. The individual should be made to feel that he or she has an excellent chance of recovery, which is true in most cases.

(2) Rest with removal from immediate danger. A short period of rest in a safe area is of great benefit.

(3) 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.

c. 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 non-hospital treatment setting as soon as their condition permits.

6-7. Prevention and Risk Communication

a. Prevention. 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. 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 MOPP 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 should have operational RADIAC equipment and dosimeters. Normally, only unit dosimetry readings are possible. Dosimeters should be issued to each individual in accordance with the commander's priorities and equipment availability constraints. Individual dose information can therefore be provided to alleviate fears of receiving large doses. In fallout fields, combat stress 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 NBC reporting procedures and formats.

b. Risk Communication.

(1) To effectively communicate 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. 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 mental health personnel.

(2) 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 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 OEG for their mission, the radiation exposure state (RES) 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.

APPENDIX A

DEPLETED URANIUM

A-1. General

Depleted uranium is neither a weapon of mass destruction nor a chemical or radiological hazard. It is also not a nuclear or a radiological weapon. The hazards associated with DU are comparable to other munitions. Depleted uranium is included in this manual for the convenient access of information by military medical personnel. Depleted uranium munitions and armor plating proved their effectiveness during Operation Desert Storm (ODS). In fact, DU armor and munitions were so successful that other nations are now using, or developing DU munitions and armor plating. Therefore, in any future conflict involving antiarmor weapons systems using kinetic energy (KE) ammunition, it is likely that the enemy will use DU munitions against US ground forces. This appendix will discuss the characteristics of DU, toxicity and health risks, and clinical treatment of personnel wounded by DU munitions.

A-2. Depleted Uranium Characteristics and Uses

Depleted uranium is a heavy, silvery-white metal when freshly machined. It is a little softer than steel, ductile and slightly paramagnetic. In air, DU becomes coated with a layer of oxide that gives it a dull black or yellow color. Chemically and toxicologically, DU has the same characteristics as natural uranium. Natural uranium is predominantly Uranium-238 (U-238) by weight, but also contains isotopes U-234 and U-235. As part of the nuclear fuel cycle, natural uranium is processed in enrichment facilities to obtain uranium with a higher U-235 content; this is called enriched uranium. The enriched uranium is then used in nuclear reactors and nuclear weapons. The waste product of the enrichment process is uranium that has a lower content of U-235 and is known as DU because it is *depleted* of the high activity radioactive isotope. Therefore, it is less radioactive than natural or enriched uranium. Table A-1 shows an isotope comparison between DU and natural uranium. Alpha, beta, and gamma radiation are emitted from DU, but because of the long half-life of U-238, the specific activity is relatively low. For example, to obtain one curie of radioactivity from DU would require a single piece weighing 6,615 pounds. DU also contains trace amounts of transuranics: Plutonium-238, 239/240, Neptunium-237, Americium-241. It also contains trace amounts of Uranium-236 and Technetium-99. These amounts are so low that they do not increase the toxicological risk, and increase the radiation dose by much less than one percent.

Table A-1. Comparison Between Depleted Uranium and Natural Uranium

URANIUM ISOTOPE	NATURAL URANIUM	DEPLETED URANIUM
U-234	0.0057%	0.0005%
U-235	0.7204%	0.2500%
U-238	99.2739%	99.7495%
TOTAL	100%	100%

a. Because of its high density and structural properties, DU is useful for conventional munitions and as part of US tank armor. Depleted uranium armor is the most effective armor for protection against all types of munitions, including KE munitions made out of tungsten carbide and DU. The Abrams tank family (M1, IPM1, M1A1, and M1A2) has an improved hull armor envelope that does not contain DU. However, M1A1 heavy armor (HA) and M1A2s have armor modules on the existing left and right frontal turret armor. The DU in these modules is completely encapsulated in steel. The front slope of the turrets of these tanks has a radioactive signature; a little less than 0.005 mSv/hour.

b. Depleted uranium is also used offensively in antiarmor ammunition. The combination of high hardness, strength, and density makes DU alloys well suited for KE ammunition. Another useful property of DU is that as it moves through the armor it maintains the sharpness of the penetrator, further enhancing its penetrating power. (The fact that tungsten carbide and other types of tungsten penetrators do not sharpen on impact—but in fact mushroom to a certain extent—is one reason they are less effective for overcoming armor plating.) Current US weapons systems and their associated DU munitions are shown in Table A-2. In general, DU ammunition may only be fired during combat and, similar to other types of service ammunition, is not fired in peacetime training. DU is fired on ranges for testing and quality assurance purposes on ranges which have been approved and licensed by the Nuclear Regulatory Commission (NRC).

Table A-2. List of Depleted Uranium Munitions by Weapons System

TANK AMMUNITION 105 mm	TANK AMMUNITION 120 mm	BRADLEY FIGHTING 25 mm	A-10 30 mm	HARRIER 25 mm	PHALANX 20 mm
M774	M827	M1919	PGU-14/B	PGU-20	MK-149
M833	M829		PGU-14A/B		
M900	M829A1		PGU-14B/B		
	M829A2		PGU-14A/A		

A-3. Depleted Uranium Toxicity

Although DU is not a chemical or radiological hazard, it can present a chemical toxicity hazard and perhaps a long-term radiological health risk under some conditions when it is introduced internally to the body. Some risks associated with DU munitions have been evaluated experimentally, some risks are still under study, and some risks were identified from practical experience during ODS. Depleted uranium internalization via inhalation is the primary concern.

a. When a kinetic energy penetrator strikes armor plating, a pyrophoric effect occurs. That is, a very fast moving, dense heavy metal penetrator striking steel armor will produce a white-hot ignition (flash) at the point of penetration. This pyrophoric effect occurs with either a conventional tungsten carbide penetrator (although to a lesser extent) or a DU penetrator. With a DU round, the penetration process generates high concentrations of airborne, breathable, DU oxides and high velocity shards of metal that can cause serious wounds. Data gathered from tests and friendly fire incidents show that only personnel in, on, or near (within 50 meters) the target vehicle at the time the vehicle was struck by a DU penetrator may

internalize DU in excess of safety standards. This internalization takes place through inhalation, ingestion, wound contamination, and embedded DU fragments. Almost as soon as the round hits and the dust has settled, the levels of airborne DU on the outside of the vehicle will rapidly fall to levels that are much lower than the safety standards prescribed by Occupational Safety and Health Act (OSHA) and the NRC. It is important to place the possible hazards due to DU penetration into perspective. When a DU penetrator strikes a vehicle, the effects include a spray of molten metal, shards of both penetrator and vehicle armor, and secondary explosions in stored ammunition. The interior of the struck vehicle will be contaminated with both DU dust and fragments, and with other materials generated from burning interior components. Therefore, medical personnel need to focus on managing the more immediate severe conventional injuries such as blast and ballistic wounds, burns, and inhalation injuries derived from the initial penetration as well as from secondary fires or explosions.

b. Inhaled uranium compounds may be metabolized, and result in urinary excretion of these compounds. Absorption will be determined by the solubility of the uranium. While soluble salts such as chlorides are readily absorbed, DU metal is not. Consequently, shortening gastrointestinal transit time will diminish adsorption.

A-4. Health Effects of Exposure to Depleted Uranium

a. General. The Gulf War was the first time there was widespread use of DU, so there is relatively little experience in dealing with the health effects of this material. However, since 1993, the Department of Veterans Affairs (VA) has been conducting a follow-up of 33 Gulf War veterans who were seriously injured in friendly fire incidents involving DU. Many of these veterans continue to have medical problems relating to the physical injuries they received during these incidents. About half of this group still have DU metal fragments in their bodies. This follow-up effort and other related studies indicate that the major health concerns about internalized DU relate to its chemical toxicity as a heavy metal rather than to its radioactivity, which is very low. In fact, DU is classified in the lowest hazard class of all radioactive materials. (See the Rand Report, *A Review of the Scientific Literature as it Pertains to Gulf War Illness,* Volume 7, *Depleted Uranium,* for a detailed discussion of the health effects of DU.)

b. External Exposure. Depleted uranium emits alpha, beta, and weak gamma radiation. Due to the metal's high density, much of the radiation never reaches the surface of the metal. It is thus "self-shielding". Also, intact DU rounds and armor are packaged to provide sufficient shielding to stop the beta and alpha radiations. Gamma radiation exposure is minimal. After several months of continuous operations in an armored vehicle completely loaded with DU munitions, crew exposures might exceed peacetime general population exposure limits but would not exceed peacetime occupational exposure limits. Hence, DU is not a serious irradiation threat.

c. Internal Exposure. In a ground combat environment, routes of internal exposure are generally inhalation, ingestion, wound contamination and embedded fragments. For example, the pyrophoric effect produces uranium dusts or aerosol particles, which can be inhaled resulting in uranium entering the blood

from the lungs.[12] Also, some inhaled uranium and some of the uranium originally in the lungs ends up in the GI tract as a result of mucociliary clearance from the respiratory tract and subsequent swallowing. In the case of embedded fragments, uranium is introduced to the body as the fragments slowly dissolve. Uranium accumulates to some degree in all organs, however, the kidney is considered to be the target organ for uranium chemical toxicity.[13] Gulf War veterans with embedded DU fragments have shown higher than normal levels of uranium in their urine since monitoring began in 1993. The key to the health effect is the amount internalized. Studies have shown that safety standards for internalized uranium may be exceeded only for personnel who were in, on, or near (less than 50 meters) an armored vehicle at the time the vehicle was struck by DU.

d. Chemical Toxicity. In 1997, 29 of the original 33 Gulf War veterans were reevaluated. Of those evaluated, about half were identified as having retained DU fragments. The majority of these individuals had elevated 24-hour urinary uranium levels. This suggests that DU was being dissolved in body fluids; thus, these metal fragments are not entirely inert. Although these individuals have an array of health problems, many of which are related to their combat injuries, to date all tests for kidney function have been normal. Laboratory tests also found DU in semen in samples from some, but not all, veterans exposed to DU. To date, all babies fathered by these veterans between 1991 and 1997 have had no birth defects. Wounds that contain DU may develop cystic lesions that alter and allow the absorption of the uranium metal. This has been demonstrated in two veterans of the Persian Gulf War who were wounded by DU fragments that were subsequently removed. Of the known casualties wounded by DU munitions, all have elevated urinary concentrations of uranium. Studies in scientific models have demonstrated that uranium will slowly be distributed systemically with primary deposition in the bone and kidneys from these wounds. Scientific data now demonstrate skeletal and renal deposition of uranium secondary to implanted DU fragments. There is uncertainty over the toxic level for long-term chronic exposure to internal uranium metal, but no renal or skeletal damage has been documented to date in Gulf War veterans with embedded DU fragments.

e. Radiological Toxicity. The biological properties of uranium in the body and its absorption from the GI and respiratory tracts are reasonably well known from occupational exposures (for example, uranium miners), studies of normal environmental intake, and animal studies. There is no evidence of cancer or any other negative health effect related to the radiation received from exposure to natural uranium, whether inhaled or ingested, even at very high doses. There is evidence of lung cancer in uranium miners from previous epidemiological studies, but this is related to exposure to a combination of airborne short-lived decay products of radon and other air toxicants, such as silica dust, diesel fumes, and cigarette smoke. Based on the distribution in the body and the known body organ content, no health effects from radiation would be expected even for high occupational exposures. This results mainly because of the low radioactivity of natural uranium and the inability to get enough into the body to deliver a radiation dose that could be significant in causing cancer. The same would be true for DU. Studies have not shown a link between the inhalation or ingestion of either natural uranium or depleted uranium and any form of cancer.

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12. Harley, Naomi H., et al., *A Review of the Scientific Literature as it Pertains to Gulf War Illnesses*, Vol. 7, *Depleted Uranium* (The Rand Corporation, 1999).

13. Ibid.

A-5. Patient Management of Personnel Wounded by Depleted Uranium Munitions

a. Determining the Presence of Depleted Uranium.

(1) There are several situational indicators pointing to the presence of DU that may have been observed by the patient or other members of the unit:

- Patient's vehicle was struck by a KE penetrator.
- Patient's vehicle was struck by friendly fire from US tanks or aircraft. This alone does not confirm DU was used since US weapons systems fire a variety of antiarmor munitions.
- An observer reports that he saw a white hot flash and sparkler-like burning fragments when the vehicle was struck (pyrophoric effect). Again, this alone does not necessarily confirm a DU munition, since all KE penetrators present a white hot flash to a certain extent.
- Patient's medical card stated suspected wounding with DU munitions or inhalation of DU particles.

(2) Because of DU's high density, fragments are readily visible on a radiograph and will appear similar to steel or lead fragments in the body. However, radiography alone is not sufficient to determine the presence of DU, since there will be some soldiers in vehicles struck by DU munitions that will have embedded metallic fragments from the vehicle's armor and other components. Also, shards from tungsten carbide penetrators will cause similar wounds and will appear radiographically the same.

(3) If readily available, Radiac Meter AN/VDR-2 *with the beta shield open* may be used to monitor wounds, burns, or suspected sites with embedded fragments. This will confirm DU wound contamination, and will provide confirmation of wound decontamination. UNDER NO CIRCUMSTANCES SHOULD TREATMENT BE DELAYED IN ORDER TO OBTAIN AN AN/VDR-2.

(4) Operation Desert Storm experience showed that the most sensitive indicator that DU has been internalized is a uranium urine bioassay. In general, embedded DU fragments will slowly dissolve and be transported in the blood. Eventually, the patients will excrete uranium in the urine. The level of uranium in the urine will remain constant for long periods of time. Results of the medical monitoring of patients from ODS showed that the highest uranium urine levels were on the order of 30 to 40 micrograms of total uranium per gram of creatinine. The monitoring was initiated in 1993, and the levels have remained generally constant. In all likelihood, the levels were higher at the time the soldiers were wounded. How much higher is not known. See Memorandum For The Commander, USA AMEDD Center and School, dated 9 April 1999, Subject: Policy for the Treatment of Personnel Wounded by Depleted Uranium Munitions for detailed procedures on conducting DU urine bioassays.

b. Clinical Treatment of Personnel Wounded By DU Munitions.

(1) Casualties may have DU contamination on their clothing and skin. UNDER NO CIRCUMSTANCES SHOULD CASUALTY EXTRACTION, TREATMENT, OR EVACUATION BE

DELAYED DUE TO THE PRESENCE OF DU. Standard aidman procedures for treating combat wounds should be followed.

(2) Wounds and burns should be cleaned and debrided using standard surgical procedures. Normal "universal precautions" (surgical gloves, surgical mask, and throwaway surgical gowns) are more than adequate to protect medical personnel from accidental contamination with DU. Items contaminated with DU should be disposed of using standard universal precaution procedures. The use of a sensitive radiation meter may assist in wound debridement and cleaning. The AN/VDR-2 RADIAC Meter *with the beta window open* may assist in locating DU contamination in the wound or burn. UNDER NO CIRCUMSTANCES SHOULD REQUIRED TREATMENT BE DELAYED TO PERFORM THIS MONITORING.

(3) Embedded DU fragments in wounds should be removed using standard surgical criteria (see *Emergency War Surgery NATO Handbook*, 1988), except that large fragments (greater than 1 cm in diameter) should be more aggressively removed unless the medical risk to the patient is too great.

(4) Monitoring of kidney function is recommended for those patients who have contaminated wounds or embedded DU fragments. The monitoring should follow the current protocol in use by the Baltimore VA Depleted Uranium Program.

(*a*) As with all heavy metals, the kidney is one of the organs most sensitive to uranium toxicity. Recommended tests include urinalysis, 24-hour uranium urine bioassay, serum blood urea nitrogen (BUN), creatinine, beta-2-microglobulin, and creatinine clearance.

(*b*) Chelation therapy is not recommended based upon current estimates of DU exposure.

(5) Once the patient is in recovery, he should be informed of the risks associated with internalized DU. The key point is that the presence of any DU fragments in the service member's body presents no risks to family members. As with other heavy metals retained in the body, the DU in all bodily fluids (urine, feces, sweat, saliva, and semen) present absolutely no hazard to the soldier or the people he has contact with. Also, no special precautions are required by anyone having contact with the patient.

APPENDIX B

MEDICATIONS

Table B-1 is a listing of medications available for use when treating nuclear and radiological casualties. Stockage levels of specific medications will be as authorized by unit assemblages and standard operating procedures (SOP). The medications are grouped according to general category (for example, "antidiarrheal agents"), and information is given on trade name, generic name, class, and so forth.

Table B-1. Medications

TRADE NAME	GENERIC NAME	CLASS	DOSE/ROUTE	INDICATION	NOTES
Systemic Antibiotics					
Cipro	ciprofloxacin	Antibiotic	500 mg PO/IV QD	Bacterial prophylaxis when neutropenic	
Flagyl	metronidazole	Antibiotic	7.5 mg/kg PO/IV q 6 hrs (maximum 4 grams QD)	Anaerobic infections	
Garamycin	gentamicin	Antibiotic	3-5 mg/kg/day IV in divided doses	Gram (–) infections	Monitor peak and trough levels
Principen	ampicillin	Antibiotic	150-200 mg/kg/day in divided doses q 3-4 hrs	Gram (+) infections	
Vancocin	vancomycin	Antibiotic	1 gram IV q 12 hrs	Gram (+) infections	Monitor peak and trough levels
Topical Antibiotics					
Silvadene Cream	silver sulfadiazine	Antibiotic	Apply 1/16" QD or BID	Gram (-) and gram (+) infections, including pseudomonas	Adjunctive therapy for patients with 2 and 3 degree burns
Sulfamylon Cream	mafenide acetate	Antibiotic	Apply 1/16" QD or BID	Gram (-) and gram (+) infections, including pseudomonas	Adjunctive therapy for patients with 2 and 3 degree burns
Systemic Antifungal Agents					
Abelcet	amphotericin B lipid complex	Antifungal	5 mg/kg/day IV	Invasive fungal infections	Use if refractory to or intolerant of amphotericin B
AmBisome	amphotericin B liposome	Antifungal	3-5 mg/kg/day IV	Invasive fungal infections	Use if refractory to or intolerant of amphotericin B
Diflucan	fluconazole	Antifungal	400 mg PO/IV QD	Fungal prophylaxis when neutropenic	
Fungizone	amphotericin B	Antifungal	0.5-1.5 mg/kg/day IV	Invasive fungal infections	Slow IV, extreme side effects
Systemic Antiviral Agents					
Cytovene-IV	ganciclovir	Antiviral	5 mg/kg IV BID for 7 days then 5 mg/kg IV QD	CMV	
Zovirax	acyclovir	Antiviral	400 mg PO TID or 500 mg IV TID	Viral prophylaxis when neutropenic	
Colony Stimulating Factors (CSF)					
Leukine (GM-CSF)	sargramostim	CSF	500 mcg SQ QD	Neutropenia	Hematopoietic Growth Factor
Neumega	oprelvekin	CSF	50 mcg/kg SQ QD	Thrombocytopenia	Questionable efficacy
Neupogen (G-CSF)	filgrastim	CSF	5 mcg/kg SQ/IV QD	Neutropenia	Hematopoietic Growth Factor

Table B-1. Medications (Continued)

TRADE NAME	GENERIC NAME	CLASS	DOSE/ROUTE	INDICATION	NOTES
Procrit (Epogen)	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. CSF 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. G-CSF 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.					
Antidiarrheal Agents					
Imodium	loperamide	Antidiarrheal	4 mg PO then 2 mg after each unformed stool (max 16 mg QD)	Diarrhea	Rule out infectious cause first
Lomotil	diphenoxylate	Antidiarrheal	2 tablets PO QID	Diarrhea	Rule out infectious cause first
Gastric Acid "Neutralizers"					
Amphojel	aluminum hydroxide	Antacid	10 ml q 4-6 hrs prn	Hyperacidity	
Carafate	sucralfate	Cytoprotectant	1 gram PO QID	Erosive esophagitis and gastritis	
Histamine Receptor Antagonists					
Prilosec	omeprazole	Gastric acid pump inhibitor	20 mg PO QD	Erosive esophagitis and gastritis	
Tagamet	cimetidine	H2 Blocker	800 mg BID	Erosive esophagitis and gastritis	Parenteral doses for erosive esophagitis and gastritis unestablished
Zantac	ranitidine	H2 Blocker	150 mg PO BID or 50 mg IV q 8 hrs	Erosive esophagitis and gastritis	
General Comments: The term "neutralizer" is used here in a 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. Amphojel directly neutralizes the effect of gastric acid; Carafate forms a sucralfate-albumin film that provides a barrier to diffusion of hydrogen ions and protects the lining of the GI 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 Zantac and Tagamet 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					
Compazine	prochlorperazine	Antiemetic	5-10 mg PO/IV q 6 hrs	Nausea/Anxiety	
Kytril	granisetron	Antiemetic	10 mcg/kg IV QD or 1 mg PO BID	Nausea/Vomiting	
Phenergan	promethazine	Antiemetic	12.5-50 mg PO/IM/PR q 4-6 hrs	Nausea	
Reglan	metoclopramide	Antiemetic/ Prokinetic	10 mg PO/IM/IV QID	Nausea	
Zofran	ondansetron	Antiemetic	8 mg IV q 6-8 hrs or 8 mg PO q 8-12 hrs	Nausea/Vomiting	
Analgesics					
Demerol	meperidine	Opioid Analgesic	50-150 mg PO/IV/IM q 3-4 hrs	Pain/Rigor	Consider as pretreatment for amphotericin B
Dilaudid	hydromorphone	Opioid Analgesic	2-4 mg PO q 4-6 hrs or 1-2 mg IV/IM q 4-6 hrs	Pain	
Morphine	morphine sulfate	Opioid Analgesic	0.1-0.2 mg/kg (up to 15 mg) SQ/IV/IM q 4 hrs	Pain	
Percocet	oxycodone and acetaminophen	Opioid Analgesic	1 tablet PO q 6 hrs	Pain	
Tylenol	acetaminophen	Analgesic/ Antipyretic	650-1000 mg PO q 6 hrs	Pain/Fevers	Use as pretreatment for amphotericin B and blood products
Tylenol #3	acetaminophen with codeine	Opioid Analgesic	1-2 tablets PO q 4 hrs	Pain	

Table B-1. Medications (Continued)

TRADE NAME	GENERIC NAME	CLASS	DOSE/ROUTE	INDICATION	NOTES
Selective Gut Decontamination					
Bactrim	Co-trimoxazole (Trimethoprim-Sulfamethoxazole)	Antibiotic	Two tablets q 8 hrs PO (total of 6 tablets QD)	Selective Gut Decontamination	
Mycostatin	nystatin	Antifungal Agent	6×10^6 IU/day	Selective Gut Decontamination	
Noroxin	norfloxacin	Antibiotic	400 mg BID PO	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					
Allegra	fexofenadine HCl	Antihistamine	60 mg PO BID	Allergies	Used for bone pain due to Neupogen
Benadryl	diphenhydramine	Antihistamine	25-50 mg PO/IV/IM q 4-6 hrs	Nausea/Allergies	Use as pretreatment for amphotericin B and blood products
Claritin	loratadine	Antihistamine	10 mg QD	Allergies/Urticaria	Relief of itching in CRS
Therapeutic Agents for Cutaneous Radiation Syndrome (CRS)					
Topical Steroids (Elocon or 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
Retin-A Cream 0.05%	tretinoin		Apply topically QD	Keratoses	Rx of chronic stage of CRS; causes skin irritation, dryness
Soriatane	acitretin	Retinoid	25-50 mg QD with the main meal	Keratoses	Rx of chronic stage of CRS; multiple side effects, administered only with MD supervision
	interferon gamma		50 mcg SQ 3x per week for 18 months	Severe radiation fibrosis	Rx of chronic stage of CRS
Trental	pentoxifylline and Vitamin E		pentoxifylline 400 mg TID and Vitamin E 300 mg QD for a minimum of six 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.					
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	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 mg by mouth daily) may be given to individuals who are sensitive to iodine.					

Table B-1. Medications (Continued)

TRADE NAME	GENERIC NAME	CLASS	DOSE/ROUTE	INDICATION	NOTES
	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	Mobilizing Agents	propylthiouracil: 100 mg PO q 8 hrs for 8 days methimazole: 10 mg PO q 8 hrs for 2 days; reduce 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 produces a uranyl bicarbonate that is less nephrotoxic
	Dimercaprol (British Anti-Lewisite [BAL])		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 $BaSO_4$ 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
	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	Rx for internal contamination with lead, plutonium, and americium	
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% D/W IV over 60 minutes or 1 gm (4 ml) in 6 ml of 5% D/W by slow IV injection (1 minute)	Rx for internal contamination with rare earths, plutonium, transplutonics, and yttrium.	
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. Alternate dosing schedules to those discussed above are as follows: Both of the salts above can be given intravenously or as a nasal inhalant. Dose recommendations are, for adults, 1 gm in 100 to 250 cc of normal saline infused IV over 3 to 4 minutes and repeated on 5 successive days per week. Given through the aerosolized route, 1 gm in a 4 cc vial is placed in a nebulizer, and the entire volume is inhaled over 3 to 4 minutes and repeated daily.					

APPENDIX C

TREATMENT BRIEFS

C-1. Scope of Treatment Briefs

In this appendix, 28 patient categories involving a range of radiation doses are briefly described. Several patient categories involve radiation alone, and others describe patients receiving radiation in combination with trauma and/or burns. These descriptions are termed Treatment Briefs (TBs) and are derived from the work of the 1999—2000 Nuclear Warfare Casualty Panel of the Joint Readiness Clinical Advisory Board (JRCAB). The primary purpose of the Treatment Briefs is to help the JRCAB develop medical planning tools and resource estimates. **The TBs are not designed or intended as medical protocols.** However, physicians and other medical staff may find much of the information helpful as quick reference material for treatment of radiation casualties. Table C-1 below lists the 28 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 that are in Section I are applied to all Treatment Briefs.

Table C-1. List of Treatment Briefs

TREATMENT BRIEF	DOSE RANGE (cGy)	COMBINED INJURY
1	75	None
2	75–125	None
3	125–300	None
4	300–530	None
5	530–830	None
6	830–1500	None
7	>1500	None
8	0–125	Nonoperative trauma
9	125–530	Nonoperative trauma
10	>530	Nonoperative trauma
11	0–125	Operative trauma
12	125–530	Operative trauma
13	>530	Operative trauma
14	0–125	Mild burn
15	125–530	Mild burn
16	>530	Mild burn
17	0–125	Moderate burn
18	125–530	Moderate burn
19	>530	Moderate burn
20	0–125	Severe burn
21	125–530	Severe burn
22	>530	Severe burn
23	0–125	Operative trauma and mild burn
24	125–530	Operative trauma and mild burn
25	>530	Operative trauma and mild burn
26	0–125	Operative trauma and moderate burn
27	0–125	Operative trauma and severe burn
28	>125	Operative trauma and moderate or severe burn

Section I. GLOBAL ASSUMPTIONS

C-2. Level of Care

Levels of Care are defined by capability rather than on unit size and geographical locations on the battlefield. The levels of care are:

a. Level 1A. Self-care/Buddy care/Combat Medic/Corpsman.

b. Level 1B. Combat Medic/Corpsman/Battalion Aid Station/Surface Combatant Ships/Amphibious Casualty Receiving Treatment Ship/Wing Support Squadron Aid Station.

c. Level 2. Level 2 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, Level 2 would receive some, but not all, of the patients that are acutely injured in combat requiring expeditious surgery to save life or limb. Level 2 will usually provide resuscitative level care and surgical interventions to improve patient chances for transport to Level 3. However, if it is possible to provide Level 3 care at the Level 2 facilities without jeopardizing the mission, then Level 3 care may be done on a case-by-case basis. This may include holding patients up to 72 hours. Note that an Army FST will only hold patients for recovery, then move them to the supported medical company for evacuation.

d. Level 3. Level 3 is the first level 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 Level 3 facilities are combat support hospitals and USAF air transportable general hospitals.

e. Level 4. Level 4 is the highest level of care provided in theater. Patients that cannot receive definitive care and RTD within the theater evacuation policy are further stabilized and evacuated out of the theater. Typical Level 4 facilities are field hospitals or general hospitals.

C-3. Combined Injury

Combined injuries include thermal burn/blast trauma/radiation injuries and are discussed in Treatment Briefs 14—28. These briefs are based on thermal injury being the dominant determinant of morbidity and mortality. Human data sets regarding treatment of radiation combined injuries are scarce. General descriptions of trauma and burns assumed in the combined injury Treatment Briefs are provided below.

a. Nonoperative Blast Trauma. Examples include concussion (without intracranial hemorrhage), simple lacerations, closed fractures, ligamental injuries, simple pneumothorax, and so forth.

b. Operative Blast Trauma. Examples include open fractures, major lacerations, hemopneumothorax, and so forth.

c. *Burns*. All burns (including White Phosphorous) 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. Percentages of body surface area (BSA) are approximations:

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

C-4. Wound Closure

a. All Level 2 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.

b. 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. All surgical procedures must be accomplished within 36 to 48 hours of radiation injury. If surgery cannot be completed at far-forward locations, patients with moderate injury will need early evacuation to a level where surgical facilities are immediately available.

C-5. Return to Surgery

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 post-irradiation.

C-6. Psychological Casualties

The Treatment Briefs do not address psychological and related combat stress casualties associated with nuclear warfare (see Chapter 6).

C-7. Decontamination

Decontamination is not included in the Treatment Briefs. 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. This should consist of destruction of uniforms/clothes, washing the casualty with soap and water, and washing personal items (glasses, etc.) with soap and water. See Chapter 4 of this manual and FM 8-10-7 for more information on patient decontamination.

C-8. Incidence Rates

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 Level 1, with 50 percent mortality at Level 2, and 50 percent mortality at Level 3, will result in 88 percent mortality and 12 percent salvage rate for in-theater care.

C-9. Evacuation

The assumed evacuation policy is that evacuation from the theater for nonreturn to duty personnel is 7 to 15 days from time of injury. Note that the Theater Commander sets the actual evacuation policy. Expected evacuation times are as follows:

- MEDEVAC Transport Categories (Level to Level of Care): 2 Hours = Urgent; 4 hours = Priority; 6 hours = Routine

- AIREVAC Transport (Out of theater): 6 Hours = Urgent; 24 Hours = Priority; 72 Hours = Routine

C-10. Patient Holding Capabilities

Level 1 has no holding capability. Those Level 2 facilities with holding capability may RTD or will have materials to provide nursing care up to 72 hours if unable to evacuate, except as otherwise noted. The holding capability at Level 2 is highly varied between the Services as shown below:

Air Force MFST—None

Air Force MASF—2 hours

Air Force EMEDS Basic—24 hours

Air Force EMEDS + 10 AFTH—7 days (evacuate when stable)

Air Force EMEDS + 25 AFTH—7 days (evacuate when stable)

Air Force EMEDS ATH—30 days

Marine Surgical Company—72 hours

Army Forward Support Medical Company with FST attached—40 cots and 8 ICU/Recovery beds — 30 surgical procedures over 72 hours (10 per 24 hours) and holds 1 to 6 hours for postoperative recovery. If evacuation assets are not available, patients would be transferred to the patient holding section of the FSMC for up to 72 hours.

Army FST—8 ICU/Recovery beds holding for 1 to 6 hours. Doctrinally always collocated with FSMC and dependent for power, lab, x-ray, and so forth.

Navy Primary Casualty Receiving & Treatment Ships—72 Hours.

C-11. Blood Products

a. Current doctrine states that group O blood—packed cells (85 percent Rh Positive and 15 percent Rh Negative (for Rh Negative females) will be available at Level 2. Albumin (100 ml 25 percent can) is also available as a volume expander. Fresh frozen plasma (FFP), type-specific blood and platelet concentrate would not generally be available. Irradiated blood products (2000 cGy) will generally not be available at Level 2 and 3. Limited storage capacity of 50 units per field medical refrigerator exists at Level 2, and maximums are usually set at this level on the amount of blood to be transfused to any specific patient. 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 level of care. Table C-2 shows supply planning factors for Level 2 and 3 matrices for blood products and crystalloid fluid. All Class IV hemorrhage patients will require large bore vascular access.

Table C-2. Level 2 and 3 Blood Product Matrices

LEVEL 2 BLOOD USE ASSOCIATED WITH HEMORRHAGE CLASSIFICATION		
Hemorrhage Classification	**Blood**	**Albumin**
Class II	0	0
Class III	0.5 Units	2 (200 ml)
Class IV	2 Units	4 (400 ml)

LEVEL 3 BLOOD USE ASSOCIATED WITH HEMORRHAGE CLASSIFICATION			
Hemorrhage Classification	**Blood**	**Crystalloid**	**Albumin**
Class II	0	4 Liters	0
Class III	2 Units	8 Liters	2 (200 ml)
Class IV	2 Units plus 4 Units FFP	12 Liters	4 (400 ml)

b. 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 disease. Irradiated blood products will likely be in short supply and might be nonexistent within theater medical supply system.

C-12. Patient Warming

Warming techniques for all patients will be accomplished to the maximum extent possible, given the situation. These techniques include wrapping the patient, utilization of ventilation heater valve, warming blood/IVs/irrigation fluids through the use of fluid warmers, warming blankets, and controlling environmental temperature as much as possible. All Level 2 and 3 fluid and blood resuscitation requires at least one blood/fluid warmer per litter/bed in EMT, OR, and ICU.

C-13. Sterilization

The preferred method for instrument reuse is sterilization. However, weight and volume constraints may prevent resupply of sterilized instrumentation and/or sterilization capability. Therefore, high-level disinfectants may be used.

C-14. C-Spine Management

The data regarding actual incidence of cervical spine injuries in combat do not warrant the added burden of cervical collars and spine boards to treat all potential cervical spine injuries. Collars and boards should be used only in the limited number of patients with very high suspicion of cervical/spine injury.

C-15. Tetanus

Tetanus toxoid usage will be high. By definition, all traumatic wounds will be "dirty" and should require boosters within 5 years of most recent booster. The current booster schedule is every 10 years. Patients should receive tetanus toxoid booster at the point where they receive their in-theater surgical care, at Level 3, or at a point prior to transport out of theater. Tetanus toxoid will not be available at Level 2. It is assumed anyone deploying will have had at least one tetanus immunization in their lifetime. According to the Center for Disease Control, there has never been a recorded case of tetanus in a person having received at least one tetanus during their lifetime. Up to a 72 hour delay between Level 2 and Level 3 should not present a risk of tetanus to previously immunized individuals.

C-16. Diets

Unless otherwise stated in the briefs:

- ICU patients will be NPO. Special diets will be specified.

- ICW patients will advance to regular diet as tolerated.
- MCW patients will advance to regular diet as tolerated.

C-17. Casts and Splints

To reduce weight and volume requirements, all casting/splinting will be done with polymer based casting and fiberglass tape in preference to plaster cast. No plaster will be available.

C-18. Lab/X-ray/Pharmacy

Diagnosis and treatment is driven by clinical examination with laboratory testing and x-rays being used for confirmation only when absolutely necessary. Point of care testing, with laboratory service support, is the optimal choice.

C-19. Oxygen

Oxygen cylinders are hazardous cargo, require a tremendous amount of weight and volume capacity, and are not readily available for resupply/refill. In the absence of an oxygen generator, oxygen should be used only if absolutely necessary due to these limiting factors.

C-20. Patient Personal Support Kits

It will be assumed that supplies issued to patients will be transferred with the patient rather than reissuing supplies such as admission kits, irrigation kits, and so forth. This will markedly reduce the logistical load for patient support items.

C-21. Water

Water sources will be limited. Conservation of potable water is critical.

C-22. Linen

Linen will not meet the demand in mass casualty (MASCAL) or patient care surges. Timely resupply of clean linen is unreliable. Disposable linen is the product of choice.

C-23. Refrigeration

There is no refrigeration at any Level 1 facility. Refrigeration exists at some Level 2 and at all Level 3 facilities.

Section II. TREATMENT BRIEFS

C-24. Treatment Brief No. 1: Radiation Exposure at 0.0–75 cGy Without Other Physical Injury

LEVEL 1A

Assumptions: Real or suspected exposure; vital signs (VS): stable; ambulatory patient; alert; oriented, anxious; 5 percent nausea, mild headache.

Treatment: Reassurance. Routine ground transport 95 percent, RTD 5 percent.

LEVEL 1B

Assumptions: VS: stable. Ambulatory patient; alert; oriented, anxious; 5 percent nausea, mild headache.

Treatment: Consultation with Combat Stress Control Unit (CSCU), reassurance, PO pain medication 10 percent; PO antiemetics 5 percent. RTD 95 percent, routine ground transport 5 percent.

LEVEL 2

Assumptions: VS: stable, ambulatory patient; alert; oriented, anxious; 100 percent nausea, mild headache; automated differential cell counter available.

Treatment: 25 percent IV fluids laboratory report (LR); rest, 75 percent PO antiemetics and 25 percent IV antiemetics; reassurance/counseling. LAB: 100 percent CBC with differential for lymphocyte count every 12 hours for two days for prognosis and determination of RTD. LAB: 100 percent draw one blood specimen per patient for biodosimetry red top tube (clot) (keep refrigerated) for radiation exposure documentation; 100 percent RTD.

C-25. Treatment Brief No. 2: Radiation Injury at 75–125 cGy Without Other Physical Injury

LEVEL 1A

Assumptions: Real exposure; VS: stable; ambulatory patient; alert; oriented, anxious; 5 to 30 percent nausea/vomiting; mild headache; pretreatment with PO antiemetics may block nausea.

Treatment: Reassurance. Routine ground transport 100 percent.

LEVEL 1B

Assumptions: VS: stable to mild tachycardia. Ambulatory patient; alert; oriented, anxious; 5 to 30 percent nausea/vomiting; mild headache.

Treatment: Consultation with CSCU, reassurance; PO pain medication 10 percent; antiemetics 30 percent; further nonmedical radiation exposure must be limited; RTD 50 percent, routine ground transport 50 percent.

LEVEL 2

Assumptions: VS: stable to mild tachycardia. Ambulatory patient; alert; oriented, anxious; nausea/vomiting 15 to 60 percent; headache; automated differential cell counter available.

Treatment: 60 percent IV fluids LR, rest, 60 percent IV antiemetics; reassurance/counseling. Consultation with CSCU. LAB: 100 percent draw one blood specimen per patient for biodosimetry (red top

tube [clot] [keep refrigerated]) for radiation exposure documentation; 100 percent CBC with differential for lymphocyte count every 12 hours for two days for prognosis; 80 percent RTD, routine ground transport 20 percent.

LEVEL 3

Assumptions: VS: stable to mild tachycardia. Ambulatory patient; alert; oriented, anxious; nausea/vomiting 5 to 10 percent; headache; automated differential cell counter available. Only 10 percent of casualties reporting to Level 1B will ultimately reach Level 3.

Treatment: EMT: VS; primary assessment, 10 percent IV antiemetics. LAB: 100 percent CBC with differential one time.

OR: None.

WARDS: ICU: None.

ICW: None.

MCW: VS once daily; supportive care; push PO fluids, advance diet. LAB: Serial CBC with differential every 12 hours times two days. RTD 100 percent.

C-26. Treatment Brief No. 3: Radiation Injury at 125–300 cGy Without Other Physical Injury

LEVEL 1A

Assumptions: Significant exposure; VS: stable to tachycardia; ambulatory patient; alert; oriented, anxious; 20 to 70 percent nausea/vomiting (n/v); mild headache; 25 to 60 percent mild to moderate fatigability and weakness; pretreatment with antiemetics decreases vomiting.

Treatment: Reassurance. Routine ground transport 100 percent.

LEVEL 1B

Assumptions: Significant exposure; 5 percent mortality if untreated in 30 days; VS: stable to tachycardia; ambulatory patient; alert; oriented, anxious; 20 to 70 percent n/v; mild headache; 25 to 60 percent mild to moderate fatigability and weakness; pretreatment with antiemetics decrease vomiting.

Treatment: VS: start IV LR in 20 percent; reassurance, pain medication 10 percent; PO antiemetics 50 percent; further radiation exposure strictly limited to medical diagnostic procedures; routine ground transport 100 percent.

LEVEL 2

Assumptions: Significant exposure; 5 percent mortality if untreated in 30 days; VS: stable to tachycardia; ambulatory patient; alert; oriented, anxious; 20 to 70 percent n/v; mild headache; 25 to 60 percent mild to moderate fatigability and weakness; pretreatment with antiemetics decrease vomiting, automated differential cell counter available.

Treatment: IV fluids 50 percent, rest, 70 percent PO antiemetics, reassurance/counseling. LAB: CBC with differential for lymphocyte count every 12 hours for prognosis; routine ground transport 100 percent. Since no patients will RTD, biodosimetry will be deferred to Level 3.

LEVEL 3

Assumptions: Significant exposure; 5 percent mortality if untreated; VS: stable to tachycardia; ambulatory patient; alert; oriented, anxious; 10 to 30 percent n/v; mild headache; 25 to 60 percent mild to

moderate fatigability and weakness; pretreatment with PO antiemetics decrease vomiting, automated differential cell counter available. Confirmation of radiation injury requires two days observation.

Treatment: EMT: VS; primary assessment, PO antiemetics. LAB: 100 percent draw one blood specimen per patient for biodosimetry red top tube (clot) (keep refrigerated) for radiation exposure documentation; 100 percent CBC with differential.

OR: None.

WARDS: ICU: None.

ICW: None.

MCW: 100 percent of patients arriving at Level 3; VS; supportive care; push PO fluids, diet as tolerated. LAB: serial CBCs with differential every 12 hours. Cytokines (G-CSF 480 mcg subcutaneous daily) in 10 percent of patients; routine air transport 100 percent of patients admitted to MCW.

C-27. Treatment Brief No. 4: Radiation Injury at 300–530 cGy Without Other Physical Injury

LEVEL 1A

Assumptions: Dangerous exposure; VS: stable to tachycardia; ambulatory patient; alert; oriented, anxious; 50 to 90 percent n/v; 10 percent diarrhea; 60 to 90 percent moderate fatigability and weakness; pretreatment with antiemetics may decrease vomiting.

Treatment: Reassurance. Routine ground transport 100 percent.

LEVEL 1B

Assumptions: Dangerous exposure; 5 to 50 percent mortality within 30 days if untreated; VS: stable to tachycardia; ambulatory patient; alert; oriented, anxious; 50 to 90 percent n/v; 60 to 90 percent moderate fatigability and weakness; pretreatment with antiemetics may decrease vomiting.

Treatment: VS: start IV LR in 80 percent; reassurance; PO antiemetics 90 percent; no further radiation exposure allowable; routine ground transport 100 percent.

LEVEL 2

Assumptions: Dangerous exposure; 5 to 50 percent mortality within 30 days if untreated; VS: stable to tachycardia; ambulatory patient; alert; oriented, anxious; 50 to 90 percent n/v; 60 to 90 percent moderate fatigability and weakness; automated differential cell counter available; pretreatment with antiemetics may decrease vomiting.

Treatment: Rest; IV fluids LR 100 percent. LAB: 25 percent electrolytes once daily times two days; 90 percent (45 percent PO and 45 percent injectable) antiemetics; counseling. LAB: CBC with differential for lymphocyte count every 12 hours for 24 to 36 hours for prognosis. Isolate from communicable diseases; urgent air transport 20 percent/urgent ground transport 80 percent.

LEVEL 3

Assumptions: Dangerous exposure; 5 to 50 percent mortality if untreated; VS: stable to tachycardia; ambulatory patient; alert; oriented, anxious; 30 to 60 percent n/v; 60 to 90 percent moderate fatigability and weakness; pretreatment with antiemetics may decrease vomiting; automated differential cell counter.

Treatment: EMT: VS; primary assessment, 60 percent (30 percent PO and 30 percent injectable) antiemetics. LAB: 100 percent CBC with differential, 100 percent draw one blood specimen per patient for biodosimetry red top (clot) (keep refrigerated) for radiation exposure documentation.

OR: None.

WARDS: ICU: None.

ICW: 10 percent of patients arriving at Level 3; VS: qid; supportive care; 100 percent of patients require IV LR fluids (4 liters/day); clear liquids. LAB: 100 percent electrolytes once daily, serial CBCs with differential every 12 hours daily. Cytokines (G-CSF 480 mcg subcutaneous daily) in 100 percent of patients; draw blood specimens for HLA typing (three yellow top tubes); reverse isolation. Patients admitted to ICW priority air transport 100 percent.

MCW: 90 percent of patients arriving at Level 3; VS; supportive care; push PO fluids, advance diet. LAB: serial CBCs with differential every 12 hours. Cytokines (G-CSF 480 mcg subcutaneous daily) in 100 percent of patients. Reverse isolation. Draw blood specimens for HLA typing (three yellow top tubes). Patients admitted to MCW—routine air transport 100 percent.

C-28. Treatment Brief No. 5: Radiation Injury at 530–830 cGy Without Other Physical Injury

LEVEL 1A

Assumptions: Critical exposure; VS: tachycardia; litter 50 percent, ambulatory 50 percent alert; oriented, anxious; 80 to 100 percent n/v; 10 percent diarrhea; 90 to 100 percent moderate to extreme fatigability and weakness; pretreatment with antiemetics is ineffective.

Treatment: Urgent ground transport 100 percent.

LEVEL 1B

Assumptions: Critical exposure; 50 to 95 percent mortality within 30 days if untreated; VS: tachycardia; litter 50 percent, ambulatory 50 percent alert; oriented, anxious; 80 to 100 percent n/v; 90 to 100 percent moderate to extreme fatigability and weakness; pretreatment with antiemetics is ineffective.

Treatment: VS once, start IV LR in 100 percent; injectable antiemetics 100 percent; pain medications 10 percent; isolate from communicable diseases; no further radiation exposure allowable; urgent ground transport 30 percent/urgent air transport 70 percent with overflight to Level 3 if possible.

LEVEL 2

Assumptions: Overflight if possible. Critical exposure; 50 to 95 percent mortality if untreated; VS: tachycardia; litter 50 percent, ambulatory 50 percent alert; oriented, anxious; 80 to 100 percent n/v; 10 percent diarrhea; 90 to 100 percent moderate to extreme fatigability and weakness; pretreatment with antiemetics is ineffective.

Treatment: VS; start IV LR in 100 percent; injectable antiemetics 100 percent; reverse isolation; no further radiation exposure allowable; urgent transport 100 percent to Level 3.

LEVEL 3

Assumptions: Critical exposure; 50 to 95 percent mortality if untreated; VS: tachycardia; litter 50 percent, ambulatory 50 percent; alert; oriented, anxious; 30 to 70 percent n/v; 10 percent diarrhea; 90 to 100 percent moderate to extreme fatigability and weakness; pretreatment with antiemetics is ineffective.

Automated differential cell counter available. Comment: Air evacuated by day 4, if unable to evacuate by day four post exposure, antibiotic and antivirals will be needed along with surveillance cultures.

Treatment: EMT: VS once; primary assessment, 70 percent injectable antiemetics, 100 percent IV LR. LAB: Draw one blood specimen per patient for biodosimetry red top (clot) (keep refrigerated) for radiation exposure documentation; CBC with differential.

OR: None.

WARDS: ICU: None.

ICW: 100 percent of patients arriving at Level 3. VS: qid; supportive care; 100 percent of patients require IV fluids (LR, 4 liters/day), NPO 50 percent, clear liquids 50 percent. LAB: Serial CBCs with differential every 12 hours for the first four days. Cytokines (G-CSF 480 mcg subcutaneous daily) in 100 percent of patients; 10 percent antidiarrheal medications; reverse isolation. Draw blood specimens for HLA typing three yellow top tubes. Patients admitted to ICW—Urgent air transport 100 percent to Level V treatment facility.

MCW: None.

C-29. Treatment Brief No. 6: Radiation Injury at 830–1500 cGy Without Other Physical Injury

LEVEL 1A

Assumptions: Critical exposure; VS: tachycardia; litter 100 percent, 90 to 100 percent disoriented, anxious; immediate onset of 100 percent n/v; diarrhea 10 percent; 100 percent extreme fatigability and weakness; pretreatment with antiemetics is ineffective.

Treatment: Urgent ground transport 100 percent.

LEVEL 1B

Assumptions: Critical exposure; 100 percent mortality within 15 to 30 days if untreated; VS: tachycardia, hypotension 25 percent; litter 100 percent, disoriented 90 to 100 percent, anxious; immediate onset of 100 percent n/v; 10 percent diarrhea; 100 percent extreme fatigability and weakness; pretreatment with antiemetics is ineffective.

Treatment: VS: once; start IV LR in 100 percent; injectable antiemetics 100 percent; IV/IM morphine 25 percent; no further radiation exposure allowable; urgent ground transport 100 percent.

LEVEL 2

Assumptions: Critical exposure; 100 percent mortality if untreated; VS: tachycardia, hypotension 25 percent, 50 percent low grade fever; litter 100 percent, disoriented 90 to 100 percent, anxious; 100 percent immediate onset of n/v; 10 percent diarrhea; 100 percent extreme fatigability and weakness; pretreatment with antiemetics is ineffective. Automated differential cell counter available.

Treatment: VS, start IV LR in 100 percent; injectable antiemetics 100 percent; antidiarrheal medication 10 percent. LAB: CBC with differential every 12 hours. Comment: Attempt reverse isolation; no further radiation exposure allowable; urgent ground transport 100 percent to Level 3.

LEVEL 3

Assumptions: Critical exposure; mortality 100 percent if untreated; VS: tachycardia, hypotension 25 percent, low grade fever 50 percent; litter 100 percent, disoriented 40 to 70 percent, anxious; 40 to 70 percent immediate onset of n/v; 10 percent diarrhea; 100 percent extreme fatigability and weakness; pretreatment with antiemetics is ineffective. Automated differential cell counter available.

Treatment: EMT: VS once; primary assessment, injectable antiemetics. LAB: Draw one blood specimen per patient for biodosimetry red top (clot) (keep refrigerated) for radiation exposure documentation; CBC with differential.

OR: None.

WARDS: ICU: None.

ICW: 100 percent of patients arriving at Level 3; VS, supportive care; 100 percent IV fluids (LR 4 liters/day), NPO 50 percent, clear liquids 50 percent.

LAB: 100 percent serial CBCs with differential every 12 hours daily, electrolytes q24h. Cytokines (G-CSF 480 mcg subcutaneous daily) in 100 percent of patients; 10 percent antidiarrheal medications; reverse isolation. 100 percent draw blood specimens for HLA typing three yellow top tubes acid-citrate dextrose (ACD) (keep refrigerated). Patients admitted to ICW —100 percent urgent air transport to a Level V treatment facility. If unable to evacuate by day four postexposure, blood products (preferably irradiated to 2000 cGy), antibiotics, antivirals, antifungals, and surveillance cultures will be needed.

MCW: None.

C-30. Treatment Brief No. 7: Radiation Injury >1500 cGy Without Other Physical Injury

LEVEL 1A

Assumptions: Lethal exposure; 95 to 100 percent mortality even with treatment; VS; unstable; litter 100 percent, disoriented 75 percent, anxious; 100 percent immediate onset of nausea/vomiting/diarrhea (n/v/d); 100 percent extreme fatigability and weakness; pretreatment with antiemetics is ineffective.

Treatment: Urgent ground transport 100 percent.

LEVEL 1B

Assumptions: Lethal exposure; 95 to 100 percent mortality even with treatment; VS, unstable; litter 100 percent, disoriented 75 percent, anxious; 100 percent immediate onset of n/v/d; 100 percent extreme fatigability and weakness; pretreatment with antiemetics is ineffective.

Treatment: VS: once; start IV LR in 25 percent; injectable antiemetics 100 percent; 100 percent IM morphine 2 to 4 mg q 1 to 4 hours as needed; no further radiation exposure allowable; routine ground transport 100 percent to Level 2. Comment: Those patients with neurologic signs are expectant.

LEVEL 2

Assumptions: Lethal exposure; 95 to 100 percent mortality even with treatment; VS; unstable; litter 100 percent, disoriented 75 percent, anxious; 100 percent immediate onset of n/v/d; 100 percent extreme fatigability and weakness; pretreatment with antiemetics is ineffective. Automated differential cell counter. Expectant patients (with neurologic deficits) 75 percent, nonexpectant 25 percent.

Treatment: For all (100 percent): VS prn; antiemetics IV, IM morphine 2 to 4 mg q 1 to 4 hours as needed for pain; antidiarrheal medications. Nonexpectant (25 percent): maintain IV LR. LAB: CBC with differential every 12 hours. Attempt reverse isolation; no further radiation exposure allowable; urgent ground transport (25 percent). Expectant (75 percent): Routine ground transport 75 percent.

LEVEL 3

Assumptions: Lethal exposure; 95 to 100 percent mortality even with treatment; VS, unstable; litter 100 percent, neurological casualties (75 percent) admitted to MCW for palliative care; 25 percent admitted

to ICW (no neurologic signs); 100 percent n/v/d; 100 percent extreme fatigability and weakness. Automated differential cell counter. Eventual mortality at this level is estimated at 80 percent.

Treatment: EMT: VS: once; maintain IV LR in 25 percent; injectable antiemetics 100 percent; 100 percent IV/IM morphine 2 to 4 mg once if needed. LAB: 100 percent of patients need blood drawn for biodosimetry (red top clot) (keep refrigerated) for radiation exposure documentation. In those without neurologic signs (25 percent of patients), CBC with differential and electrolytes; reverse isolation.

OR: None.

WARDS: ICU: None.

ICW: 25 percent of patients arriving at Level 3; VS q4h; supportive care; 100 percent IV fluids (LR 4 liters per day), NPO 100 percent. LAB: 100 percent serial CBCs with differential every 12 hours daily, 100 percent electrolytes q24h. Cytokines (G-CSF 480 mcg subcutaneous daily) in 100 percent of patients; 100 percent antidiarrheal medications. Eventual mortality is 80 percent from this radiation exposure; reverse isolation. Draw blood specimens for HLA typing three yellow top tubes (ACD) 100 percent (keep refrigerated). Note: If unable to evacuate by day four postexposure, blood products preferably irradiated to 2000 cGy, antibiotics, antivirals, antifungals, and surveillance cultures will be needed. Patients admitted to ICW—Urgent air transport 100 percent air evacuate to Level V treatment facility.

MCW: 75 percent of patients arriving at Level 3; palliative care; 100 percent morphine IV every 1 to 4 hours daily as needed for pain (mortality 100 percent). Patients admitted to MCW—100 percent mortality.

C-31. Treatment Brief No. 8: Radiation at 0–125 cGy With Nonoperative Trauma (Examples include concussion, simple lacerations, closed fractures, ligamental injuries, and so forth.)

LEVEL 1A

Assumptions: Real or suspected radiation exposure; 50 percent litter patient (from morphine)/50 percent ambulatory patient (no morphine); VS stable; severe pain in upper extremity; neurovascular status intact; no significant hemorrhage; moderate deformity of elbow noted; alert; oriented. Radiation effects include: apprehension and agitation; n/v 5 to 30 percent; mild headache; pretreatment with antiemetics decreases vomiting; radiation does not contribute to mortality at this level.

Treatment: Sling and swathe extremity; 50 percent patients IM morphine; dress open wounds; reassurance; 100 percent routine ground transport.

LEVEL 1B

Assumptions: Real or suspected radiation exposure; 50 percent litter patient/50 percent ambulatory patient; VS stable; severe pain in upper extremity; neurovascular status intact; no significant hemorrhage; moderate deformity of elbow noted; alert; oriented. Radiation effects include: apprehension and agitation; n/v 5 to 30 percent; mild headache; pretreatment with antiemetics decrease vomiting; radiation does not contribute to mortality at this level.

Treatment: VS: start IV LR in 50 percent; sling and swathe extremity; IM morphine 50 percent; 30 percent PO antiemetics promethazine; reassurance; 100 percent routine ground transport.

LEVEL 2

Assumptions: Real or suspected radiation exposure; 50 percent litter patients/50 percent ambulatory patients; VS stable; severe pain in upper extremity; neurovascular status intact in 99 percent; no significant

hemorrhage; moderate deformity of elbow noted. Radiation effects include: apprehension and agitation; n/v 5 to 30 percent; mild headache; pretreatment with antiemetics decrease vomiting; radiation may contribute to morbidity at this level.

Treatment: IV/IM morphine; IV fluids LR 80 percent, rest, 30 percent PO antiemetics, reassurance/ counseling. X-ray, neurovascular checks, one percent axillary block and fasciotomy and/or attempted reduction for compartment syndrome and vascular compromise; splint extremity; sling applied; saline lock. LAB: CBC with differentials twice daily until transferred; 100 percent routine ground transport.

LEVEL 3

Assumptions: Real or suspected radiation exposure; 50 percent litter patients/50 percent ambulatory patients; VS stable; x-ray reveals fracture, dislocation of elbow; neurovascular status intact; no other apparent injuries. Radiation effects include: apprehension and agitation; n/v 5 to 30 percent; mild headache; pretreatment with antiemetics decreases vomiting; radiation may contribute to morbidity at this level.

Treatment: EMT: VS; primary assessment. LAB: 100 percent CBC with differential; draw one blood specimen per patient for biodosimetry (red top tube [clot] [keep refrigerated]) for radiation exposure prognosis. Maintain IV; 50 percent IM/IV morphine; orthopedist consult; doppler assessment; x-ray: elbow, humerus, forearm; compartment pressure assessment 10 percent; orthopedist reduces 90 percent in EMT and places arm in posterior plaster long arm splint and sling; x-ray: repeat of elbow after reduction.

OR: 10 percent have open reduction with possible fixation of fracture with plates and screws/K-wires; further definitive stabilization may be required at higher level; fasciotomy of forearm and application of long arm splint under axillary block; IV antibiotics; x-ray: elbow; 2 liters RL; OR table time—180 min. Digital portable radiography in OR.

WARDS: ICU: None.

ICW: 100 percent of patients arriving at Level 3. VS; 100 percent IV LR; IV antibiotics (10 percent) for operative cases; IV/IM morphine; elevate limb; neuro and circulatory checks; doppler; dressing changes; CBC with differentials twice daily times four days; reverse isolation. Priority air transport 100 percent.

MCW: None.

C-32. Treatment Brief No. 9: Radiation at 125–530 cGy With Nonoperative Trauma (Examples include concussion, simple lacerations, closed fractures, ligamental injuries, and so forth.)

LEVEL 1A

Assumptions: Significant radiation exposure; 75 percent litter patient/25 percent ambulatory patient; VS stable; severe pain in upper extremity; neurovascular status intact; no significant hemorrhage; moderate deformity of elbow noted; alert; oriented. Radiation effects include: apprehension and agitation; n/v 50 to 90 percent; mild headache; fatigue and weakness 25 to 60 percent; pretreatment with antiemetics decrease vomiting; radiation does not contribute to mortality at this level.

Treatment: Sling and swathe extremity; 75 percent IM morphine; dress open wounds; reassurance; 100 percent routine ground transport.

LEVEL 1B

Assumptions: Significant radiation exposure; 75 percent litter patient/25 percent ambulatory patient; VS stable; severe pain in upper extremity; neurovascular status intact; no significant hemorrhage; moderate

deformity of elbow noted; alert; oriented. Radiation effects include: apprehension and agitation; n/v 50 to 90 percent; mild headache; fatigue and weakness 25 to 60 percent; pretreatment with antiemetics decreases vomiting; radiation does not contribute to mortality at this level.

Treatment: VS: start IV LR in 90 percent; sling and swathe extremity; IM morphine 100 percent; 90 percent PO/IM antiemetics; reassurance; further radiation exposure strictly limited to medical diagnostic procedures; 100 percent routine transport.

LEVEL 2

Assumptions: Significant and potentially lethal radiation exposure; 75 percent litter patients/25 percent ambulatory patients; VS stable; severe pain in upper extremity; neurovascular status intact in 99 percent; no significant hemorrhage; moderate deformity of elbow noted. Radiation effects include: apprehension and agitation; n/v 50 to 90 percent; mild headache; fatigue and weakness 25 to 60 percent; pretreatment with antiemetics may decrease vomiting; radiation contributes to morbidity at this level. Automated cell counter available.

Treatment: IV/IM morphine; IV fluids LR 100 percent; rest; 90 percent PO antiemetics, counseling. X-ray, neurovascular checks, one percent axillary block and fasciotomy and/or attempted reduction for compartment syndrome and vascular compromise. Splint extremity; sling applied; saline lock. LAB: CBC with differentials twice daily until transferred; 100 percent routine ground transport.

LEVEL 3

Assumptions: Significant and potentially lethal radiation exposure; 75 percent litter patients/25 percent ambulatory patients; VS stable; x-ray reveals fracture, dislocation of elbow; neurovascular status intact; no other apparent injuries. Radiation effects include: apprehension and agitation; n/v 50 to 90 percent; mild headache; fatigue and weakness 25 to 60 percent; pretreatment with antiemetics may decrease vomiting; radiation contributes to morbidity at this level. Radiation will contribute to morbidity at this level due to immunosuppression.

Treatment: EMT: VS; primary assessment. LAB: CBC with differential, 100 percent draw one blood specimen per patient for biodosimetry red top tube (clot) (keep refrigerated) for radiation exposure prognosis; maintain IV; 75 percent IM/IV morphine. Orthopedist consult; doppler assessment; x-ray: elbow, humerus, forearm; compartment pressure assessment 10 percent; orthopedist reduces 90 percent in EMT and places arm in posterior plaster long arm splint and sling; x-ray: repeat of elbow after reduction.

OR: 10 percent have open reduction with possible fixation of fracture with plates and screws/K-wires; further definitive stabilization may be required at higher level; fasciotomy of forearm and application of long arm splint under axillary block; IV antibiotics; x-ray: elbow; 2 liters RL. OR table time—180 minutes. Digital portable radiography in OR.

WARDS: ICU: None.

ICW: 100 percent of patients arriving at Level 3. VS; 100 percent IV LR; IV antibiotics (10 percent) for operative cases; IV/IM morphine; elevate limb; neuro and circulatory checks; doppler; dressing changes. Administer cytokines (480 mcg G-CSF) subcutaneous daily in 100 percent; CBC with differentials twice daily. Draw blood specimens for HLA typing (three yellow top tubes [ACD] [keep refrigerated]). Reverse isolation. Patients admitted to ICW—10 percent early mortality due to combination of surgery and high dose radiation; 90 percent priority air transport.

MCW: None.

C-33. Treatment Brief No. 10: Radiation >530 cGy With Nonoperative Trauma (Examples include concussion, simple lacerations, closed fractures, ligamental injuries, and so forth.)

LEVEL 1A

Assumptions: Critical to lethal radiation exposure; 100 percent litter patients; VS stable; severe pain in upper extremity; neurovascular status intact; no significant hemorrhage; moderate deformity of elbow noted; alert; oriented. Extreme radiation doses will cause neurological deficits; additional radiation effects include: apprehension and agitation; n/v 100 percent; fatigue and weakness 100 percent; pretreatment with antiemetics may have no effects; radiation may contribute to morbidity at this level.

Treatment: Dress open wounds; reassurance; sling and swathe extremity; IM morphine; 100 percent priority ground transport.

LEVEL 1B

Assumptions: Critical to lethal radiation exposure; 100 percent litter patients; VS stable; severe pain in upper extremity; neurovascular status intact; no significant hemorrhage; moderate deformity of elbow noted. Extreme radiation doses will cause neurological deficits; additional radiation effects include: apprehension and agitation; n/v 100 percent; fatigue and weakness 100 percent; pretreatment with antiemetics may have no effects; radiation may contribute to morbidity at this level. Critical radiation injury with persistent central neurological signs places 10 percent of patients in expectant category at this level.

Treatment: VS; start IV LR in nonexpectant patients (90 percent of patients); sling and swathe extremity; IM morphine 100 percent; 90 percent PO/IM antiemetics; reassurance. Note: All surgery must be completed within 36—48 hours; evacuation to a level of care that can provide appropriate wound closure surgery is essential. 90 percent priority ground transport; 10 percent routine ground transport.

LEVEL 2

Assumptions: Critical to lethal radiation exposure; 100 percent litter patients; VS stable; severe pain in upper extremity; neurovascular status intact in 90 percent; no significant hemorrhage; moderate deformity of elbow noted. Extreme radiation doses will cause neurological deficits; additional radiation effects include: apprehension and agitation; n/v 100 percent; fatigue and weakness 100 percent; pretreatment with antiemetics may have no effects; radiation may contribute to morbidity at this level. Critical radiation injury with persistent central neurological signs places 20 percent of patients in expectant category at this level.

Treatment: VS; Maintain IV LR in nonexpectant patients (80 percent of patients); IV/IM morphine; x-ray, neurovascular checks, one percent axillary block and fasciotomy and/or attempted reduction for compartment syndrome and vascular compromise; splint extremity; sling applied; saline lock. LAB: CBC with differentials twice daily until transferred. Note: All surgery must be completed within 36 to 48 hours; evacuation to a level of care that can provide appropriate wound closure surgery is essential. Attempt reverse isolation. 80 percent priority air transport; 20 percent routine air transport.

LEVEL 3

Assumptions: Critical to lethal radiation exposure; 100 percent litter patients; VS stable; x-ray reveals fracture, dislocation of elbow; neurovascular status intact in 90 percent of patients arriving at Level 3; no other apparent injuries. Radiation effects include: apprehension and agitation; n/v 100 percent; fatigue and weakness 100 percent; pretreatment with antiemetics may have no effects; radiation may

contribute to morbidity at this level. Critical radiation injury with persistent central neurological signs places 30 percent of patients in expectant category at this level.

Treatment: EMT: VS; primary assessment, maintain IV; 100 percent IM/IV morphine; orthopedist consult; doppler assessment; x-ray: elbow, humerus, forearm; compartment pressure assessment 10 percent; orthopedist reduces 90 percent in EMT and places arm in posterior plaster long arm splint and sling; x-ray: repeat of elbow after reduction. LAB: (for nonexpectant patients—70 percent); CBC with differential for radiation exposure; 100 percent draw one blood specimen per patient for biodosimetry (red top [clot] [keep refrigerated]) for prognosis.

OR: 10 percent have open reduction with possible fixation of fracture with plates and screws/K-wires; further definitive stabilization may be required at higher level; fasciotomy of forearm and application of long arm splint under axillary block; IV antibiotics; x-ray: elbow; 2 liters RL; OR table time—180 minutes. Digital portable radiography in OR.

WARDS: ICU: None.

ICW: 70 percent of patients arriving at Level 3; VS; 100 percent IV LR; IV antibiotics (10 percent) for operative cases; IV/IM morphine; elevate limb; neuro and circulatory checks; doppler; dressing changes. Administer cytokines (G-CSF 480 mcg subcutaneous daily) in 100 percent; CBC with differentials twice daily. Three yellow top tubes (ACD) for HLA typing, keep refrigerated. Reverse isolation. Patients admitted to ICW: Mortality 5 percent at this level at 5 to 7 days, 95 percent priority air transport.

MCW: Expectant patients only (30 percent of patients arriving at Level 3); IV/IM morphine as needed. Patients admitted to MCW: Mortality 100 percent by seven days.

C-34. Treatment Brief No. 11: Radiation at 0–125 cGy With Operative Trauma

LEVEL 1A

Assumptions: Real or suspected radiation exposure; litter patient; alert, cooperative and oriented; VS: pulse greater than 100, B/P 100/60, no respiratory distress, evidence of closed intra-abdominal hemorrhage and injury. Radiation effects include: apprehension and agitation; n/v 5 to 30 percent; mild headache; pretreatment with antiemetics decrease vomiting and possibly increase fatigability; radiation does not contribute to mortality at this level.

Treatment: Start IV 100 percent (LR); reassurance; 100 percent priority ground transport.

LEVEL 1B

Assumptions: Real or suspected radiation exposure; 100 percent litter patients; alert, cooperative and oriented; VS: pulse greater than 100, B/P 100/60, no respiratory distress; evidence of closed intra-abdominal hemorrhage and injury. Radiation effects include: apprehension and agitation; n/v 5 to 30 percent; mild headache; pretreatment with antiemetics decrease vomiting; radiation does not contribute to mortality at this level.

Treatment: VS: Maintain IV LR in 100 percent; stabilization and IM morphine; reassurance; 30 percent treatment with antiemetics; 10 percent cervical spine stabilized; 100 percent urgent air transport. Note: All surgery must be completed within 36 to 48 hours; evacuation to a level of care that can provide appropriate urgent surgery.

LEVEL 2

Assumptions: Real or suspected radiation exposure; 100 percent litter patients; alert, cooperative and oriented; VS: pulse greater than 100, B/P 100/60, no respiratory distress; evidence of closed intra-abdominal hemorrhage and injury. Radiation effects include: apprehension and agitation; n/v 5 to 30 percent; mild headache; pretreatment with antiemetics decrease vomiting and possibly increase fatigability; radiation may contribute to morbidity at this level.

Treatment: 25 percent exploratory laparoscopy at this level; general anesthesia; 2d IV; NG tube, parenteral pain medications (morphine), HCT, type and cross, blood, irrigation and debridement, hemorrhage control, hemostatic agents, IV antibiotics, dressing, cardiac monitor, pulse oximeter, ventilator, Foley catheter. Remaining 75 percent: IV fluids LR 100 percent; rest; 30 percent IV/IM antiemetics; reassurance/counseling. Note: All surgery must be completed within 36 to 48 hours; evacuation to a level of care that can provide appropriate urgent surgery. If appropriate surgery has been provided at this level, then routine evacuation (25 percent) to Level 3; otherwise urgent air transport (75 percent).

LEVEL 3

Assumptions: Real or suspected radiation exposure; litter patient; Class III hemorrhage; VS: pulse 120, B/P 100/70, respirations normal; alert; oriented. Radiation effects include: apprehension and agitation; n/v 5 to 30 percent; mild headache; pretreatment with antiemetics decreases vomiting; 25 percent will receive appropriate wound closure surgery at Level 2; radiation may contribute to morbidity at this level.

Treatment: EMT: VS; primary assessment, IV restarted in 20 percent, give 2 liters LR; 2d IV started; IV antibiotics; parenteral morphine; Foley catheter; NG tube; LAB: 100 percent CBC with differential, UA, TC for 4 units; x-rays: chest, 50 percent pelvis films. LAB: 100 percent draw one blood specimen per patient for biodosimetry red top tube (clot) (keep refrigerated), for radiation exposure prognosis.

OR: 75 percent of patients arriving at Level 3. Laparotomy and drainage of liver injury under general anesthesia; 50 percent large bore central line; IV antibiotics; 8 liters RL; 2 units blood; arterial line 10 percent. Lab: CBC, blood gases; OR table time—120 minutes. Note: All surgery must be completed within 36 to 48 hours of radiation exposure.

WARDS: 25 percent of patients arriving at Level 3—direct admit from Level 2.

ICU: 100 percent of patients arriving at Level 3. VS; maintain IV fluids; IV antibiotics; parenteral morphine; Foley catheter care; drain care; NG tube care, NPO; 10 percent maintain ET tube and ventilator with O_2, extubate before leaving ICU; 90 percent on O_2 by mask; maintain central line and monitoring and arterial line; cardiac monitor and pulse oximeter; dressing reinforcement; dc central/arterial line before leaving ICU. LAB: CBC with differential twice daily, electrolytes, clotting studies, Amylase, LFTs on admission; x-ray: chest, 10 percent c-spine. Consider cytokines (G-CSF 480 mcg subcutaneous daily).

ICW: 100 percent of patients arriving at Level 3 will be transferred from ICU by day 2. VS; IVs with IV antibiotics; parenteral pain medications; 25 percent on O_2 by mask; Foley catheter care; maintain NG tube; NPO; dressing reinforcement; drain care. Consider cytokines (G-CSF 480 mcg subcutaneous daily); CBC with differentials three times daily. Routine air transport 100 percent.

MCW: None.

C-35. Treatment Brief No. 12: Radiation at 125–530 cGy With Operative Trauma

LEVEL 1A

Assumptions: Significant radiation exposure; 100 percent litter patient; alert, cooperative and oriented; VS pulse greater than 100, B/P 100/60, no respiratory distress, evidence of closed intra-abdominal hemorrhage and injury. Radiation effects include: apprehension and agitation; n/v 50 to 90 percent; mild headache; fatigue and weakness 25 to 60 percent; pretreatment with antiemetics decrease vomiting; radiation does not contribute to mortality at this level.

Treatment: Start IV 100 percent (LR); reassurance; 100 percent priority ground transport.

LEVEL 1B

Assumptions: Significant radiation exposure; 100 percent litter patients; alert, cooperative and oriented; VS: pulse greater than 100, B/P 100/60, no respiratory distress; evidence of closed intra-abdominal hemorrhage and injury. Radiation effects include: apprehension and agitation; n/v 50 to 90 percent; mild headache; fatigue and weakness 25 to 60 percent; pretreatment with antiemetics decrease vomiting; radiation contributes to morbidity at this level.

Treatment: VS; maintain IV LR in 100 percent; stabilization and IM morphine; reassurance; 90 percent Kytril IV; 10 percent cervical spine stabilized; 100 percent urgent air transport. Note: All surgery must be completed within 36 to 48 hours; evacuation to a level of care that can provide appropriate urgent surgery.

LEVEL 2

Assumptions: Significant and potentially lethal radiation exposure; 100 percent litter patients; alert, cooperative and oriented; VS: pulse greater than 100, B/P 100/60, no respiratory distress; evidence of closed intra-abdominal hemorrhage and injury. Radiation effects include apprehension and agitation; n/v 50 to 90 percent; mild headache; fatigue and weakness 25 to 60 percent; pretreatment with antiemetics may decrease vomiting; radiation contributes to morbidity at this level. Automated cell counter available.

Treatment: 25 percent exploratory laparotomy at this level; general anesthesia; 2d IV; NG tube, parenteral pain medications (morphine), HCT, type and cross, blood, irrigation and debridement, hemorrhage control, hemostatic agents, IV antibiotics, dressing, cardiac monitor, pulse oximeter, ventilator, Foley catheter. Remaining 75 percent: 90 percent IV antiemetics (Kytril), counseling. LAB: CBC with differentials twice daily until transferred. Note: All surgery must be completed within 36 to 48 hours; evacuation to a level of care that can provide appropriate urgent surgery. If appropriate surgery has been provided at this level, then routine evacuation (25 percent) to Level 3; otherwise urgent air transport (75 percent).

LEVEL 3

Assumptions: Significant and potentially lethal radiation exposure; litter patient; Class III hemorrhage; VS: pulse 120, B/P 100/70, respirations normal; alert; oriented. Radiation effects include apprehension and agitation; n/v 50 to 90 percent; mild headache; fatigue and weakness 25 to 60 percent; pretreatment with antiemetics may decrease vomiting; radiation contributes to morbidity at this level. 25 percent will receive appropriate surgery at Level 2; radiation will contribute to mortality and morbidity at this level. Radiation at this level combined with trauma multiplies mortality rates over baseline values.

Treatment: EMT: VS; primary assessment, IV restarted in 20 percent, give 2 liters LR; 2d IV started; IV antibiotics; parenteral morphine; Foley catheter; NG tube; lab: CBC with differential, UA, TC

for 4 units; x-rays: chest, 50 percent pelvis films, 90 percent IV antiemetic (Kytril); 100 percent draw one blood specimen per patient for biodosimetry red top tube (clot).

OR: 75 percent of patients arriving at Level 3. Laparotomy and drainage of liver injury under general anesthesia; 50 percent large bore central line; IV antibiotics; 8 liters LR; 2 units blood; arterial line 10 percent. LAB: CBC, blood gases; OR table time—120 minutes. Note: All surgery must be completed within 36—48 hours of radiation exposure.

WARDS: ICU: 100 percent of patients arriving at Level 3. VS; maintain IV fluids; IV antibiotics; parenteral morphine; Foley catheter care; drain care; NG tube care, NPO; 10 percent maintain ET tube and ventilator with O_2, extubate before leaving ICU; 90 percent on O_2 by mask; maintain central line and monitoring and arterial line; cardiac monitor and pulse oximeter; dressing reinforcement; dc central/arterial line before leaving ICU. LAB: CBC with differential twice daily, electrolytes, clotting studies, Amylase, LFTs on admission; x-ray: chest, 10 percent c-spine. Administer cytokines (G-CSF 480 mcg subcutaneous daily) in 100 percent. 100 percent draw blood specimens for HLA typing (three yellow top tubes [ACD] [keep refrigerated]). Reverse isolation.

ICW: 100 percent of patients arriving at Level 3 will be transferred from ICU by day 2. VS; IVs with IV antibiotics; parenteral pain medications; 25 percent on O_2 by mask; Foley catheter care; maintain NG tube; NPO; dressing reinforcement; drain care. Administer cytokines (G-CSF 480 mcg subcutaneous daily) in 100 percent. LAB: CBC with differentials twice daily. 100 percent draw blood specimens for HLA typing (three yellow top tubes [ACD]; keep refrigerated). Reverse isolation. 100 percent urgent air transport.

MCW: None.

C-36. Treatment Brief No. 13: Radiation >530 cGy With Operative Trauma

LEVEL 1A

Assumptions: Critical to lethal radiation exposure; 100 percent litter patient; VS: pulse greater than 100, B/P 100/60, no respiratory distress, evidence of closed intra-abdominal hemorrhage and injury. Extreme radiation doses will cause neurological deficits; additional radiation effects include: apprehension and agitation; n/v 100 percent; fatigue and weakness 100 percent; pretreatment with antiemetics may have no effects; radiation may contribute to morbidity at this level. Critical radiation injury with major trunk and/or head trauma places patient in expectant category.

Treatment: Start IV 100 percent (LR) reassurance. Patients with major trauma and high dose radiation have the lowest transport priority; 95 percent expectant patients routine ground transport; 5 percent nonexpectant patients urgent ground transport.

LEVEL 1B

Assumptions: Critical to lethal radiation exposure; 100 percent litter patients; VS: pulse greater than 100, B/P 100/60, no respiratory distress; evidence of closed intra-abdominal hemorrhage and injury. Extreme radiation doses will cause neurological deficits; additional radiation effects include: apprehension and agitation; n/v 100 percent; fatigue and weakness 100 percent; pretreatment with antiemetics may have no effects; radiation contributes to morbidity at this level. Critical radiation injury with major trunk and/or head trauma places patient in expectant category.

Treatment: VS: Maintain IV LR in 5 percent (nonexpectant); stabilization and IM morphine; reassurance; 90 percent Kytril IV; 10 percent cervical spine stabilized; 5 percent Overfly—urgent air

transport, 95 percent routine ground transport. Note: All surgery must be completed within 36 to 48 hours; evacuation to a level of care that can provide appropriate urgent surgery.

LEVEL 2

Assumptions: Critical to lethal radiation exposure; 100 percent litter patients; VS: pulse greater than 100, B/P 100/60, no respiratory distress; evidence of closed intra-abdominal hemorrhage and injury. Extreme radiation doses will cause neurological deficits; additional radiation effects include: apprehension and agitation; n/v 100 percent; fatigue and weakness 100 percent; pretreatment with antiemetics may have no effects; radiation contributes to morbidity at this level. Critical radiation injury with major trunk and/or head trauma places the patient in expectant category. Radiation at this level combined with trauma multiplies mortality rates over baseline values.

Treatment: Parenteral pain medications (morphine); 100 percent routine ground transport.

LEVEL 3

Assumptions: Critical to lethal radiation exposure; litter patient; Class III hemorrhage; VS: pulse 120, B/P 100/70, respirations normal. Extreme radiation doses will cause neurological deficits; additional radiation effects include: apprehension and agitation; n/v 100 percent; fatigue and weakness 100 percent; pretreatment with antiemetics may have no effects; radiation contributes to morbidity and mortality at this level. Critical radiation injury with major trunk and/or head trauma places patient in expectant category. Radiation at this level combined with trauma multiplies mortality rates over baseline values.

Treatment: EMT: VS; primary assessment, 3 percent of patients arriving at Level 3 are nonexpectant requiring surgery. IV restarted, give 2 liters LR; 2d IV started; IV antibiotics; parenteral morphine; Foley catheter; NG tube; LAB: CBC with differential, UA, TC for 4 units; x-rays: chest, 50 percent pelvis films, 90 percent IV antiemetic (Kytril); 97 percent of patients arriving at Level 3 are expectant and transferred to MCW. One hundred percent of patients arriving at Level 3 draw one blood specimen per patient for biodosimetry red top tube (clot).

OR: 3 percent of patients arriving at Level 3. Laparotomy and drainage of liver injury under general anesthesia; 50 percent large bore central line; IV antibiotics; 8 liters RL; 4 units blood; arterial line 10 percent. LAB: CBC, blood gases; OR table time—120 minutes. Note: All surgery must be completed within 36 to 48 hours of radiation exposure.

WARDS: ICU: 3 percent of patients arriving at Level 3. VS; maintain IV fluids; IV antibiotics; parenteral morphine; Foley catheter care; drain care; NG tube care, NPO; 10 percent maintain ET tube and ventilator with O_2, extubate before leaving ICU; 90 percent on O_2 by mask; maintain central line and monitoring and arterial line; cardiac monitor and pulse oximeter; dressing reinforcement; dc central/arterial line before leaving ICU. LAB: CBC with differential twice daily, electrolytes, clotting studies, Amylase, LFTs on admission. Administer cytokines (480 mcg G-CSF) subcutaneous daily in 100 percent. Draw blood specimens for HLA typing (three yellow top tubes ACD; [keep refrigerated]). Reverse isolation. Patients admitted to ICU—100 percent of patients to ICW after two days.

ICW: 3 percent of patients arriving at Level 3 will be transferred from ICU by day 2. VS; IVs with IV antibiotics; parenteral pain medications; 25 percent on O_2 by mask; Foley catheter care; maintain NG tube; NPO; dressing reinforcement; drain care. Administer cytokines (G-CSF 480 mcg subcutaneous daily) in 100 percent. LAB: CBC with differentials twice daily; 100 percent draw blood specimens for HLA typing (three yellow top tubes [ACD] [keep refrigerated]). Reverse isolation.

MCW: Expectant patients only (97 percent of patients arriving at Level 3); IM pain medications as needed. Patients admitted to MCW—mortality 90 percent by seven days.

C-37. Treatment Brief No. 14: Radiation at 0–125 cGy With Mild Burn

LEVEL 1A

Assumptions: Real or suspected radiation exposure; 100 percent ambulatory patients; VS stable, alert and oriented; additional radiation effects include: apprehension and agitation; n/v 5 to 30 percent; mild headache; pretreatment with antiemetics decrease vomiting; radiation does not contribute to mortality at this level.

Treatment: Clean and dress burns; pain medication; reassurance; 100 percent routine ground transport.

LEVEL 1B

Assumptions: Real or suspected radiation exposure; 100 percent ambulatory patients; VS stable, alert and oriented; additional radiation effects include: apprehension and agitation; n/v 5 to 30 percent; mild headache; pretreatment with antiemetics decrease vomiting; radiation does not contribute to mortality at this level.

Treatment: VS; stabilization, IV LR; pain medication; reassurance; 100 percent routine ground transport.

LEVEL 2

Assumptions: Real or suspected radiation exposure; 100 percent ambulatory patients; VS stable, alert and oriented. Additional radiation effects include: apprehension and agitation; n/v 5 to 30 percent; mild headache; pretreatment with antiemetics decreases vomiting; radiation does not contribute to mortality at this level.

Treatment: IV fluids LR (1 Liter); pain medication; moist cool compress/bulky dressing, one percent of patients receive O_2 (carbon monoxide poison), rest, reassurance/counseling. LAB: CBC with differentials twice daily until transferred; routine ground/air transport 100 percent.

LEVEL 3

Assumptions: Real or suspected radiation exposure; 100 percent ambulatory patients; VS stable, alert and oriented; additional radiation effects include: apprehension and agitation; n/v 5 to 30 percent; mild headache; pretreatment with antiemetics decrease vomiting; radiation does not contribute to mortality at this level.

Treatment: EMT: VS; primary assessment. LAB: 100 percent draw one blood specimen per patient for biodosimetry (red top [clot] [keep refrigerated]), CBC with differential for radiation exposure prognosis; tetanus toxoid; topical antibiotics.

OR: 1 percent of patients arriving at Level 3; 1 percent escharotomy, under MAC anesthesia, maintain IVs; topical burn agents; wound dressing; OR table time 60 minutes.

WARDS: ICU: None.

ICW: 30 percent of patients arriving at Level 3. CBC with differentials twice daily. Patients admitted to ICW—routine air transport 100 percent.

MCW: 70 percent of patients arriving at Level 3, VS; supportive care; push PO fluids, advance diet. LAB: 100 percent CBC with differentials twice daily; topical burn agents; wound dressing. Patients admitted to MCW—RTD 10 percent; routine air transport 90 percent.

C-38. Treatment Brief No. 15: Radiation at 125–530 cGy With Mild Burn (Without treatment 90 percent mortality.)

LEVEL 1A

Assumptions: Significant radiation exposure; 75 percent ambulatory patients; VS stable, alert and oriented; additional radiation effects include: apprehension and agitation; n/v 50 to 90 percent; mild headache; mild fatigability and weakness 25—60 percent; pretreatment with antiemetics decrease vomiting; radiation does not contribute to mortality at this level.

Treatment: Clean and dress burns; reassurance; 25 percent IM morphine; 75 percent oral pain medications; 100 percent priority ground transport.

LEVEL 1B

Assumptions: Significant radiation exposure; 80 percent ambulatory patients; 20 percent litter patients; VS stable, alert and oriented; additional radiation effects include: apprehension and agitation; n/v 50 to 90 percent; mild headache; mild fatigability and weakness 25 to 60 percent; pretreatment with antiemetics decreases vomiting; radiation does not contribute to mortality at this level.

Treatment: VS: Stabilization, IV LR, and 25 percent IM morphine; reassurance; 90 percent IV antiemetics, 100 percent priority ground transport.

LEVEL 2

Assumptions: Significant radiation exposure; 75 percent ambulatory patients; 25 percent litter patients; VS stable, alert and oriented; additional radiation effects include: apprehension and agitation; n/v 50 to 90 percent; mild headache; mild fatigability and weakness 25 to 60 percent; pretreatment with antiemetics decreases vomiting; radiation does not contribute to mortality at this level.

Treatment: IV fluids LR (1 Liter) and IV/IM morphine; moist cool compress/bulky dressing, 1 percent of patients receive O_2 (carbon monoxide poison), rest, reassurance; counseling. LAB: CBC with differential twice daily until transferred; attempt reverse isolation; 100 percent priority ground transport.

LEVEL 3

Assumptions: Significant radiation exposure; no respiratory injuries; 75 percent ambulatory patients; 25 percent litter patients; VS stable, alert and oriented; additional radiation effects include: apprehension and agitation; n/v 30 to 60 percent; mild headache; mild fatigability and weakness 25 to 60 percent; pretreatment with antiemetics decrease vomiting.

Treatment: EMT: VS; primary assessment. LAB: Draw one blood specimen per patient for biodosimetry (red top [clot] [keep refrigerated]) CBC with differential for radiation exposure prognosis, parenteral/oral morphine; tetanus toxoid; topical antibiotics.

OR: 1 percent escharotomy, under MAC anesthesia, maintain IVs; topical burn agents; wound dressing; OR table time 60 minutes.

WARDS: ICU: None.

ICW: 100 percent of patients arriving at Level 3. CBC with differentials twice daily. Draw blood specimens for HLA typing (three yellow top tubes [ACD] [keep refrigerated]). Cytokines (G-CSF 480 mcg subcutaneous daily). Sixty percent IV antiemetics. Reverse isolation. Patients admitted to ICW—100 percent priority air transport.

MCW: None.

C-39. Treatment Brief No. 16: Radiation >530 cGy With Mild Burn (Without treatment 100 percent mortality.)

LEVEL 1A

Assumptions: Critical to lethal radiation exposure; 100 percent litter patients; VS stable, alert and oriented. Central neurological deficits will be indicative of extreme radiation doses. Additional radiation effects include: apprehension and agitation; n/v 90 to 100 percent; fatigue and weakness 90 to 100 percent; pretreatment with antiemetics may have no effects; radiation may contribute to morbidity at this level.

Treatment: Clean and dress burns; IM morphine; reassurance; 100 percent priority ground transport.

LEVEL 1B

Assumptions: Critical to lethal radiation exposure; 100 percent litter patient; VS alert and oriented; central neurological deficits will be indicative of extreme radiation doses. Additional radiation effects include: apprehension and agitation; n/v 90 to 100 percent; fatigue and weakness 90 to 100 percent; pretreatment with antiemetics may have no effects; radiation will contribute to morbidity at this level. Critical radiation injury with persistent central neurological signs places patient in expectant category (10 percent of patients at this level).

Treatment: VS: start IV LR in nonexpectant patients (90 percent of patients); stabilization and IM morphine/IV antiemetics; reassurance; 90 percent priority ground transport; 10 percent routine ground transport.

LEVEL 2

Assumptions: Critical to lethal radiation exposure; 100 percent litter patients; VS stable, alert and oriented. Central neurological deficits will be indicative of extreme radiation doses; additional radiation effects include: apprehension and agitation; n/v 90 to 100 percent; fatigue and weakness 90 to 100 percent; pretreatment with antiemetics may have no effect; radiation will contribute to morbidity at this level. Critical radiation injury with persistent central neurological signs places patient in expectant category (10 percent of patients at this level). Automated differential cell counter available.

Treatment: Maintain IV fluids LR and IV/IM morphine; 100 percent injectable antiemetics; moist cool compress/bulky dressing, 1 percent of patients receive O_2 (carbon monoxide poison), rest, reassurance/ counseling. LAB: CBC with differentials twice daily until transferred; attempt reverse isolation; 10 percent routine ground/air transport, 90 percent priority air transport.

LEVEL 3

Assumptions: Critical to lethal radiation exposure; 100 percent litter patient; no respiratory injuries. VS stable; central neurological deficits will be indicative of extreme radiation doses; additional radiation effects include: apprehension and agitation; n/v 90 to 100 percent; fatigue and weakness 90 to 100 percent; pretreatment with antiemetics may have no effects; radiation will contribute to morbidity and mortality at this level. Critical radiation injury with persistent central neurological signs places patient in expectant category.

Treatment: EMT: VS; primary assessment. LAB: 100 percent draw one blood specimen per patient for biodosimetry (red top [clot] [keep refrigerated]), CBC with differential for radiation exposure prognosis; parenteral/oral morphine; tetanus toxoid; topical antibiotics.

OR: 1 percent escharotomy, under MAC anesthesia, maintain IVs; topical burn agents; wound dressing; OR table time 60 minutes. Third degree burn excision skin grafts must be in place by 48 hours.

WARDS: ICU: None.

ICW: 80 percent of patients arriving at Level 3. CBC with differentials twice daily times four days. Administer cytokines (480 mcg G-CSF) subcutaneous daily in 100 percent; CBC with differentials twice daily times four days. Draw blood specimens for HLA typing (three yellow top tubes [ACD] [keep refrigerated]); reverse isolation. Patients admitted to ICW— mortality 12 percent at this level at 5 to 7 days; 60 percent priority air transport; 38 percent routine air transport.

MCW: 20 percent of patients arriving at Level 3; expectant patients only; IM morphine as needed. Patients admitted to MCW—mortality 100 percent by seven days.

C-40. Treatment Brief No. 17: Radiation at 0–125 cGy With Moderate Burn

LEVEL 1A

Assumptions: Real or suspected radiation exposure; 100 percent ambulatory patients; both upper extremities involved in burn; alert; oriented; VS: stable; no other apparent injuries. Radiation effects include: apprehension and agitation; n/v 5 to 30 percent; mild headache; pretreatment with antiemetics decrease vomiting; radiation does not contribute to mortality at this level.

Treatment: Clean and dress burns; 80 percent IM morphine; reassurance; 100 percent priority ground transport.

LEVEL 1B

Assumptions: Real or suspected radiation exposure; 20 percent ambulatory patients; 80 percent litter patients; VS stable, alert and oriented. Radiation effects include: apprehension and agitation; n/v 5 to 30 percent; mild headache; pretreatment with antiemetics decrease vomiting; radiation does not contribute to mortality at this level.

Treatment: VS: Stabilization, 100 percent IV LR; reassurance; 80 percent IM morphine/antiemetics; 100 percent priority ground transport.

LEVEL 2

Assumptions: Real or suspected radiation exposure; 100 percent ambulatory patients; VS stable, alert and oriented. Radiation effects include: apprehension and agitation; n/v 5 to 30 percent; mild headache; pretreatment with antiemetics decrease vomiting; radiation does not contribute to mortality at this level. Automated differential cell counter available.

Treatment: VS: Stabilization; 100 percent IV LR and 80 percent IV/IM morphine; IV antiemetic; rest, reassurance, counseling. LAB: CBC with differentials twice daily until transferred; 100 percent priority ground/air transport.

LEVEL 3

Assumptions: Real or suspected radiation exposure; 20 percent ambulatory patients; 80 percent litter patients; VS stable, alert and oriented. Radiation effects include: apprehension and agitation; n/v 5 to 30 percent; mild headache; pretreatment with antiemetics decrease vomiting; radiation does not contribute to morbidity and mortality at this level.

Treatment: EMT: VS; primary assessment. LAB: Draw one blood specimen per patient for biodosimetry (red top [clot] [keep refrigerated]); CBC with differential for radiation exposure prognosis. Start IV in unburned area on 20 percent, give 3 liters LR; tetanus toxoid; topical antibiotics; debridement in EMT.

OR: 10 percent escharotomy, under MAC anesthesia, maintain IV's; topical burn agents; wound dressing; OR table time 60 minutes. Comment: For 3d degree burn excision skin grafts must be in place by 48 hours (those with 6 to 10 percent 3d degree burns).

WARDS: ICU: None.

ICW: 100 percent of patients arriving at Level 3; CBC with differentials twice daily. IV/IM morphine; (topical antibiotic); IV LR 6 liters per day; general surgeon consult; PT consult; CBC with differentials twice daily times four days. Reverse isolation; culture surveillance beginning day 3. Patients admitted to ICW—mortality 5 percent estimated at this level at 5 to 7 days; 95 percent priority transport.

MCW: None.

C-41. Treatment Brief No. 18: Radiation at 125–530 cGy With Moderate Burn (Without treatment 100 percent mortality.)

LEVEL 1A

Assumptions: Significant radiation exposure; 100 percent litter patients; both upper extremities involved in burn; alert; oriented; VS: stable; no other apparent injuries. Radiation effects include: apprehension and agitation; n/v 50 to 90 percent; mild headache; fatigue and weakness 25 to 60 percent; pretreatment with antiemetics decreases vomiting; radiation does not contribute to mortality at this level.

Treatment: Clean and dress burns; 100 percent IV LR; pain medication prn, IM morphine; reassurance; 100 percent priority ground transport.

LEVEL 1B

Assumptions: Significant radiation exposure; 100 percent litter patients; VS stable, alert and oriented. Radiation effects include: apprehension and agitation; n/v 50 to 90 percent; mild headache; fatigue and weakness 25 to 60 percent; pretreatment with antiemetics decreases vomiting; radiation does not contribute to mortality at this level.

Treatment: VS; stabilization, maintain IV LR; reassurance; injectable pain medication (IM morphine) antiemetic medication; 100 percent priority ground transport.

LEVEL 2

Assumptions: Significant radiation exposure; 100 percent litter patients; VS stable, alert and oriented. Radiation effects include: apprehension and agitation; n/v 50 to 90 percent; mild headache; fatigue and weakness 25 to 60 percent; pretreatment with antiemetics decrease vomiting; radiation does not contribute to mortality at this level. Automated differential cell counter available.

Treatment: VS: Stabilization, 100 percent IV LR, 90 percent IV antiemetics and pain medication (IV/IM morphine); reassurance; attempt reverse isolation as operational constraints and logistics allow; 100 percent priority ground/air transport.

LEVEL 3

Assumptions: Significant radiation exposure; 100 percent litter patients; VS stable, alert and oriented. Radiation effects include: apprehension and agitation; n/v 50 to 90 percent; mild headache; fatigue and weakness 25 to 60 percent; pretreatment with antiemetics decrease vomiting; radiation does contribute to morbidity and mortality at this level.

Treatment: EMT: VS; primary assessment. LAB: Draw one blood specimen per patient for biodosimetry (red top [clot] [keep refrigerated]); CBC with differential every 6 hours for radiation exposure prognosis, electrolytes every 12 hours. Start IV in unburned area on 20 percent, give 3 liters LR; tetanus toxoid; topical antibiotics; debridement in EMT.

OR: 10 percent escharotomy, under MAC anesthesia, maintain IVs; topical burn agents; wound dressing; OR table time 60 minutes. Comment: For 3d degree burn excision skin grafts must be in place by 48 hours (those with 6 to 10 percent 3d degree burns and < 300 cGy).

WARDS: ICU: None.

ICW: 100 percent of patients arriving at Level 3; CBC with differentials twice daily. IV/IM morphine; (topical antibiotic); IV LR 6 liters per day; general surgeon consult; PT consult; administer cytokines (480 mcg G-CSF) subcutaneous daily in 100 percent; CBC with differentials twice daily draw blood specimens for HLA typing (three yellow top tubes [ACD] [keep refrigerated]). Reverse isolation. Culture surveillance beginning day 3. Patients admitted to ICW—mortality 40 percent estimated at this level at 5 to 7 days, 30 percent to (MCW—Expectant), 60 percent priority air transport.

MCW: 30 percent of patients arriving at Level 3 (transferred from ICW); 100 percent IV/IM morphine for pain control.

C-42. Treatment Brief No. 19: Radiation >530 cGy With Moderate Burn (With or without treatment 100 percent mortality.)

LEVEL 1A

Assumptions: Critical to lethal radiation exposure; 100 percent litter patients; both upper extremities involved in burn; alert; oriented; VS: stable; no other apparent injuries. Central neurological deficits will be indicative of extreme radiation doses; additional radiation effects include: apprehension and agitation; n/v 100 percent; fatigue and weakness 100 percent; pretreatment with antiemetics may have no effects; radiation may contribute to morbidity at this level.

Treatment: Clean and dress burns; IM morphine; reassurance; 100 percent priority ground transport.

LEVEL 1B

Assumptions: Critical to lethal radiation exposure; 100 percent litter patient; VS stable, alert and oriented. Central neurological deficits will be indicative of extreme radiation doses; additional radiation effects include: apprehension and agitation; n/v 100 percent; fatigue and weakness 100 percent; pretreatment with antiemetics may have no effects; radiation will contribute to morbidity at this level. Critical radiation injury with persistent central neurological signs places the patient in expectant category (10 percent of patients at this level).

Treatment: VS: IV LR in nonexpectant patients (70 percent of patients at this point); stabilization and injectable morphine/antiemetic medication; reassurance; 70 percent priority ground transport; 30 percent routine ground transport.

LEVEL 2

Assumptions: Critical to lethal radiation exposure; 100 percent litter patients; VS stable. Central neurological deficits will be indicative of extreme radiation doses; additional radiation effects include: apprehension and agitation; n/v 100 percent; fatigue and weakness 100 percent; pretreatment with antiemetics may have no effects; radiation will contribute to morbidity at this level. Critical radiation injury with persistent central neurological signs places patient in expectant category (10 percent of patients at this level). Automated differential cell counter available.

Treatment: 100 percent IV fluids LR and IV/IM morphine; 100 percent injectable antiemetics; rest, reassurance/counseling. LAB: CBC with differentials twice daily until transferred; attempt reverse isolation; 70 percent priority air transport; 30 percent routine ground transport.

LEVEL 3

Assumptions: Critical to lethal radiation exposure; 100 percent litter patient; VS stable. Central neurological deficits will be indicative of extreme radiation doses; additional radiation effects include: apprehension and agitation; n/v 100 percent; fatigue and weakness 100 percent; pretreatment with antiemetics may have no effects; radiation will contribute to mortality and morbidity at this level. Critical radiation injury with persistent central neurological signs places the patient in expectant category (10 percent of patients at this level).

Treatment: EMT: VS; primary assessment, 100 percent IV antiemetics. LAB: Draw one blood specimen per patient for biodosimetry (red top [clot] [keep refrigerated]); CBC with differential every 6 hours for radiation exposure prognosis, electrolytes every 12 hours. Start IV in unburned area on 20 percent, give 3 liters LR; tetanus toxoid; topical antibiotics; debridement in EMT.

OR: 10 percent escharotomy, under MAC anesthesia, maintain IV's; topical burn agents; wound dressing; OR table time 60 minutes. Comment: For 3d degree burn excision skin grafts must be in place by 48 hours.

WARDS: ICU: 20 percent of patients arriving at Level 3; maintain IVs; topical burn agents; wound dressing; administer cytokines (480 mcg G-CSF) subcutaneous daily in 100 percent; LAB: CBC with differentials twice daily. Draw blood for HLA typing (three yellow top tubes [ACD] [keep refrigerated]). Reverse isolation. Patients admitted to ICU—100 percent to ICW after two days.

ICW: 50 percent of patients arriving at Level 3; CBC with differentials twice daily. IV/IM morphine; (topical antibiotic); IV LR 6 liters per day; general surgeon consult; PT consult. Administer cytokines (480 mcg G-CSF) subcutaneous daily in 100 percent; CBC with differentials twice daily. Draw blood specimens for HLA typing (three yellow top tubes [ACD]; keep refrigerated). Reverse isolation. Patients admitted to ICW at 5 to 7 days; 75 percent estimated mortality at this level; 30 percent priority air transport.

MCW: 30 percent of patients arriving at Level 3, expectant patients; IM/IV morphine as needed. Patients admitted to MCW—mortality 100 percent by seven days.

C-43. Treatment Brief No. 20: Radiation at 0–125 cGy With Severe Burn (Without treatment 20 percent mortality.)

LEVEL 1A

Assumptions: Real or suspected radiation exposure; 100 percent litter patients; VS stable, alert, oriented, both extremities injured; no other traumatic injuries. Radiation effects include: apprehension and

agitation; n/v 5 to 30 percent; pretreatment with antiemetics decreases vomiting; radiation does not contribute to mortality at this level. Deaths and expectant designation in accordance with burn protocols.

Treatment: Clean and dress burns; 100 percent IV LR; IM morphine; reassurance; 100 percent priority ground transport.

LEVEL 1B

Assumptions: Real or suspected radiation exposure; 100 percent litter patients; VS stable, alert, oriented, both extremities injured; no other traumatic injuries. Radiation effects include: apprehension and agitation; n/v 5 to 30 percent; pretreatment with antiemetics decreases vomiting; radiation does not contribute to mortality at this level.

Treatment: VS: Stabilization, IV LR (1 Liter); reassurance; injectable morphine/antiemetic (Promethazine) medication; 100 percent priority ground transport.

LEVEL 2

Assumptions: Real or suspected radiation exposure; 100 percent litter patients; VS stable, alert, oriented, both extremities injured; no other traumatic injuries. Radiation effects include: apprehension and agitation; n/v 5 to 30 percent; pretreatment with antiemetics decreases vomiting; radiation does not contribute to mortality at this level. Automated differential cell counter available.

Treatment: VS: Stabilization; IV fluids LR and IV/IM morphine; rest, reassurance/counseling. 90 percent IV antiemetics. Moist cool compress/bulky dressing, 10 percent of patients O_2, splint. LAB: CBC with differentials twice daily until transferred; 100 percent priority air transport.

LEVEL 3

Assumptions: Real or suspected radiation exposure; 100 percent litter patients; VS stable, alert, oriented, both extremities injured; no other traumatic injuries. Radiation effects include: apprehension and agitation; n/v 5 to 30 percent; pretreatment with antiemetics decreases vomiting; radiation does not contribute to morbidity and mortality at this level. Deaths and expectant designation in accordance with burn protocols.

Treatment: EMT: VS; primary assessment. LAB: Draw one blood specimen per patient for biodosimetry (red top [clot] [keep refrigerated]), CBC with differential for radiation exposure prognosis. Maintain LR IVs; topical antibiotics; IM/IV morphine; forced fluids; dressing changes.

OR: 50 percent of patients arriving at Level 3 undergo debridement of the hands; MAC anesthesia; 2 liters LR; OR table time 60 minutes.

WARDS: ICU: 50 percent of patients arriving at Level 3. LAB: CBC with differentials twice daily. Maintain LR IVs; topical antibiotics; IM/IV morphine; forced fluids; dressing changes. Reverse isolation. Patients admitted to ICU—100 percent transferred out of ICU after two days (50 percent AIREVAC; 45 percent of patients to ICW; 5 percent to MCW).

ICW: 70 percent of patients arriving at Level 3; VS; maintain IVs; physical therapy consult; topical antibiotics; IM/IV morphine; forced fluids; dressing changes. LAB: CBC with differentials twice daily. Reverse isolation; culture surveillance beginning day 3; patients admitted to ICW—100 percent priority air transport.

MCW: 10 percent of patients arriving at Level 3. Mortality 100 percent by day 7.

C-44. Treatment Brief No. 21: Radiation at 125–530 cGy With Severe Burn (Without treatment 100 percent mortality.)

LEVEL 1A

Assumptions: Significant radiation exposure; 100 percent litter patients; VS: stable, alert, oriented, both extremities injured; no other traumatic injuries. Additional radiation effects include: apprehension and agitation; n/v 50 to 90 percent; mild headache; fatigue and weakness 25 to 60 percent; pretreatment with antiemetics decreases vomiting; radiation does not contribute to mortality at this level.

Treatment: Clean and dress burns; 100 percent IV LR; IM morphine; reassurance; 100 percent priority ground transport.

LEVEL 1B

Assumptions: Significant radiation exposure; 100 percent litter patients; VS stable, alert, oriented, both extremities injured; no other traumatic injuries. Additional radiation effects include: apprehension and agitation; n/v 50 to 90 percent; mild headache; fatigue and weakness 25 to 60 percent; pretreatment with antiemetics decreases vomiting; radiation does not contribute to mortality at this level.

Treatment: VS: Stabilization, IV LR (1 Liter), and IM morphine; reassurance; 100 percent priority ground transport.

LEVEL 2

Assumptions: Significant radiation exposure; 100 percent litter patients; VS stable, alert, oriented, both extremities injured; no other traumatic injuries. Additional radiation effects include: apprehension and agitation; n/v 50 to 90 percent; mild headache; fatigue and weakness 25 to 60 percent; pretreatment with antiemetics decrease vomiting; radiation will not contribute to mortality at this level. Third degree burn patients are expectant. Automated differential cell counter available.

Treatment: Third degree burn patients (50 percent of patients arriving at Level 2); 100 percent IV/IM morphine as needed for pain; 100 percent injectable antiemetic medication; reassurance; routine ground transport. Second degree burn patients (50 percent of patients arriving at Level 2): VS: Stabilization, 100 percent IV LR (2 liters), and IV/IM morphine; moist cool compress/bulky dressing, 10 percent of patients O_2, splint, CBC with differential. Reassurance; 100 percent priority air transport.

LEVEL 3

Assumptions: Significant radiation exposure; 100 percent litter patients; VS stable, alert, oriented, both extremities injured; no other traumatic injuries. Additional radiation effects include: apprehension and agitation; n/v 50 to 90 percent; mild headache; fatigue and weakness 25 to 60 percent; pretreatment with antiemetics decreases vomiting; radiation will significantly contribute to mortality at this level. Third degree burn patients are expectant.

Treatment: EMT: VS; primary assessment. LAB: Draw one blood specimen per patient for biodosimetry (red top [clot] [keep refrigerated]), CBC with differential for radiation exposure prognosis. Maintain LR IVs; topical antibiotics; IM/IV morphine; forced fluids; dressing changes.

OR: 50 percent of patients arriving at Level 3 undergo debridement of the hands; MAC anesthesia; 2 liters LR; OR table time—60 minutes.

WARDS: ICU: None.

ICW: 50 percent of patients arriving at Level 3; VS; maintain IVs; physical therapy consult; topical antibiotics; IM/IV morphine; forced fluids; dressing changes; CBC with differentials

twice daily. Reverse isolation. Draw blood specimens for HLA typing (three yellow top tubes [CD] [keep refrigerated]). Cytokines (G-CSF 480 mcg subcutaneous daily). Patients admitted to ICW—100 percent priority air transport.

MCW: 50 percent of patients arriving at Level 3 are expectant; IM/IV morphine for pain as needed. Patients admitted to MCW—mortality 100 percent by 15 days. Comment: Approximately 67 percent of expectant patients will have a prolonged dying process of greater than one week. Routine air transport when and if available.

C-45. Treatment Brief No. 22: Radiation >530 cGy with Severe Burn (With or without treatment 100 percent mortality.)

LEVEL 1A

Assumptions: Critical to lethal radiation exposure, but 100 percent mortality when combined with this severity of burn injury; litter patient; central neurological deficits will be indicative of extreme radiation doses. Additional radiation effects include: apprehension and agitation; n/v 100 percent; fatigue and weakness 100 percent; pretreatment with antiemetics may have no effects.

Treatment: Clean and dress burns; IM morphine; reassurance; 100 percent routine ground transport.

LEVEL 1B

Assumptions: Critical to lethal radiation exposure, but 100 percent mortality when combined with this severity of burn injury; litter patient; central neurological deficits will be indicative of extreme radiation doses. Additional radiation effects include: apprehension and agitation; n/v 100 percent; fatigue and weakness 100 percent; mortality 10 percent at this level.

Treatment: Comfort measures only; 100 percent morphine IV/IM as needed for pain, 100 percent injectable antiemetic medication; reassurance; 90 percent routine ground transport.

LEVEL 2

Assumptions: Critical to lethal radiation exposure, but 100 percent mortality when combined with this severity of burn injury; litter patient; central neurological deficits will be indicative of extreme radiation doses. Additional radiation effects include: apprehension and agitation; n/v 100 percent; fatigue and weakness 100 percent; mortality 50 percent within 24 hours.

Treatment: Comfort measures only; 100 percent morphine IV/IM as needed for pain, 100 percent injectable antiemetic medication; reassurance; 100 percent routine ground/air transport.

LEVEL 3

Assumptions: Critical to lethal radiation exposure, but 100 percent mortality when combined with this severity of burn injury; litter patient; central neurological deficits will be indicative of extreme radiation doses. Additional radiation effects include: apprehension and agitation; n/v 100 percent; fatigue and weakness 100 percent.

Treatment: EMT: Patients are all expectant. LAB: Draw one blood specimen per patient for biodosimetry (red top [clot] [keep refrigerated]), CBC with differential for radiation exposure.

OR: None.

WARDS: ICU: None.

ICW: None.

MCW: 100 percent of patients arriving at Level 3 are expectant. IM pain medications (morphine) as needed. Patients admitted to MCW—mortality 100 percent by five days.

C-46. Treatment Brief No. 23: Radiation at 0–125 cGy with Operative Trauma and Mild Burn

LEVEL 1A

Assumptions: Real or suspected radiation exposure; litter patient; alert, cooperative and oriented; VS pulse greater than 100, B/P 100/60, no respiratory distress, evidence of closed intra-abdominal hemorrhage and injury. Radiation effects include: apprehension and agitation, n/v 5 to 30 percent; mild headache; pretreatment with antiemetics decrease vomiting and possibly increase fatigability; radiation does not contribute to mortality at this echelon.

Treatment: Dress open wounds; start IV 100 percent (LR); IM morphine; reassurance; 100 percent priority ground transport.

LEVEL 1B

Assumptions: Real or suspected radiation exposure; 100 percent litter patients, alert, cooperative and oriented; VS: pulse greater than 100, B/P 100/60, no respiratory distress; evidence of closed intra-abdominal hemorrhage and injury. Radiation effects include: apprehension and agitation; n/v 5 to 30 percent; mild headache; pretreatment with antiemetics decrease vomiting and possibly increase fatigability; radiation does not contribute to mortality at this level.

Treatment: VS: Maintain IV LR in 100 percent; stabilization and IM morphine; reassurance; 30 percent IV/IM antiemetics (Kytril); 10 percent cervical spine stabilized; 100 percent urgent air transport. Note: All surgery must be completed within 36 to 48 hours; evacuation to a level of care that can provide appropriate urgent surgery.

LEVEL 2

Assumptions: Real or suspected radiation exposure; 100 percent litter patients; alert, cooperative and oriented; VS: pulse greater than 100, B/P 100/60, no respiratory distress; evidence of closed intra-abdominal hemorrhage and injury; thermal burns to extremities. Radiation effects include: apprehension and agitation; n/v 5 to 30 percent; mild headache; mild fatigability and weakness 25 to 60 percent; pretreatment with antiemetics decrease vomiting and possibly increase fatigability; radiation may contribute to morbidity at this level due to immunosuppression.

Treatment: 25 percent exploratory laparotomy at this level; general anesthesia; 2d IV; NG tube, parenteral pain medications (morphine), HCT, type and cross, blood, irrigation and debridement, hemorrhage control, hemostatic agents, IV antibiotics, dressing, cardiac monitor, pulse oximeter, ventilator, Foley catheter, moist cool compress/bulky dressing, 1 percent O_2 (carbon monoxide poison). Remaining 75 percent: 30 percent IV/IM antiemetics (Kytril), topical antibiotic, counseling. LAB: CBC with differentials twice daily until transferred. Note: All surgery must be completed within 36 to 48 hours; evacuation to a level of care that can provide appropriate urgent surgery. If appropriate surgery has been provided at this level, then routine evacuation (25 percent) to Level 3; otherwise urgent air transport (75 percent).

LEVEL 3

Assumptions: Real or suspected radiation exposure; litter patient; Class III hemorrhage; VS: pulse 120, B/P 100/70, respirations normal; alert; oriented. 25 percent will receive appropriate surgery at Level 2.

Radiation effects include: apprehension and agitation; n/v 5 to 30 percent; mild headache; pretreatment with antiemetics decreases vomiting; radiation will contribute to morbidity at this level due to immuno-suppression.

Treatment: EMT: VS; primary assessment, IV restarted in 20 percent, give 2 liters LR; 2d IV started; IV antibiotics; parenteral morphine; Foley catheter; NG tube. LAB: CBC with differential, UA, TC for 4 units; x-rays: chest, 50 percent pelvis films, start IV in unburned area on 20 percent, give 3 liters LR; tetanus toxoid; topical antibiotics (sulfamylon); 10 percent debridement; 30 percent IV/IM antiemetics; 100 percent draw one blood specimen per patient for biodosimetry (red top tube [clot] [keep refrigerated]) for radiation exposure prognosis.

OR: 75 percent of patients arriving at Level 3. Laparotomy and drainage of liver injury and debridement under general anesthesia; 50 percent large bore central line; IV antibiotics; 8 liters RL; 2 units blood; arterial line 10 percent. LAB: CBC, blood gases; OR table time—150 minutes. Note: All surgery must be completed within 36 to 48 hours of radiation exposure.

WARDS: ICU: 100 percent of patients arriving at Level 3; moist cool compress/ bulky dressing, 1 percent O_2 (carbon monoxide poison). LAB: CBC with differential twice daily for radiation exposure prognosis. Consider cytokines (G-CSF 480 mcg subcutaneous daily); maintain IV fluids; IV antibiotics; parenteral morphine; Foley catheter care; drain care; NG tube care, NPO; 10 percent maintain ET tube and ventilator with O_2, extubate before leaving ICU; 90 percent on O_2 by mask; maintain central line and monitoring and arterial line; cardiac monitor and pulse oximeter; CBC with differentials twice daily. IV/IM morphine; topical antibiotic sulfamylon); IV LR 6 liters per day; dressing reinforcement; dc central/arterial line before leaving ICU; 90 percent to ICW by day 2; 10 percent transferred to MCW. Percentages based on patients admitted to ICU.

ICW: 90 percent of patients arriving at Level 3 will be transferred from ICU by day 2. VS; IVs with IV antibiotics; 25 percent on O_2 by mask; Foley catheter care; maintain NG tube; NPO; CBC with differentials twice daily. IV/IM morphine; topical antibiotic (sulfamylon); IV LR 6 liters per day; dressing reinforcement; drain care, moist cool compress/bulky dressing, 1 percent O_2 (carbon monoxide poison). LAB: CBC with differential twice daily for radiation exposure prognosis. Consider cytokines (G-CSF 480 mcg subcutaneous daily); routine air transport 40 percent, priority air transport 60 percent. Percentages based on patients admitted to ICW.

MCW: 10 percent of patients arriving at Level 3. VS; supportive care; IV/IM morphine. LAB: CBC with differential twice daily; 100 percent mortality. Percentages based on patients admitted to MCW.

C-47. Treatment Brief No. 24: Radiation at 125–530 cGy With Operative Trauma and Mild Burn (Without treatment 100 percent mortality.)

LEVEL 1A

Assumptions: Significant and potentially lethal radiation exposure; 100 percent litter patients; alert, cooperative and oriented; VS: pulse greater than 100, B/P 100/60, no respiratory distress, evidence of closed intra-abdominal hemorrhage and injury. Radiation effects include: apprehension and agitation; n/v 50 to 90 percent; significant fatigability and weakness 25 to 60 percent; pretreatment with antiemetics decrease vomiting; radiation does not contribute to mortality at this level.

Treatment: Dress open wounds; reassurance; start IV 100 percent (LR); IM morphine; 100 percent priority ground transport.

LEVEL 1B

Assumptions: Significant and potentially lethal radiation exposure; 100 percent litter patients; alert, cooperative and oriented; VS: pulse greater than 100, B/P 100/60, no respiratory distress; evidence of closed intra-abdominal hemorrhage and injury. Radiation effects include: apprehension and agitation; n/v 50 to 90 percent; headache; significant fatigability and weakness 25 to 60 percent; pretreatment with antiemetics decrease vomiting; radiation does not contribute to mortality at this level.

Treatment: VS: Maintain IV LR in 100 percent; stabilization and IV morphine; reassurance; IV antiemetics (Kytril); 10 percent cervical spine stabilized; 100 percent urgent air transport. Note: All surgery must be completed within 36 to 48 hours; evacuation to a level of care that can provide appropriate urgent surgery.

LEVEL 2

Assumptions: Significant and potentially lethal radiation exposure. 100 percent litter patients; alert, cooperative and oriented; VS: pulse greater than 100, B/P 100/60, no respiratory distress; evidence of closed intra-abdominal hemorrhage and injury; thermal burns to extremities. Radiation effects include: apprehension and agitation; n/v 50 to 90 percent; headache; significant fatigability and weakness 25 to 60 percent; pretreatment with antiemetics decrease vomiting; radiation will contribute to morbidity at this level due to immunosuppression.

Treatment: 25 percent exploratory laparotomy at this level; general anesthesia; 2d IV; NG tube, parenteral pain medications (morphine), HCT, type and cross, blood, irrigation and debridement, hemorrhage control, hemostatic agents, IV antibiotics, dressing, cardiac monitor, pulse oximeter, ventilator, Foley catheter, moist cool compress/bulky dressing, 1 percent O_2 (carbon monoxide poison). Remaining 75 percent: 90 percent IV/IM antiemetics (Kytril), topical antibiotic (sulfamylon), counseling. LAB: CBC with differentials twice daily until transferred. If appropriate surgery has been provided at this level, then routine evacuation (25 percent) to Level 3; otherwise urgent air transport (75 percent). Note: All surgery must be completed within 36 to 48 hours; evacuation to a level of care that can provide appropriate urgent surgery.

LEVEL 3

Assumptions: Significant and potentially lethal radiation exposure; 100 percent litter patients; Class III hemorrhage; VS: pulse 120, B/P 100/70, respirations normal; alert; oriented. Radiation effects include: apprehension and agitation; n/v 50 to 90 percent; headache; fatigability and weakness 25 to 60 percent; pretreatment with antiemetics decreases vomiting; 25 percent will receive appropriate surgery at Level 2; radiation will contribute to morbidity at this level due to immunosuppression.

Treatment: EMT: VS; primary assessment, IV restarted in 20 percent, give 2 liters LR; 2d IV started; IV antibiotics; parenteral morphine; Foley catheter; NG tube. LAB: CBC with differential, UA, TC for 4 units; x-rays: chest, 50 percent pelvis films, start IV in unburned area on 20 percent, give 3 liters LR; tetanus toxoid; topical antibiotics (sulfamylon); 10 percent debridement; 30 percent IV/IM antiemetics; 100 percent draw one blood specimen per patient for biodosimetry (red top tube [clot] [keep refrigerated]) for radiation exposure prognosis.

OR: 75 percent of patients arriving at Level 3, laparotomy and drainage of liver injury and debridement under general anesthesia; 50 percent large bore central line; IV antibiotics; 8 liters RL; 2 units blood; arterial line 10 percent. LAB: CBC, blood gases; OR table time—150 minutes. Note: All surgery must be completed within 36 to 48 hours of radiation exposure.

WARDS: ICU: 100 percent of patients arriving at Level 3; moist cool compress/ bulky dressing, 1 percent O_2 (carbon monoxide poison). LAB: CBC with differential twice daily for radiation exposure prognosis; 100 percent cytokines (G-CSF 480 mcg subcutaneous daily); maintain IV fluids; IV antibiotics; parenteral morphine; Foley catheter care; drain care; NG tube care, NPO; 10 percent maintain ET tube and ventilator with O_2, extubate before leaving ICU; 90 percent on O_2 by mask; maintain central line and monitoring and arterial line; cardiac monitor and pulse oximeter; CBC with differentials twice daily. IV/IM morphine; topical antibiotic (sulfamylon); IV LR 6 liters per day; dressing reinforcement; dc central/arterial line before leaving ICU; 20 percent to MCW, 50 percent priority air transport, and 30 percent to ICW by day 3. Percentages based on patients admitted to ICU.

ICW: 30 percent of patients arriving at Level 3, VS; IVs with IV antibiotics; 25 percent on O_2 by mask; Foley catheter care; maintain NG tube; NPO; CBC with differentials twice daily. IV/IM morphine; topical antibiotic (sulfamylon); IV LR 6 liters per day; dressing reinforcement; drain care, moist cool compress/bulky dressing, 1 percent O_2 (carbon monoxide poison). LAB: CBC with differential twice daily; 100 percent cytokines (G-CSF 480 mcg subcutaneous daily); 70 percent mortality; 30 percent priority air transport. Percentages based on patients admitted to ICW.

MCW: 20 percent of patients arriving at Level 3, VS; supportive care; IV/ IM morphine. LAB: CBC with differential twice daily 100 percent mortality. Percentages based on patients admitted to MCW.

C-48. Treatment Brief No. 25: Radiation >530 cGy With Operative Trauma and Mild Burn (With or without treatment 100 percent mortality.)

LEVEL 1A

Assumptions: Critical to lethal radiation exposure, but 100 percent mortality when combined with this severity of burn injury; litter patient; central neurological deficits will be indicative of extreme radiation doses. Additional radiation effects include: apprehension and agitation; n/v 100 percent; fatigue and weakness 100 percent; pretreatment with antiemetics may have no effects.

Treatment: Clean and dress burns; IM morphine; reassurance; 100 percent routine ground transport.

LEVEL 1B

Assumptions: Critical to lethal radiation exposure, but 100 percent mortality when combined with this severity of burn injury; litter patient; central neurological deficits will be indicative of extreme radiation doses. Additional radiation effects include: apprehension and agitation; n/v 100 percent; fatigue and weakness 100 percent; mortality 10 percent at this level.

Treatment: Comfort measures only; 100 percent morphine IV/IM as needed for pain, 100 percent injectable antiemetic medication; reassurance; 90 percent routine ground transport.

LEVEL 2

Assumptions: Critical to lethal radiation exposure, but 100 percent mortality when combined with this severity of burn injury; litter patient; central neurological deficits will be indicative of extreme radiation doses. Additional radiation effects include: apprehension and agitation; n/v 100 percent; fatigue and weakness 100 percent; mortality 50 percent within 24 hours.

Treatment: Comfort measures only; 100 percent morphine IV/IM as needed for pain, 100 percent injectable antiemetic medication; reassurance; 100 percent routine ground/air transport.

LEVEL 3

Assumptions: Critical to lethal radiation exposure, but 100 percent mortality when combined with this severity of burn injury; litter patient; central neurological deficits will be indicative of extreme radiation doses. Additional radiation effects include: apprehension and agitation; n/v 100 percent; fatigue and weakness 100 percent.

Treatment: EMT: Patients are all expectant. LAB: Draw one blood specimen per patient for biodosimetry (red top [clot] [keep refrigerated]), CBC with differential for radiation exposure.

OR: None.

WARDS: ICU: None.

ICW: None.

MCW: 100 percent of patients arriving at Level 3; expectant patients only; IM pain medications (morphine) as needed. Patients admitted to MCW—mortality 100 percent by five days.

C-49. Treatment Brief No. 26: Radiation at 0–125 cGy With Operative Trauma and Moderate Burn (Without treatment 100 percent mortality.)

LEVEL 1A

Assumptions: Real or suspected radiation exposure; 100 percent litter patients; alert, cooperative and oriented; VS pulse greater than 100, B/P 100/60, no respiratory distress, evidence of closed intra-abdominal hemorrhage and injury. Radiation effects include: apprehension and agitation; n/v 50 to 90 percent; mild headache; pretreatment with antiemetics decrease vomiting; radiation does not contribute to mortality at this level.

Treatment: Dress open wounds; start IV 100 percent (LR); IM morphine; reassurance; 100 percent priority ground transport.

LEVEL 1B

Assumptions: Real or suspected radiation exposure; 100 percent litter patients; alert, cooperative and oriented; VS: pulse greater than 100, B/P 100/60, no respiratory distress; evidence of closed intra-abdominal hemorrhage and injury. Radiation effects include: apprehension and agitation; n/v 50 to 90 percent; mild headache; pretreatment with antiemetics decrease vomiting; radiation contributes to morbidity at this level.

Treatment: VS: Maintain IV LR in 100 percent; stabilization and IM morphine; reassurance; 90 percent Kytril IV; 10 percent cervical spine stabilized; 100 percent urgent air transport. Note: All surgery must be completed within 36 to 48 hours; evacuation to a level of care that can provide appropriate urgent surgery.

LEVEL 2

Assumptions: Real or suspected radiation exposure; 100 percent litter patients; alert, cooperative and oriented; VS: pulse greater than 100, B/P 100/60, no respiratory distress; evidence of closed intra-abdominal hemorrhage and injury; thermal burns to extremities. Radiation effects include: apprehension and agitation; n/v 50 to 90 percent; mild headache; pretreatment with antiemetics may decrease vomiting; radiation contributes to morbidity at this level. Automated cell counter available.

Treatment: 25 percent exploratory laparotomy at this level; general anesthesia; 2d IV; NG tube, parenteral pain medications (morphine), HCT, type and cross, blood, irrigation and debridement,

hemorrhage control, hemostatic agents, IV antibiotics, dressing, cardiac monitor, pulse oximeter, ventilator, Foley catheter. Remaining 75 percent: 90 percent IV antiemetics (Kytril), topical antibiotic (sulfamylon), counseling. LAB: CBC with differentials twice daily until transferred. Note: All surgery must be completed within 36 to 48 hours; evacuation to a level of care that can provide appropriate urgent surgery. If appropriate surgery has been provided at this level, then routine evacuation (25 percent) to Level 3; otherwise urgent air transport (75 percent).

LEVEL 3

Assumptions: Real or suspected radiation exposure; 100 percent litter patients; Class III hemorrhage; VS: pulse 120, B/P 100/70, respirations normal; alert; oriented. Radiation effects include: apprehension and agitation; n/v 50 to 90 percent; mild headache; pretreatment with antiemetics may decrease vomiting; radiation contributes to morbidity at this level; 25 percent will receive appropriate surgery at Level 2; radiation will contribute to mortality and morbidity at this level. Radiation at this level combined with trauma multiplies mortality rates over baseline values.

Treatment: EMT: VS; primary assessment, IV restarted in 20 percent, give 2 liters LR; 2d IV started; IV antibiotics; parenteral morphine; Foley catheter; NG tube. LAB: CBC with differential, UA, TC for 4 units; x-rays: chest, 50 percent pelvis films. Start IV in unburned area on 20 percent, give 3 liters LR; tetanus toxoid; topical antibiotics (sulfamylon); 10 percent debridement; 90 percent IV antiemetic (Kytril); 100 percent draw one blood specimen per patient for biodosimetry red top tube (clot) for radiation exposure prognosis.

OR: 75 percent of patients arriving at Level 3. Laparotomy and drainage of liver injury and debridement under general anesthesia; 50 percent large bore central line; IV antibiotics; 8 liters RL; 2 units blood; arterial line 10 percent. LAB: CBC, blood gases; OR table time—150 minutes. Note: All surgery must be completed within 36 to 48 hours of radiation exposure.

WARDS: ICU: 100 percent of patients arriving at Level 3. VS; IV antibiotics; parenteral morphine; Foley catheter care; drain care; NG tube care, NPO; 10 percent maintain ET tube and ventilator with O_2, extubate before leaving ICU; 90 percent on O_2 by mask; maintain central line and monitoring and arterial line; cardiac monitor and pulse oximeter. IV/IM morphine; topical antibiotic (sulfamylon); IV LR 6 liters per day; dressing reinforcement; dc central/arterial line before leaving ICU. LAB: CBC with differential twice daily, electrolytes, clotting studies, Amylase, LFTs on admission; x-ray: chest, 10 percent c-spine. Administer cytokines (G-CSF 480 mcg subcutaneous daily) in 100 percent. 100 percent draw blood specimens for HLA typing (three yellow top tubes [ACD] [keep refrigerated]). Reverse isolation.

ICW: 90 percent of patients arriving at Level 3 will be transferred from ICU by day 2. VS; IV antibiotics; 25 percent on O_2 by mask; Foley catheter care; maintain NG tube; NPO; CBC with differentials twice daily. IV/IM morphine; topical antibiotic (sulfamylon); IV LR 6 liters per day; dressing reinforcement; drain care. Administer cytokines (G-CSF 480 mcg subcutaneous daily) in 100 percent. LAB: CBC with differentials twice daily; 100 percent draw blood specimens for HLA typing (three yellow top tubes [ACD] [keep refrigerated]). Reverse isolation. Ten percent mortality; 90 percent priority air evacuation.

MCW: 10 percent of patients arriving at Level 3 will become expectant and transferred from ICU by day 2. Mortality 100 percent.

C-50. Treatment Brief No. 27: Radiation at 0–125 cGy With Operative Trauma and Severe Burn (Without treatment 100 percent mortality.)

LEVEL 1A

Assumptions: Real or suspected radiation exposure; 100 percent litter patients; VS: pulse greater than 100, B/P 100/60, no respiratory distress; alert, oriented, both extremities burned, evidence of closed intra-abdominal hemorrhage and injury. Radiation effects include: apprehension and agitation; n/v 5 to 30 percent; mild headache; pretreatment with antiemetics decrease vomiting and possibly increase fatigability; radiation does not contribute to mortality at this level.

Treatment: Dress open wounds and burns; reassurance; start IV LR 100 percent, IM morphine; 100 percent urgent ground transport.

LEVEL 1B

Assumptions: Real or suspected radiation exposure; 100 percent litter patients, alert, cooperative and oriented; VS: pulse greater than 100, B/P 100/60, no respiratory distress; evidence of closed intra-abdominal hemorrhage and injury, both extremities burned. Additional radiation effects include: apprehension and agitation; n/v 5 to 30 percent; mild headache; pretreatment with antiemetics decrease vomiting and possibly increase fatigability; radiation does not contribute to mortality at this level.

Treatment: VS: Maintain IV LR in 100 percent; stabilization and IM morphine; 100 percent IV antiemetics (promethazine); reassurance; reevaluate dressing; 10 percent cervical spine stabilized; 100 percent urgent air transport.

LEVEL 2

Assumptions: Real or suspected radiation exposure; 100 percent litter patients, alert, cooperative and oriented; VS: Pulse greater than 100, B/P 100/60, no respiratory distress; evidence of closed intra-abdominal hemorrhage and injury. Additional radiation effects include: apprehension and agitation; n/v 5 to 30 percent; mild headache; pretreatment with antiemetics decrease vomiting and possibly increase fatigability; radiation will contribute to morbidity at this level due to immunosuppression.

Treatment: 25 percent exploratory laparotomy at this level; general anesthesia; 2d IV; NG tube, parenteral pain medications (morphine), HCT, type and cross, blood, irrigation and debridement, hemorrhage control, hemostatic agents, IV antibiotics, dressing, cardiac monitor, pulse oximeter, ventilator, Foley catheter, moist cool compress/bulky dressing, 10 percent escharotomy, 10 percent 0_2, splint. Remaining 75 percent: IV fluids LR 100 percent; rest; 30 percent IV/IM antiemetics. LAB: CBC with differential; reassurance/counseling. Note: All surgery must be completed within 36 to 48 hours; evacuation to a level of care that can provide appropriate urgent surgery. If appropriate surgery has been provided at this level, then routine evacuation (25 percent) to Level 3; otherwise urgent air transport (75 percent).

LEVEL 3

Assumptions: Real or suspected radiation exposure; 100 percent litter patients, Class III hemorrhage, alert; oriented; VS pulse 120, B/P 100/70, respirations normal. Radiation effects include: apprehension and agitation; n/v 5 to 30 percent; mild headache; pretreatment with antiemetics decreases vomiting; 25 percent will receive appropriate wound closure surgery at Level 2; radiation will contribute to morbidity at this level due to immunosuppression.

Treatment: EMT: VS; primary assessment, IV restarted in 20 percent, give 2 liters LR; 2d IV started; IV antibiotics; parenteral morphine; Foley catheter; NG tube. LAB: 100 percent CBC with

differential, UA, TC for 4 units; x-rays: chest, 50 percent pelvis films; doppler assessment, tetanus toxoid, topical antibiotics (sulfamylon); LAB: 100 percent draw one blood specimen per patient for biodosimetry (red top tube [clot] [keep refrigerated]), for radiation exposure prognosis.

OR: 75 percent of patients arriving at Level 3. Laparotomy and drainage of liver injury under general anesthesia; 50 percent large bore central line; IV antibiotics; 8 liters LR; 2 units blood; arterial line 10 percent. LAB: CBC, blood gases; 50 percent escharotomy for burn; MAC anesthesia; 2 liters LR; OR table time—120 minutes. Note: All surgery must be completed within 36 to 48 hours of radiation exposure.

WARDS: 25 percent of patients arriving at Level 3—direct admit from Level 2.

ICU: 100 percent of patients arriving at Level 3. VS; maintain IV fluids; IV antibiotics; parenteral morphine; Foley catheter care; drain care; NG tube care, NPO; 10 percent maintain ET tube and ventilator with O_2, extubate before leaving ICU; 90 percent on O_2 by mask; maintain central line and monitoring and arterial line; cardiac monitor and pulse oximeter; dressing reinforcement; dc central/arterial line before leaving ICU; topical antibiotics; 20 percent cytokines (G-CSF 480 mcg subcutaneous daily). LAB: CBC with differential twice daily, electrolytes, clotting studies, Amylase, LFTs on admission; x-ray: chest, 10 percent c-spine. Twenty-percent to ICW by day 3; 60 percent priority transport; 20 percent to MCW. Percentages based on patients admitted to ICU.

ICW: 20 percent of patients arriving at Level 3; LAB: CBC with differential twice daily times four days for radiation exposure prognosis. VS; IVs with IV antibiotics; parenteral morphine; topical antibiotics (sulfamylon), 25 percent on O_2 by mask; Foley catheter care; maintain NG tube; NPO; dressing reinforcement; drain care, doppler. Twenty-percent cytokines (G-CSF 480 mcg subcutaneous daily). Mortality 50 percent, priority air transport 50 percent. Percentages based on patients admitted to ICW.

MCW: 20 percent of patients arriving at Level 3; VS; supportive care. LAB: CBC with differential twice daily for radiation exposure prognosis. 100 percent mortality. Percentages based on patients admitted to MCW.

C-51. Treatment Brief No. 28: Radiation >125 cGy With Operative Trauma and Moderate or Severe Burn (With or without treatment 100 percent mortality.)

LEVEL 1A

Assumptions: Critical to lethal radiation exposure, but 100 percent mortality when combined with this severity of burn injury; litter patient; central neurological deficits will be indicative of extreme radiation doses. Additional radiation effects include: apprehension and agitation; n/v 100 percent; fatigue and weakness 100 percent; pretreatment with antiemetics may have no effects.

Treatment: Clean and dress burns; IM morphine; reassurance; 100 percent routine ground transport.

LEVEL 1B

Assumptions: Critical to lethal radiation exposure, but 100 percent mortality when combined with this severity of burn injury; litter patient; central neurological deficits will be indicative of extreme radiation doses. Additional radiation effects include: apprehension and agitation; n/v 100 percent; fatigue and weakness 100 percent; mortality 10 percent at this level.

Treatment: Comfort measures only; 100 percent morphine IV/IM as needed for pain, 100 percent injectable antiemetic medication; reassurance; 90 percent routine ground transport.

LEVEL 2

Assumptions: Critical to lethal radiation exposure, but 100 percent mortality when combined with this severity of burn injury; litter patient; central neurological deficits will be indicative of extreme radiation doses. Additional radiation effects include: apprehension and agitation; n/v 100 percent; fatigue and weakness 100 percent; mortality 50 percent within 24 hours.

Treatment: Comfort measures only; 100 percent morphine IV/IM as needed for pain, 100 percent injectable antiemetic medication; reassurance; 100 percent routine ground/air transport.

LEVEL 3

Assumptions: Critical to lethal radiation exposure, but 100 percent mortality when combined with this severity of burn injury; litter patient; central neurological deficits will be indicative of extreme radiation doses. Additional radiation effects include: apprehension and agitation; n/v 100 percent; fatigue and weakness 100 percent.

Treatment: EMT: Patients are all expectant. LAB: Draw one blood specimen per patient for biodosimetry (red top [clot] [keep refrigerated]), CBC with differential for radiation exposure.

OR: None.

WARDS: ICU: None.

ICW: None.

MCW: 100 percent of patients arriving at Level 3; expectant patients only; IM pain medications (morphine) as needed. Patients admitted to MCW: Mortality 100 percent by five days.

GLOSSARY

Section I. ABBREVIATIONS AND ACRONYMS

ABCA American, British, Canadian and Australian

ACD acid-citrate dextrose

ADM atomic demolition munition

AFMAN United States Air Force Manual

ALARA as low as reasonably achievable

ALCM air launched cruise missile

AMEDDC&S Army Medical Department Center and School

ANC absolute neutrophil count

ARS acute radiation syndrome

ATC air transportable clinic

ATH air transportable hospital

atm atmospheres (of pressure)

BAS battalion aid station

BDO battle dress overgarment

BEIR V Biological Effects of Ionizing Radiations, 5th Consensus Summary

BID *bis in die* (twice a day)

BP blood pressure

Bq Becquerel

BSA body surface area

BUN blood urea nitrogen

BW biological warfare

C Celsius/carbon

C/kg-air coulombs per kilogram in air

CaDTPA calcium diethylenetriaminepentaacetic acid

CaEDTA calcium ethylenediaminetetraacetate

cal calorie

CAM chemical agent monitor

CBC complete blood count

CBF cerebral blood flow

cc cubic centimeter(s)

CD-ROM compact disk–read-only memory

CFU colony-forming units

cGy centiGray

cGy/hr centiGray per hour (0.01 Gy = 1 rad)

ChRS chronic radiation syndrome

Ci curie

cm centimeter(s)

CMV cytomegalovirus

CNS central nervous system (syndrome)

Co cobalt

CONUS continental United States

CRS Cutaneous Radiation Syndrome

CRTS casualty receiving and treatment ship

CSCU Combat Stress Control Unit

CSF colony stimulating factor(s)

CSH combat support hospital

cSv centiSievert (0.01 Sv = 1 rem)

CT computed tomography

CV cardiovascular

CV/CVN aircraft carrier designation

CW chemical warfare

DA Department of the Army

DECON decontamination

DIA Defense Intelligence Agency

DMPS 2,3-dimercapto-1-propanesulfonic acid

DMSA meso-2,3-dimercaptosuccinic acid

DNA deoxyribonucleic acid

DNBI disease and nonbattle injury

DOD Department of Defense

DODI Department of Defense Instruction

DOE Department of Energy

DTPA diethylenetriaminepentaacetic acid (pentetic acid)

DU depleted uranium

D/W dextrose in water

E energy

Ebq exabecquerel (10^{18}Bq)

EDTA ethylenediaminetetraacetic acid (edetic acid)

EMG electromyography

EMP electromagnetic pulse

EMT emergency medical treatment

ER enhanced radiation

erg electroretinogram

ETI early transient incapacitation

ETI-PD early transient incapacitation and performance decrement

Ev electron volt

F Fahrenheit

FAST forward area surgical team

FDA Food and Drug Administration

FFP fresh frozen plasma

FM field manual

FSMC forward support medical company

FST forward surgical team

FSU former Soviet Union

GBq Giga Bequerel

G-CSF granulocyte-colony stimulating factor(s)

GI gastrointestinal

GLCM ground-launched cruise missile

gm gram(s)

GM-CSF granulocyte macrophage-colony stimulating factor

gm/dl gram/deciliter

GTX granulocyte transfusions

GU genitourinary

GVHD graft-versus-host disease

Gy gray (1 Gy = 100 rads)

H hydrogen

HA heavy armor

HCT hematocrit

He helium

HE high explosive

HEPA high efficiency particulate air

HEU highly enriched uranium

HLA human leukocyte antigen

HOB height of burst

HQDA Headquarters, Department of the Army

HREC health record

hrs hours

HSS health service support

I iodine/Interservice

IAEA International Atomic Energy Agency

ICBM intercontinental ballistic missile

ICRP International Council on Radiation Protection

ICU intensive care unit

ICW intermediate care ward

IFN interferon

Ig immunoglobulin

IL Interleukin

IM intramuscular

IND improvised nuclear devices

IU international unit

IV intravenous(ly)

JRCAB Joint Readiness Clinical Advisory Board

K potassium

$K10^3$ potassium iodate

kBq thousand becquerels

KE kinetic energy

kg kilogram(s)

km kilometer(s)

kPa kilopascals

KT kiloton(s)

l liter

LAB laboratory diagnostic tests

LBRM long range ballistic missile (intercontinental ballistic missile [ICBM])

LD lethal dose

LET linear energy transfer

LIHOPO a hydroxypridizone ligand

LLR low-level radiation

LR laboratory report

m mass

MASCAL mass casualty

MASF mobile aeromedical staging facility

MBq Mega Becquerel

mCi millicurie

mcg microgram

MCRP Marine Corps Reference Publication

MCW minimal care ward

MD doctor of medicine

MES medical equipment sets

mg milligram(s)

MGDF/Tpo megakaryocyte growth and development factor/thrombopoietin

mGy milligray (0.001 Gy; 10 mGy = 1 rad)

ml milliliter(s)

mm millimeter(s)

mm3 cubic millimeter

mo month

MOLLE modular lightweight load-carrying equipment

MOPP mission-oriented protective posture

MOX mixed oxide

mph miles per hour

mrad millirad

MRBM medium range ballistic missile

mrem millirem

MRI magnetic resonance imaging

mSv milliSievert (0.001 Sv; 10 mSv = 1 rem)

MT megaton

MTF medical treatment facility

MUPS medically unexplained physical symptoms

MW megawatt

Na sodium

NATO North Atlantic Treaty Organization

NAVMED P US Navy Medical Publication

NBC nuclear, biological, and chemical

NCRP National Council on Radiation Protection

NDI nondestructive inspection

NIGA neutron-induced ground activity

nm nanometer

NPO *nil per os* (nothing by mouth)

NRC Nuclear Regulatory Commission

NTRP Navy Tactical Reference Publication

n/v nausea/vomiting

n/v/d nausea/vomiting/diarrhea

NVD night vision device

NW nuclear warfare

O_2 oxygen

ODS Operation Desert Storm

OEG operational exposure guidance

OR operating room

OSHA Occupational Safety and Health Act

PAF platelet activating factor

PBq pico Becquerel

PBSC peripheral blood stem cell

PBSCT peripheral blood stem cell transplantation

PCC prematurely condensed chromosome

PCR polymerase chain reaction

PD performance decrement

pg picograms

PHS Public Health Service

PIES proximity, immediacy, expectancy, simplicity (mnemonic for treatment of psychiatric casualties)

PMN polymorphonuclear neutrophil

PO *per os* (by mouth)

PO_2 plutonium oxide

ppm parts per million

PPW patient protective wrap

PR per rectum

PRBC peripheral red blood cell

prn *pro re nata* (for the emergency, as needed)

psi pounds per square inch

PTSD post-traumatic stress disorder

PTX pentoxifylline

Pu plutonium

PVNTMED preventive medicine

PWR pressurized water reactor

q *quaque* (every)

QD *quaque die* (every day)

QF quality factor

QID *quater in die* (four times a day)

QSTAG Quadripartite Standardization Agreement

R roentgen

Ra radium

rad radiation absorbed dose

RADIAC radiation detection, identification, and computation

RBC red blood cell

RBE relative biological effectiveness

R&D research and development

RDD radiological dispersal device

REAC/TS Radiation Emergency Assistance Center/Training Site

rem roentgen equivalent in man/mammal

RES radiation exposure status

Rn radon

RNA ribonucleic acid

RPL radiophotoluminescent

RTD return to duty

Rx a medical prescription

SAT serum-agglutinating titers

SD skin dose

sec second(s)

SI systems international

SLBM submarine launched ballistic missile

SNM special nuclear material

SOP standard operating procedure(s)

SQ subcutaneous

SRBM short range ballistic missile

SSB single-strand break(s)

STANAG Standardization Agreement

Sv Sievert (SI unit of roentgen dose equivalent)

TB Treatment Brief(s)

TBq Tera Bequerel

TCDO tetrachlorodekaoxide

TDM trehalose dimycolate

TID *ter in die* (three times a day)

TG Technical Guide

TGF-beta transforming growth factor beta

ThO thorium oxide

TLAM/N Tomahawk land attack missile/nuclear

TLD thermo-luminescent dosimeter

TMP trimethoprim

TNF tumor necrosis factor

TNT trinitrotoluene

TO theater of operations

TPN total parenteral nutrition

TSH thyroid-stimulating hormone

TSST-1 toxic shock syndrome toxin-1

μ microns

μCi microcurie

μg microgram

μl microliter

U uranium

UO_2 uranium oxide

US United States

USACHPPM US Army Center for Health Promotion and Preventative Medicine

USAF United States Air Force

USAMRIID United States Army Medical Research Institute for Infectious Diseases

USTRANSCOM United States Transportation Command

UTC unit type code (United States Air Force)

VA Department of Veterans Affairs

VS vital signs

vWf von Willenbrand factor, clotting factor 8

WHO World Health Organizations

WMD weapons of mass destruction

WMDT wartime medical decontamination team

W_R radiation weighting factor

yr year

ZnDTPA zinc diethylenetriaminepentaacetic acid

Section II. DEFINITIONS

acute radiation syndrome a combination of clinical syndromes occurring in stages, during a period of hours to weeks after exposure, as radiation injury to various tissues and organs is expressed.

agranulocytosis a complex of symptoms characterized by marked decrease in the number of granulocytes and by lesions of the throat and other mucous membranes, of the gastrointestinal tract, and of the skin.

airburst an explosion of a bomb or projectile above the surface as distinguished from an explosion on contact with the surface or after penetration.

alpha particle a positively charged particle ejected from the nucleus of a radioactive atom, being a high-speed ionized atom of helium. A stream of these particles constitutes alpha rays.

aplasia lack of development of an organ or tissue, or of the cellular products from an organ or tissue.

atomic number the number of protons in an atomic nucleus.

beta particle an electron emitted from an atomic nucleus during beta decay.

bioassay sampling indirect means of measuring contamination in body tissue or fluids from which body burden is extrapolated.

blast wave a pulse of air in which the pressure increases sharply at the front propagated by the explosion.

bremsstrahlung the process by which a beta particle emits an x-ray photon during its interaction with an atomic nucleus.

carcinogenesis the development of cancer; various malignant growths that manifest invasiveness and a tendency to metastasize to another location.

cataractogenesis the development of cataracts; opacity of the lens causing blindness.

cerebral anoxia absence of an oxygen supply to the brain despite adequate perfusion of the tissue by blood.

congestion excessive or abnormal accumulation of blood in a tissue or organ.

critical mass the minimum amount of fissile material capable of supporting a chain reaction under precisely specified conditions.

critical organ body organ with an affinity for a particular substance and in which that substance concentrates.

cytokine a nonantibody protein released by one cell population that acts as an intercellular mediator on another cell population(s). Synthetic cytokines are metabolically active in pico-molar concentrations.

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.

delayed fallout radioactive fallout that returns to earth later than 24 hours after a nuclear detonation; usually ascends into the stratosphere and is distributed worldwide.

desquamation the shedding of epithelial elements, chiefly of the skin, in scales or small sheets; exfoliation.

deterministic effect one that occurs after a certain dose threshold, with the severity of the effect determined by the dose; example: cataractogenesis.

dose rate a measure of the amount of ionizing radiation an individual is exposed to, per unit of time; commonly expressed in units of gray (or rads) per hour.

dynamic pressure pressure resulting from some medium in motion, such as the air following the shock front of a bast wave.

early fallout radioactive fallout that returns to earth within 24 hours after a nuclear detonation; also referred to as local fallout.

edema the presence of abnormally large amounts of fluid in the intercellular tissue.

exposure a measure of the number of ionizations produced by gamma or x-rays in a volume of air; expressed in units of roentgen.

fallout the precipitation to Earth of radioactive particulate matter from a nuclear cloud; also applied to the particulate matter itself.

fireball the luminous sphere of hot gases which forms a few millionths of a second after detonation of a nuclear weapon and immediately starts expanding and cooling.

fission the process whereby the nucleus of a heavy element splits into (generally) two nuclei of lighter elements, with the release of substantial amounts of energy.

fission products a general term for the complex mixture of substances produced as a result of nuclear fission.

flash burn a burn caused by excessive exposure of the skin to thermal radiation.

free-in-air-dose radiation that would be measured in air at a certain point. Military tactical dosimeters measure free-in-air-doses.

gamma rays high energy electromagnetic radiation emitted from atomic nuclei during a nuclear reaction. Gamma rays and very high energy X-rays differ only in origin. X-rays do not originate from atomic nuclei but are produced in other ways.

granulocyte any cell containing granules in its cytoplasm, especially a leukocyte (neutrophil, basophil, or eosinophil).

granulocytopenia agranulocytosis; a symptom complex consisting of a marked decrease in the number of circulating white blood cells, with lesions of the throat and mucous membranes.

hematopoietic pertaining to, or effecting, the formation of blood cells.

hemorrhage the escape of blood from the vessels; hemorrhages, classified according to size: petechiae (pinpoint) or ecchymoses (larger than 1 centimeter in diameter).

hyperpyrexia a highly elevated body temperature.

hypotension abnormally low blood pressure.

induced radiation radiation produced as a result of exposure to radioactive materials, particularly the capture of neutrons.

ingestion pathway route for internalization of radioactive contaminants; the pathway most accessible for decontamination.

inhalation pathway primary pathway for internalization of radioactive contaminants.

ionization the process of stripping electrons from their atomic orbits by radiation.

isotope one of two or more atoms whose nuclei have equal numbers of protons but different numbers of neutrons.

late effect a biological effect that occurs long after radiation exposure ends; example: cancer.

lymphocyte a mononuclear leukocyte; chiefly a product of lymphoid tissue and participates in humoral and cell-mediated immunity.

malformation a birth defect; an abnormal structure or form; example: small head.

morbidity the ratio of sick to well individuals in a community; the sick rate.

mortality the ratio of people who die to those who survive irradiation; the death rate.

nadir the point at which a blood count drops to, or closest to zero, before beginning to increase.

neutron an electrically neutral or uncharged particle of matter existing along with protons in the atoms of all elements except the isotope of hydrogen with the mass of 1.

neutropenia a decrease in the number of neutrophilic leukocytes in the blood.

nosocomial pertaining to or originating in a hospital.

nuclear material traditionally, uranium or plutonium used to produce a nuclear detonation via the fission or fusion process. The fuel is compressed into a given volume to cause supercriticality. The major products include blast effects, heat, nuclear radiation, and fallout.

nucleated blood cell a blood cell that contains a nucleus, to include white cells and reticulocytes.

nucleon a proton or neutron as part of an atomic nucleus.

nuclide all nuclear species, both stable (about 270) and unstable (about 500), of the chemical elements, as distinguished from the two or more nuclear species of a single chemical element which are called "isotopes."

orbital excitation change in energy level of an orbital electron that occurs when the energy lost by the incident radiation is insufficient to cause ionization.

overpressure the pressure resulting from the blast wave of an explosion. It is referred to as "positive" when it exceeds atmospheric pressure and "negative" during the passage of the wave when resulting pressures are less than atmospheric pressure.

pathognomonic specifically distinctive or characteristic of a disease or pathologic condition; a sign or symptom on which a diagnosis can be based.

perceived threat a threat that is experienced by a person subjectively and out of proportion to the real threat or physical danger.

phagocytosis the engulfing of microorganisms, other cells, and foreign particles by phagocytes.

pressor tending to increase blood pressure.

prodrome a premonitory symptom or precursor; a symptom indicating the onset of a disease.

Prussian blue ferric ferrocyanide; a chemical that is not absorbed by the gastrointestinal system and is an effective means to reduce the body's uptake of cesium, thallium, and rubidium; approved as an investigational new drug by the United States Food and Drug Administration with the license held by Radiation Emergency Assistance Center/Training Site.

radioactive cloud an all-inclusive term for the cloud of hot gases, smoke, dust, dirt, and debris from a weapon and the environment. The cloud is carried aloft in conjunction with the rising fireball produced by the detonation of a nuclear weapon.

radioactive contamination radioactive material in an undesirable location such as on structures, areas, objects, or personnel.

radionuclide a radioactive nuclide; one that disintegrates with the emission of particulate or electromagnetic radiations.

rainout radioactive material in the atmosphere brought down by precipitation.

relative biological effectiveness the ratio of the number of rads of gamma (or X) radiation of a certain energy which will produce a specified biological effect to the number of rads of another radiation required to produce the same effect is the relative biological effectiveness of the latter radiation.

reproductive death the loss of the ability to reproduce. Many organs must have cells that can reproduce to function. Thus, even though injured cells may remain biologically viable, reproductive death may cause irreversible organ damage.

scavenging the selective removal of material from the radioactive cloud by inert substances, such as precipitation, introduced into the fireball.

sepsis the presence of pathogenic microorganisms (bacteria) or their toxins in the blood or other tissues.

septicemia systemic disease associated with the presence and persistence of pathogenic microorganisms or their toxins in the blood.

skin permeability the rate at which the skin absorbs a liquid; expressed as a coefficient. The lower a substance's coefficient, the greater the rate of absorption.

Specific ionization number of ion pairs per unit distance formed along the path of a particle, often expressed as ion pairs per centimeter.

stochastic effect an effect that has no-dose threshold and for which the severity of the effect is not dose-related, although its probability is; example: carcinogenesis

stratosphere the layer of the atmosphere above the troposphere in which the change of temperature with height is relatively small.

subsurface burst the explosion of a nuclear weapon beneath the surface of the earth.

syndrome a set of symptoms that occur together.

synergistic acting together to enhance the effect of another force or agent.

thermal radiation the heat and light produced by a nuclear explosion. Electromagnetic radiations emitted from a heat or light source as a consequence of its temperature; it consists essentially of ultraviolet, visible, and infrared radiations.

total parenteral nutrition by injection through some route other than the alimentary canal.

washout the removal of radioactive particles from a nuclear cloud by precipitation when the nuclear cloud is below a rain or snow cloud.

weapon debris (nuclear) the residue of a nuclear weapon after it has exploded; that is, materials used for the casing and other components of the weapon, plus unexpended plutonium or uranium, together with fission products.

wound contamination the presence of a radioactive substance in a wound, whether an abrasion, puncture, or laceration; condition in which the loss of intact skin increases the risk that the contaminant will be absorbed.

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