Medical Planning and Response Manual for a Nuclear Detonation Incident: A Practical Guide

United States Department of Health and Human Services

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Preparing for and responding to the health and medical consequences of a nuclear or radiological incident: essential concepts, information and resources

Introduction

"Two decades after the end of the Cold War, we face a cruel irony of history—the risk of a nuclear confrontation between nations has gone down, but the risk of nuclear attack has gone up." Remarks by President Obama at the Opening Plenary Session of the Nuclear Security Summit, April 13, 2010[1]

The successful detonation of a nuclear device on U.S. soil would be a catastrophic event, causing an unprecedented number of injuries and lives lost, as well as economic, political, and social disruption. However, an effective medical response and a public prepared to protect itself from fallout could save tens of thousands of lives. Since 2001, all levels of government, academic institutions, and professional organizations have done significant work to enhance our ability to prepare for and respond to a nuclear detonation. The following series of papers distill and translate key pieces of that work on protective actions and medical response to make them more accessible and easier to translate into practice. In addition, policies to enhance our nation's ability to respond to a nuclear detonation are suggested.

For example, the Center for Biosecurity of UPMC's May 2011 conference, *Advancing U.S. Resilience to a Nuclear Catastrophe*, addressed two issues that complement the articles that follow.[2] One is the critical importance of a public prepared to take immediate shelter following a nuclear detonation. Despite recent research showing that sheltering is more effective than previously thought and should be the immediate default protective action, there has been little public discussion about how to counter the public's natural inclination to flee the area. To fill this gap, a new Center for Biosecurity project to help create radiation (rad) resilient cities was introduced.[3] The initiative provides an expert advisory consensus checklist for leaders of high risk cities to provide a path to enhanced fallout preparedness. The Center also presented a novel proposal for a public-private partnership to screen up to a million people for dangerous levels of radiation in just a few days.[4] Discussions with large commercial medical laboratories suggest that there is the capability to perform absolute lymphocyte counts (ALC), an indicator of radiation exposure, on a massive scale.

Systems-based approach

Preparation for a nuclear detonation builds on expertise and contributions from a wide range of federal agencies; state, local, regional, and tribal planners; academia; and the private sector. Over the last few years, a number of comprehensive publications and products have been published including the *Planning Guidance for Response to a Nuclear Detonation*[5] and a 10-paper series on *Scarce Resources for a Nuclear Detonation*.[6] Health and medical educational material is available from the Centers for Disease Control and Prevention (CDC)[7] and just-in-time material, including algorithm-based management, is on the Radiation Emergency Medical Management (REMM) website.[8]

We in the Department of Health and Human Services (HHS) are leading the development of preparedness plans to respond to the public health and medical consequences of a nuclear detonation. This is one of the most challenging events to plan for and tremendous progress has been made in our understanding of how we as a country and world can respond most effectively to save lives. Throughout development, we realized that the complex information included in these plans—much of it created for the first time by government and non-government experts who committed extraordinary effort to addressing this overwhelming scenario—needed to more readily available for planners and responders. There is the need for a quick, broad overview of complex topics available at one's fingertips, with an ability to drill down as necessary.

Practical information with links to details

The 13 manuscripts in this document were designed to be no more than 7-15 journal pages with illustrations, tables and bulleted points so the reader can quickly get a sense of the topic and where to find more detailed information. The resulting 125-page manual can be printed and easily thumbed through, and also exists as an electronic document with links to more detailed information. To prepare this manual, we assembled contributors who are leaders in the field and bring knowledge and experience in planning and in response to nuclear and radiological incidents.

During the course of preparing this series, an earthquake and tsunami struck Fukushima and triggered its nuclear power plant meltdown. The Office of the Assistant Secretary for Preparedness and Response (ASPR)[9] supported sending a team of health and medical experts from ASPR, CDC,[6] the National Cancer Institute, and the Food and Drug Administration to Japan as part of an extensive response by the U.S. This experience provided real-life experience for dealing with the world-wide fear of radiation. Educating and informing the public on radiation required a careful blend of sophisticated explanations and clarity—no easy task with such a complex topic. Ongoing lessons learned include the need for timely, expert communication and the recognition that an important component of community resilience is the ability to make science-based decisions as the situation unfolds.[10] This series provides much of the information that would be needed to understand and help manage a major nuclear or radiological disaster.

Working with the community

In December of 2009, HHS published the first-ever National Health Security Strategy (NHSS).[11] This strategy provides a unified and clear national approach to minimizing the risks associated with all hazards, including nuclear detonation. Two of the major goals outlined in the NHSS are building community resilience and strengthening and sustaining health and emergency response systems. The preparedness plans developed by HHS support national health security only if the plans are integrated at the community level across the nation. One goal of publishing this supplement is to make the tools that have been developed more readily available and usable at the community level.

Another way we promote national health security is through the ASPR Regional Emergency Coordinators, who engage in integrated planning with states and localities. Under the

National Response Framework, HHS is the lead for federal public health and medical support to states who request assistance. By engaging in integrated planning with states, HHS is able to identify states' gaps and anticipate requests for federal resources. In a catastrophic event such as a nuclear detonation or a large earthquake involving multiple states, it is possible that state requests for assistance will exceed the available federal resources. Integrated plans for maximizing available resources and ethically allocating scarce resources need to be developed in advance, and not in the midst of a catastrophic event.

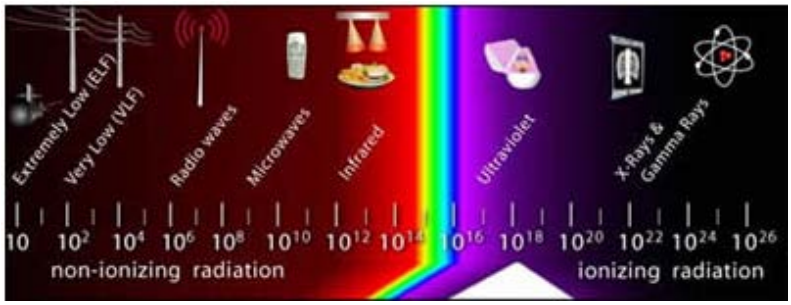
Leadership

Crisis leadership will be critical during response to a nuclear detonation. Public health and medical leaders typically make decisions once data have been collected and analyzed. In a crisis, the available data will be insufficient to make fully informed decisions, and it is critical that leaders learn the important skill of making decisions with incomplete information. A continuous process of re-evaluating decisions as additional information is obtained is the hallmark of public health and medical leadership during disasters.[10] The alternative would be to wait until more complete information is gathered, which can hamper response and lead to disorganization and loss of confidence.

Mini-primer on radiation

Ionizing and non-ionizing radiation: There is constant exposure to non-ionizing and ionizing radiation. The long-term risk of radiation-induced cancer is from ionizing radiation.

Figure 1. Electromagetic radiation spectrum[12]

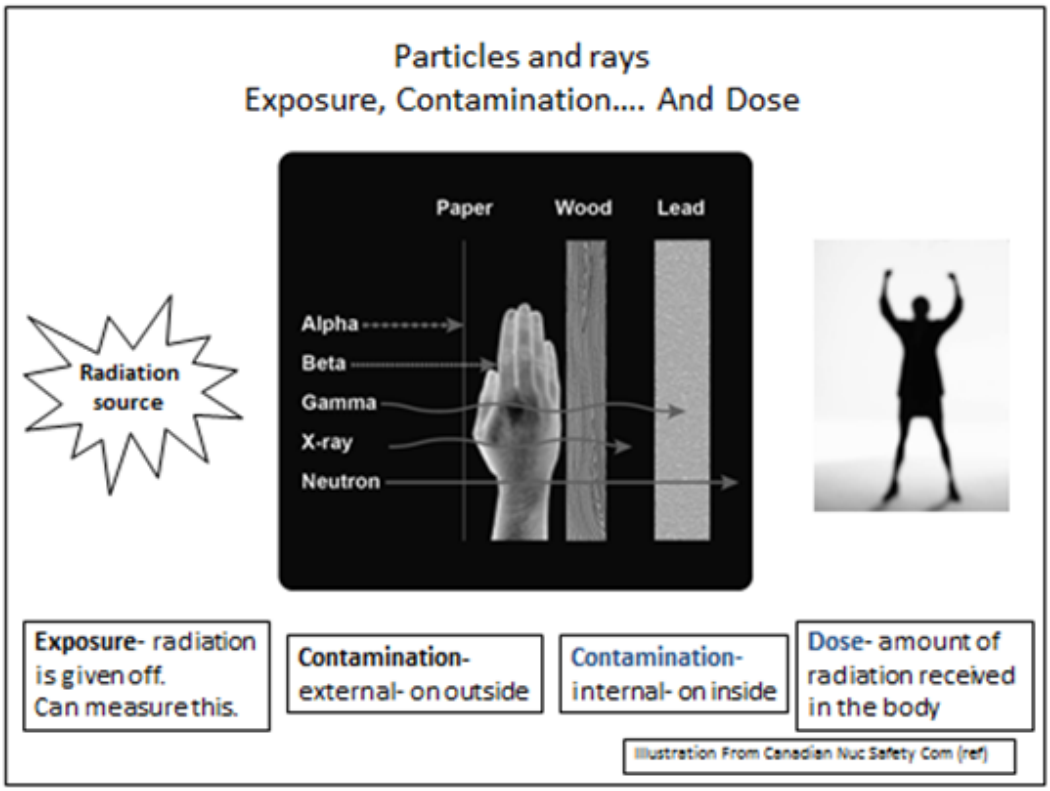


Non-ionizing radiation has less energy than ionizing radiation. Its uses include lasers, microwaves, infrared lamps, and radio waves. The most energetic form of radiation is ionizing radiation. Ionizing radiation is used to generate electric power, treat cancer, take x-rays, and disinfect medical instruments.

Exposure, contamination and dose: The ionizing radiation of concern includes particles that have an electrical charge (alpha and beta particles), uncharged particles (neutrons), and X-rays and gamma rays (which are similar). As illustrated in Figure 2, charged particles have limited penetration. Alpha particles can produce a significant dose only if they are internalized. Beta particles can cause skin burns (beta burns) and also produce significant dose if internalized. X-rays/gamma-rays and neutrons are penetrating.

Figure 2 defines exposure, contamination/external, contamination/internal and dose. It is **dose**—the amount of radiation received in the body—that determines the health and medical consequences.

Figure 2. Particles and rays. Exposure, Contamination and Dose (radiation illustration from[13])



Assembling the information

The overarching principle of the preparation, planning, and response at ASPR is that the best science and knowledge must be made available and comprehensible so that is it useable, often without much advance knowledge of the issues. The question we aim to answer for each of the topics is "What do I DO?!" To assemble and present information, we depend on the experts on education and information management including the Specialized Information Services (http://sis.nlm.nih.gov/) of the National Library of Medicine[14] and the National Institutes of Health Library. We continuously update the various resources on REMM and we have developed a new approach with a *State and Local Planners Playbook.*[15]

This manual complements these other resources by providing a rapid overview of the complex subject matter. All of these resources can be updated in their electronic versions which will make this a living document along with the Playbook and REMM.

We hope this series of papers provides clear and useful information on the complex issue of preparation for and response to a nuclear or radiological incident and that we achieved the recommendation of Albert Einstein:[16]

"Make everything as simple as possible, but not simpler."

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Health Risks From Exposure To Radiation: The Basics

Overview

In the wake of a nuclear detonation in a populated or metropolitan area, many people will die from the blast and heat combined with lethal doses of radiation. However, people who are at some distance from the detonation and those who are in shielded structures will have survivable doses. Others will have some potential health consequences, despite very minimal exposures. In general, health consequences can be divided into ”early” health conditions, that appear within minutes to days after exposure, and “late” health conditions, that typically occur several years to decades after exposure. Early conditions are generally associated with high exposures that are often life-threatening in the short-term. Those who may develop late conditions can number thousands or more since, by definition, those persons survived the blast and other immediate life-threatening circumstances (e.g., loss of medical and hospital services). Late conditions include damage to organ systems (e.g., lung, thyroid or cardiovascular system) and radiation-induced cancer, which is the major issue of concern to the public.

The study of radiation health consequences usually differentiates early organ damaging conditions by the fact that the *severity* of the early health condition is related to the magnitude of the dose. In contrast, late radiation-induced cancers occur in a higher frequency with increasing dose but with a severity not related to the dose. In other words, it is the *chance* of developing a radiation-induced cancer that is the actual late consequence of exposure, not the severity of the effect. The chance associated with the development of a radiation-related health effect is usually termed “radiation risk.” In this paper, we discuss the concepts underlying radiation health risks including the types of health outcomes, how they are similar or different from health conditions occurring in the absence of radiation, the rate at which they might be expected to occur after a mass exposure event, and how those rates are related to doses that might be received.

As a frame of reference, everyday life exposes people to ionizing radiation from a variety of natural and manmade sources, including:

a) Naturally-occurring radiation that emanates from minerals in the ground;
b) Radiation that is incident on the earth directly from space and as a result of the way it interacts with molecules in the atmosphere;
c) Naturally-occurring radioactivity that enters the body through foods we eat, in particular, from crops grown on soil that is partly composed of naturally-occurring radioactive minerals; and
d) Radiation used in industry, medical care, and consumer products.

Introduction

Health consequences from radiation exposure can include both early and late consequences.[1] [Note: concepts of dose and exposure are in Coleman[2]]

Early ("Acute") Health Effects:

- The *severity* of the condition is related to exposure.
- Only observed a few times since they are associated with exposures that are much greater than typically received from any normal occupational or medical exposure.
- Radiation accidents have resulted in radiation doses high enough to produce early effects in very few persons, despite drawing great national and international interest.
- Often mistaken as the most likely outcome of unintended exposures, such as a might occur from a nuclear detonation, they will affect only a small fraction of those exposed because of the serious competing causes of death involved (including both radiation and physical injury).

Late Health Effects:

- The *likelihood of occurrence* is related to exposure.
- Those that manifest themselves most commonly are an increase in the rate of development of cancer years or decades after the exposure.
- Much more important in terms of numbers of persons likely affected.

Radiation Risk: What It Means and What It Implies

It is important to define the concept of radiation risk.[3-5] In its most general sense, the risk of radiation exposure includes the possibility of developing any of the health consequences that are known to be associated with radiation exposure, and it includes both early and late effects. For persons who receive a whole-body radiation dose of approximately 1 Sievert (Sv) [doses to be discussed in a subsequent section], certain conditions are quite likely to occur—in particular, nausea and vomiting, possibly diarrhea, and a mild decrease in the white blood cell count (leukopenia). Fortunately, at this dose none of those conditions are life threatening, although moderate level doses (1-2 Sv) combined with major physical trauma or burn—called "combined injury"—can be life threatening. At whole-body doses over 2 Sv , more serious acute medical conditions occur from hours to days after exposure, including damage to specific systems of the body such as the blood-forming tissues, the brain, and the gastro-intestinal and cardiovascular systems (discussed in Chao[6]).

The more conventional scientific meaning of radiation risk is important to understand because it is used in all radiation recovery planning efforts. Several terms with similar meanings are often used to explain radiation risk: *chance*, *likelihood* or *probability*. As noted earlier, the severity of radiation-induced cancer is not related to the radiation dose. Instead, the chance (or the likelihood or the probability) of the effect to occur is related to the radiation dose. On

an individual level, the chance of developing a cancer is challenging to define and to understand since each person develops a cancer or does not—there is no intermediate condition. Conceptually, what we mean when discussing radiation risk is that if a person were to be exposed along with a large group of similar persons (e.g., adult males or adult females), a radiation-related cancer would develop among a certain percentage of that group. For example, a 10% chance of an individual developing a radiation-related cancer would mean that about 10% *of the group that is similar to them* and who were equally exposed to radiation would develop a radiation-related cancer. In simple terms, we can equate individual risk with the proportion of persons in a similar population to develop the health condition. The chance of developing a radiation-related condition is the essence of the concept of radiation health risk.

Key points:

1) Early or acute affects occur in a person with a *severity* generally related to the amount of radiation dose received.
2) Relatively few persons have experienced acute effects from nuclear events because of serious competing factors (high radiation dose and physical trauma) that limit survival.
3) Late effects (e.g., cancer) occur in a population with an increase in the frequency (over the baseline rate) that is related to the amount of dose the population has received, but the severity is not related to dose.
4) Radiation risk for an exposed person is the increased *chance* for them to develop a late effect and is related to the amount of radiation dose they received.
5) Radiation risk can either be interpreted as the increased chance for an individual to develop cancer or the increase in frequency of that cancer within the larger exposed population.
6) Radiation-induced cancers are medically similar to the same conditions that develop in unexposed persons.

Radiation Dose: The Basics

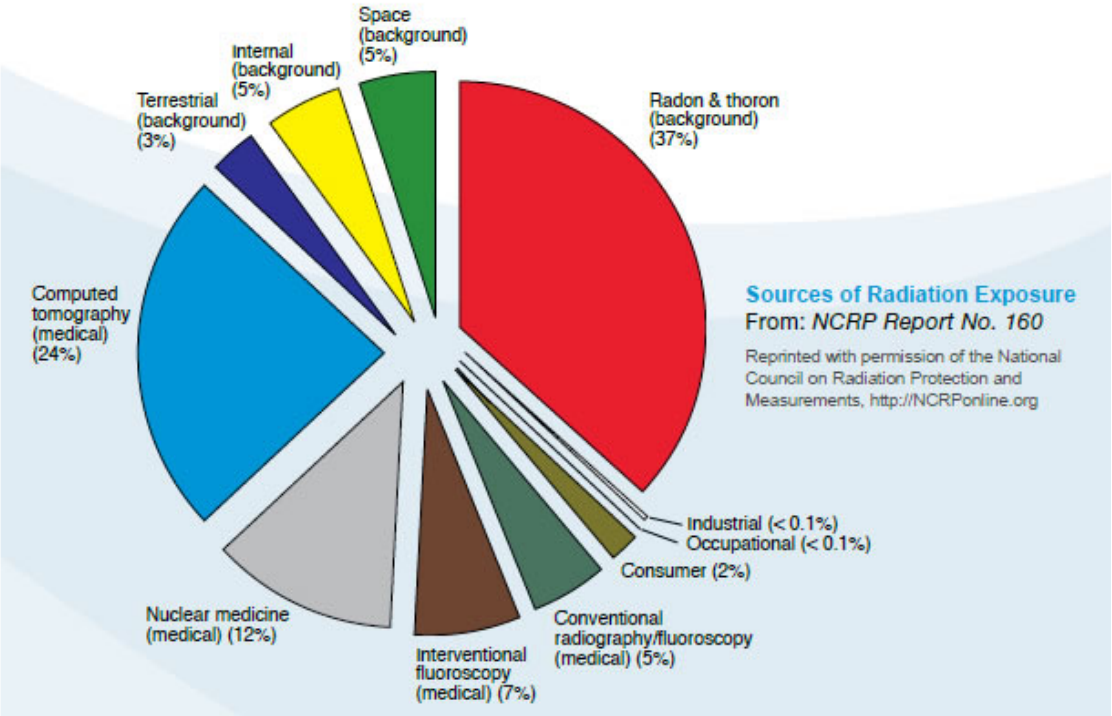
Everyday life exposes people to ionizing radiation from a variety of natural and manmade sources, including:

e) Naturally-occurring radiation that emanates from minerals in the ground (e.g., uranium) and from radioactive by-products those minerals emit (e.g., radon gas);
f) Radiation that is incident on the earth directly from space and as a result of the way it interacts with molecules in the atmosphere;

g) Naturally-occurring radioactivity that enters the body through foods we eat, in particular, from crops grown on soil that is partly composed of naturally-occurring radioactive minerals; and
h) Radiation used in industry, medical care, and consumer products.

All of these sources have been long studied and are known to have been present throughout the evolutionary history of Homo sapiens. Hence, our bodies' cells and tissues have developed in the presence of radiation and have repair mechanisms to deal with injury. The dose we are routinely exposed to from the natural environment is well cataloged and represents about one-half of the radiation exposure typically received by Americans and others living in societies with modern medical care. The natural radiation exposure of society today is supplemented considerably by the use of radiation in modern medical care, most notably by computed tomography (CT scans) and fluoroscopy, which is widely used for cardiovascular procedures in older adults. The division of typical exposures between natural sources and medical radiation is presented in Figure 1.[7]

Figure 1. Sources and average proportions of annual radiation exposure (Reprinted with permission of the National Council on Radiation Protection and Measurements, NCRPpublications.org[7]).



Radiation dose describes the amount of energy absorbed by the human body that is of sufficient strength to ionize—to remove electrons—from atoms in the tissue with which it interacts. The concept of ionization distinguishes x-ray and gamma radiation from ultra-violet radiation from the sun, which has sufficient energy to damage the skin, but cannot ionize the atoms of the body. [Note: See electromagnetic spectrum discussed in Coleman[2]] While many

molecules in the body can be ionized by x-rays and gamma rays, damage to the DNA (hereditary material) in cells is felt to be the key lesion that either may lead to mutation, if the cell is not too heavily damaged, or cell death if the damage is extensive. While extensive cell death could result in an acute syndrome, it is important to note that cells that die from extensive radiation damage cannot produce cancer. A detailed understanding of radiation dose and its effect has been developed from scientific studies and is used in medicine, the nuclear power industry, and other occupations that use radiation.

Radiation doses that might be received from any source (e.g., a medical procedure, working in a nuclear power plant, or an exposure from a nuclear detonation) all use the same scientific theory and units to describe the magnitude of the radiation effect. Efforts to communicate the basics of radiation science to the public have always been challenging—the unfamiliarity of radiation concepts and units often leads to ineffective communication and an incorrect understanding of the magnitude of doses that might be received.

The lowest typical levels received over the course of a year by Americans range from about 1 milliSievert (1 mSv = 1/1000 of a Sievert) of radiation emitted from minerals in the ground up to about 6 mSv (total) from all sources of natural and background radiation, including the radiation from typical medical care (averaged over all persons in the U.S.).[7] Persons who receive an above average amount of medical care due to specific disease conditions may accumulate significantly greater amounts of radiation, though usually limited to the specific portion of the body receiving treatment or examination.

The upper end of exposures considered here are for persons who might be exposed to a nuclear detonation or involved in the recovery activities of a nuclear or radiation accident. In such cases, a dose of 1 Sievert over the whole body would be considered undesired. If received over a short time (a few minutes or less), a 1 Sv dose would likely lead to vomiting and nausea. Persons who might receive more than 2 Sv but less than 8 Sv would undoubtedly have significant damage to their blood-forming tissues and gastrointestinal tract and would require medical care to ensure survival. Those in the upper end of this range (7-10 Sv) would be at very high risk of radiation-related death within days of exposure.

In the U.S. and other developed nations, a system of regulations and strategies for radiation protection ensures the health of workers by limiting their long-term cancer risk to accepted norms. This is accomplished by standards that permit annual occupational exposures to be only a few times greater than background radiation. For example, in the U.S., radiation workers are allowed an annual occupational exposure up to 50 mSv (= 0.050 Sv) or about eight-times the typical dose received by Americans.

Table 1. General dose ranges for radiation. Note **that each row is about 10 times higher** than the one below it so that top row and bottom row differ by a factor of 100,000. Adapted from a Department of Energy chart.[8]

[The preferred unit is the Sievert. The dose in rem is included as a point of reference.]

Description of Dose Range	Dose, Sv (top of range in mSv)	Dose, rem (top of range)
Cancer radiotherapy (total dose to tumor)	10 – 100 Sv (100,000 mSv)	10,000 rem
Acute Radiation Syndrome (ARS)	1- 10 Sv (10,000 mSv)	1,000 rem
Very high background; Dose limits for rescuing people during radiation catastrophe	0.1- 0.25 Sv (250 mSv)	25 rem
Moderately high natural background; CT scans or fluoroscopy Dose limit for nuclear worker [n]	0.02- 0.09 Sv (90 mSv) [50mSv]	9 rem [5 rem]
Natural background range (including medical radiation)	0.003 – 0.006 Sv (6 mSv)	0.6 rem
Air travel, recommended annual limit for public	0.0001-0.001 Sv (1 mSv)	0.1 rem

Key points on radiation dose:

1) All Americans, as well as people everywhere, receive radiation doses each year of several mSv (a few thousandths of a Sv);
2) Exposures to radiation in medicine may increase the dose a person has received in a given year by tens of mSv, depending on the number of CT examinations, fluoroscopy procedures, etc. they have had;
3) Annual occupational doses in the U.S. are permitted up to 50 mSv. This dose limit is considered highly protective;
4) Few if any early or acute effects are associated with doses less than 1,000 mSv (1 Sv); while
5) Doses of several thousand mSv (i.e., > 2 Sv or 2000 mSv) will likely produce early or acute effects and may require sophisticated medical care to ensure survival.

Early and Late Health Risks: The Basics

As noted earlier, the general concept of health risk can include both early and late effects. Figure 2 summarizes the radiation syndromes, the doses at which they occur, and the general time scale. Detailed discussions on the radiation syndromes are available on the Radiation Emergency Medical Management site[9] and in Chao.[6] Delayed effect of acute radiation exposure (DEARE) is a useful concept in that it may take months or even years for some radiation effects to develop that depend on the dose received. These include lung fibrosis (scarring), soft tissue fibrosis, and damage to blood vessels.

Figure 2. Radiation syndromes

Radiation Syndromes:

- **Acute Radiation Syndrome (ARS) andDelayed Effect of Acute Radiation Exposure (DEARE). [*Severity depends on dose*]**
  - **Continuum of injuries**
  - **Time to clinical manifestation depends on organ system and dose**
  - **Phases: Prodrome →Latent→ Manifest**
- **Hematological syndrome (>2 Sv)** — **few days to 2 months**
- **Gastrointestinal syndrome (>6 Sv)** — **few days to a week**
- **CNS/Cardiovascular syndrome (>10 Sv)** — **immediate**
- **Cutaneous syndrome (>6 Sv)** — **few days to weeks**
- **Combined injury (early intervention required)** — **immediate**
- **Radiation-induced cancer [*risk depends on dose*]** — **years to decades**

The concept of health risk applies most clearly to long-term or late health effects because the probability of the health effect occurring is related to the magnitude of the dose received. Understanding health risk from radiation requires, however, an appreciation of the background rates of cancer in the world population. U.S. rates are traced annually by the National Cancer Institute's SEER registry.[10] The cancer incidence in the overall population is over 40% which implies that the lifetime risk (chance) for Americans to develop cancer is over 40%. Any increase in the cancer risk due to exposure to radiation will simply add to that chance. [Note: Recent review of SEER data[11] suggested the risk of developing cancer and risk of dying from cancer for all invasive sites was 44.29% and 23.20%, respectively, for males and 37.76% and 19.58%, respectively, for females.]

The studies of Japanese atomic-bomb survivors and persons exposed to occupational and medical radiation are some of the primary subjects in the field of radiation epidemiology. Epidemiology studies follow the health of an exposed population for many years or decades and relate the excess cancer incidence (excess above the background rate) to the exposures the persons in the group received. These types of studies have allowed scientists to estimate the magnitude of the increase in cancer risk that would likely result from each increment in exposure. There are many specifics about radiation cancer risk beyond what can be effectively discussed here but which allow projections of cancer risk to be made for subgroups with specific attributes (e.g., age at time of exposure, gender, nationality, ethnic group).

Key points on long-term cancer risk:

1) Risk is higher for many types of cancer when exposed in childhood, in part due to the longer time for late effects to develop;
2) Within the dose range studied (near zero to near fatal dose levels), the risk increases relatively linearly with increasing dose, the only exception being for leukemia;
3) There is no evidence for a threshold dose below which there is no risk;
4) The absolute increase in risk at low doses (10's of mSv) might be considered as small (i.e., a few percent increase at most);
5) Long-term cancer risk can continue for decades after exposure;
6) Not all organs are at equal risk for cancer development after exposure. The most sensitive appear to be blood-forming tissues, the breast, thyroid, colon, and liver, followed by others to a lesser degree;
7) Each gender has unique risks to radiation, for example, risks to breast, lung, and bladder are greatest for females, while liver and colon are higher for males;
8) There are some non-cancer risks for which evidence is accumulating, in particular, risks to the cardiovascular system;
9) A synthesis of the data on A-bomb survivors indicates that the absolute increase in cancer risk is about 5%-8% for each Sievert of radiation received, or fraction thereof for lower doses.
10) In a rough calculation, for a dose of 10 mSv (1 rem), the increased lifetime risk of developing cancer would be approximately 0.8% and of having a fatal cancer of approximately 0.46%.[12] Thus, 10 mSv, which is about 2-3 times the annual background dose would increase the lifetime risk of developing cancer from approximately 42%[11,12] to 42.8%.

How and What We Learned about the Effects of Exposure to Radiation from Nuclear Weapons

It may be surprising to many that much is known about the effects of exposure of people to radiation from nuclear weapons. A distinction lies in whether the persons studied were exposed to radiation from an actual nuclear weapon (direct information) or whether the persons studied were exposed to radiation from another type of source or device, e.g., a nuclear reactor accident (indirect information), that emits radiation similar to the radiation from a nuclear detonation.

Indirect studies are by far the most common and include a diverse set of exposure conditions over the past 40 years, including the following:

- Radioactive emissions from weapons fuel (plutonium) production facilities in Hanford in the U.S. and Mayak in the former Soviet Union;
- Radioactive fallout[13] from nuclear weapons tests in Nevada, Utah, and New Mexico, Marshall Islands,[14] Kazakhstan, French Polynesia and elsewhere;

- Radioactive emissions from nuclear power plant accidents including Three Mile Island,[15] Chernobyl,[16] and most recently, the Fukushima Daiichi;
- Gamma radiation from nuclear criticality accidents, such as the Tokaimura criticality accident in Japan in 1999.

The only persons exposed directly to the gamma rays (as well as neutrons) from the detonation of a nuclear weapon are those present at the atomic bomb detonations in Japan during World War II. While the number of early fatalities from the Hiroshima and Nagasaki weapons totaled more than 200,000, several hundreds of thousands of people survived the detonations and have been the most valuable source of information on radiation health risks of any population in history. Even today, the U.S. and Japan continue joint studies of health risks of more than 80,000 A-bomb survivors through a bi-national research organization, the Radiation Effects Research Foundation in Hiroshima and Nagasaki.[16,17]

It is worthwhile to briefly review the radiation types and circumstances of exposure from a nuclear detonation. Nuclear detonations emit both high intensity gamma rays and neutron radiation. Gamma radiation energies range from those used in medical diagnostic examinations to high-energy isotopes created by the fission of nuclear materials, i.e., within a reactor or weapon detonation. The gamma ray energy from nuclear detonations is, on average, similar to the energy generated by medical accelerators that are used for radiation therapy of cancer; however, the way they are delivered differs.

Nuclear weapon:

- Gamma radiation from a nuclear detonation, often termed prompt radiation, is emitted in a fraction of a second at the time of the detonation, which does not allow for cellular and DNA repair systems to function.
- Persons exposed to prompt gamma radiation are generally exposed equally over their entire body, although there may be some partial shielding by walls or other structures. Whole-body or major partial-body doses of several Sievert can result in the acute radiation syndrome in **Figure 2**.

Cancer Radiotherapy

- Radiation for cancer therapy is delivered much more slowly, often in numerous fractions over a multi-week period. Radiation that is delivered more slowly allows the body to repair damaged DNA and replace cells. The body's repair capabilities are utilized in the treatment of cancer where healthy tissues adjacent to the tumor are given the opportunity to maintain their health and integrity by a slow enough delivery of the radiation to the tumor.
- Only the tumor and a limited amount of normal tissue are highly exposed, which is seen in the dose ranges in **Table 1**.

The important concepts here are two-fold:

1) Radiation received in a short time (seconds to minutes at most) does not allow for cellular and DNA repair systems to function; and
2) Radiation received over the entire the body is much more detrimental to the exposed person since entire organ and tissues systems are subject to damage or failure.

Radionuclide exposure

In addition to the near instantaneous irradiation of the body by gamma rays from a nuclear detonation, radioactive debris continues to irradiate the environment and persons in it for many years. Radioactive debris from a detonation contaminates the area that is downwind of the detonation. The debris is dispersed both by local wind currents and also by winds in the upper-level atmosphere. These contaminated dust particles eventually fall to the ground. The radioactive material, termed fallout, includes a large number of radioactive isotopes (over 200) that have half-lives (the time for the radioactive emissions to decrease by 50%) ranging from seconds to thousands of years. The most important radioactive isotopes (termed radionuclides) in terms of their potential to expose the public are radioactive Iodine-131 (written ^{131}I) and radioactive Cesium-137 (written ^{137}Cs), which have been studied for nearly 60 years.

Ingestion, inhalation, and radioactive shrapnel (particles in wounds) exposures are termed "internal" since the radioactivity exposes the body from the inside. Exposure from radiation of the ground and surfaces of the environment is termed "external" since the radioactivity exposes the body from the outside.

	Exposure Pathway	Health Effects
Iodine-131 (8-day half-life)	**Internal** • Ingestion of fresh milk products, following contamination of the feed of dairy animals • Can also be inhaled from the air, though that is almost always a minor addition to radiation dose in a nuclear detonation.	• Increased chance of thyroid cancer, usually taking many years and sometimes decades to develop. One of the most treatable and survivable of all cancers. • Iodine is a required nutrient and the human body cannot distinguish between the natural (non-radioactive) variety and the radioactive variety. • Risk from exposure is much higher in children as the thyroid is more active and smaller, which concentrates the radiation. Conversely, there is substantial evidence to suggest that exposure after reaching adulthood is relatively inconsequential.
Cesium-137	**External**: Contaminated	Does not accumulate in any particular organ

(30-year half-life)	ground and surfaces of environment **Internal**: Via meat products when cattle consume contaminated feed, though exposure is much smaller	or tissue and, for that reason, tends to expose the body uniformly.

A comparison between exposure to the prompt gamma rays from the detonation and exposure to fallout is relatively simple near a detonation (within approximately 1 km). The gamma ray exposure is likely to be the most serious component and potential cause of death. Exposure to prompt gamma rays is greatly attenuated at greater distances and with substantial sheltering as in a basement of a large building. Thus with distance or sheltering, the dose from fallout is the more significant source or radiation. The exposure to prompt gamma rays takes place quickly, preventing cellular and DNA repair processes, while exposure to fallout continues for many years and decades.

Essential facts about exposure from gamma rays and radionuclides following a nuclear detonation:

1) Detonations expose person externally by gamma rays and some neutrons;
2) Exposure within seconds is usually more dangerous than equal exposure over long periods of times (days, months, or years);
3) Detonations create radioactive debris that contaminates the environment by fallout;
4) Fallout particles can expose persons externally and the exposure can continue for years or decades, depending on clean-up and recovery;
5) Of the fallout radionuclides created, Iodine-131 and Cesium-137 impart the greatest health risks and are well understood.

Radiation Risk After a Nuclear Detonation: What Might Be Expected

The health consequences after a nuclear detonation will depend on several variables that are impossible to predict, but some generalizations can be made. The explosive yield and whether it is a ground or air burst will largely determine the amount of prompt radiation released and fallout created. An improvised nuclear device may “fizzle,” meaning little prompt radiation would be released; however, the local area would be contaminated with unfissioned plutonium or uranium. While this would be a hazard to unprepared persons, trained personnel with proper protective gear could effectively clean up and decontaminate the area.

Following a nuclear detonation, persons receiving less than one (or even two) Sievert of prompt and fallout radiation may have only limited acute effects. This group of people would be the largest group of “victims” and would be at an increased risk for future cancers. Recall that the

rate of increase in cancers—but not the severity—would be related to the dose each person received.

Present understanding suggests that there could be a 5% to 8% increase in the absolute cancer rate for those exposed to 1 Sv (100 rem).[19,20] This means that among persons exposed to 1 Sv (1000 mSv), their individual cancer risk might increase from 40% to about 45% or 48%. Similarly, the percentage of people developing cancer might increase from 40% to 45%-48%.

Not all cancer types would be increased equally by the radiation exposure. Those organs most at risk, as discussed earlier, would include the blood-forming tissues (leading to leukemia), the thyroid, and the breast, followed by others to lesser degrees. While it may be true that cancer can be induced in any organ, there is substantial evidence to suggest that not all organs are at equal risk.

Many people would undoubtedly receive doses much less than 1 Sv from a nuclear detonation. The most common dose received by the A-bomb survivors presently being studied is 5 to 10 mSv, or about equal to one or two years exposure to natural background radiation. The incremental risk experienced by each person would be generally proportional to the dose received and one can simply reduce the estimate of 5% to 8% increase per Sv of radiation by half, quarter, or any fraction, depending on the dose received. Hence, a person receiving 10 mSv would have received 1% of a Sievert and, thus, their incremental risk would be 1% of the possible 5-8% increase found in scientific studies, which is equal 0.05- 0.08%. This could be equivalently stated that the cancer risk would go from the background risk, ~40%, to about 40.05% or as much as 40.08% if they received 10 mSv. In this way, one can see that the most common increase in risk by persons surviving a nuclear detonation will not be large compared to the background cancer risk.

Concluding Remarks

Exposure to ionizing radiation from natural background and manmade sources is always present in our lives. Likewise, diseases such as cancer are common and, while not completely understood, the incidence of cancer is believed to be a result of other causes than background radiation. Cancer is a ubiquitous illness affecting approximately 40% of people in the U.S. and being fatal to over 20% of our population.[11] Additional radiation exposure, whether it be from medical radiation or a nuclear incident, can potentially increase a person's lifetime risk of developing cancer, though small increments of radiation impart only very small risks.

Early consequences from a nuclear event would be relatively few, but may require expert medical care to ameliorate the health consequences, some of which might be life threatening. Most important to society and to recovery efforts is to have an understanding about long-term cancer risks and to be able to put those into a proper perspective compared to the background cancer risk.

Radiation is only one of many risks faced in daily life, and its fear is often associated with the fact that radiation cannot be seen or felt. Epidemiological studies of many groups of people

who have been exposed to radiation have been used to estimate the additional risk of cancer from radiation exposure. However, the survivors of the A-bomb detonations in Japan have given us the greatest insights. This knowledge allows us to quantitatively estimate the individual or population cancer risk after a nuclear detonation or reactor accident if a reliable estimate of the radiation dose is possible.

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Response, Resources, and Resilience: Preparedness and Planning for a Nuclear Detonation

Overview

Effectively planning for the public health and medical response to a major disaster is critical to saving lives and offering comfort care to as many people as possible. Such planning also enhances the resiliency of the providers, institutions, and community. Preparedness efforts should focus on "all-hazard"[1] issues to ensure that the command, control, coordination, and communications elements of an effective response are as robust and well-practiced as possible within a community. The resources to support a medical response should be understood and augmented to the degree possible given economic and other constraints prior to an incident.

The priority areas and technologies and tools being developed by federal agencies for community resilience are recognized and discussed through planning activities mentioned in this chapter. Response Phases, Organization of the Response, Resource Availability, the Federal Response, and the Continuum of Responders are the key activities identified as vital planning components for establishing community resilience. These key activities, in conjunction with coordination, communication, education, cooperation, and collaboration among the broad spectrum of government, academia, the private sector, and, in particular, the general public, can create communities that will be empowered to endure after a catastrophic and traumatic incident.

It is important to remember that there are two key features of resilience:

- Have as effective a response as possible; and
- Recognize that despite a major tragedy, there is a path toward a plausible, structured recovery that will help survivors cope with inevitable stress and see a way forward to eventually reach a state of "new normalcy."

Scope of the Threat

Certain threats, such as a nuclear device detonation, require specific planning to address the following issues:

- Coping with multiple systems failures, including command and communications and possible loss of major systems or emergency operations center locations;
- Contingencies for overwhelmed responder agencies and organizations;
- Integrating an unparalleled regional, federal and perhaps international response in the face of compromised local infrastructure (e.g., transportation, facilities);
- Medical resource deficits; and
- Patient movement within and out of the affected area.

The breadth and immediacy of response requirements necessitate a ready-to-use checklist that can guide decision making before exact requirements are known. The checklist provides tools, resources, approaches to inter-agency and inter-disciplinary coordination, and flexibility to predict actions and needs during an incident

Resilience

The National Health Security Strategy (NHSS) of the United States of America[2] defines community resilience as "the sustained ability of communities to withstand and recover—in both the short and long terms—from adversity." Resilient communities draw from numerous community elements (individual, public, and private) to promote healthy lifestyles, prevent disease, and provide access to good healthcare and public health systems. The ultimate goals of resilience are to systematically integrate into the overall community structure a certain amount of risk reduction that is achieved through good baseline health status, strengthened institutions and capacities, and programmatically implemented preparedness, response, and recovery plans.

Five priority areas for community resilience to disasters include:

- Governance and leadership,
- Risk and capability assessment,
- Stakeholder knowledge and education,
- Risk management and vulnerability assessment, and
- Disaster preparedness and response.[3]

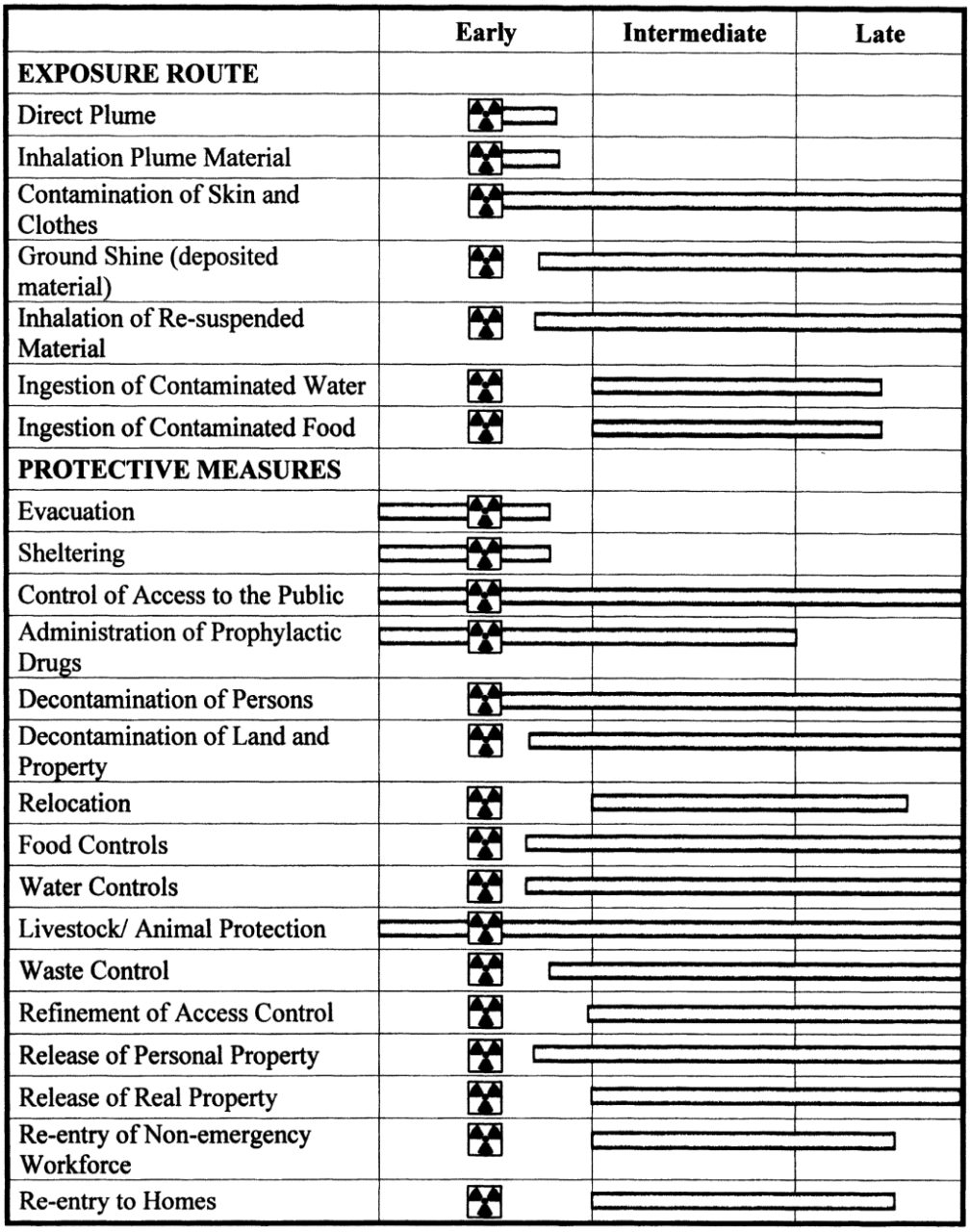
Two key features of resilience:

- Have as effective a response as possible; and
- Recognize that despite a major tragedy, there is a path toward a plausible, structured recovery that will help survivors cope with inevitable stress and see a way forward to eventually reach a state of "new normalcy."

Response Phases

The medical and public health response to a nuclear detonation unfolds in phases (Figure 1).[4] Some actions that occur primarily in the later phase must begin very early in the response in order to be effective (e.g., evacuation of patients in the latent phase of radiation syndrome before the full syndrome is present). There are different preparation and response activities by sector: emergency management, emergency medical services, health care facilities, public health, and overall medical system.

Figure 1.—Relationship between Exposure Routes, Protective Measures, & Timeframes for Effects[a, b]



[a] For some activities, the figure indicates that protective actions may be taken before a release occurs. This would be the case if authorities have prior warning about a potential RDD/IND incident.

[b] In certain circumstances, food and water interdiction may occur in early phases. In addition, some exposure routes (e.g., ingestion of contaminated food) may occur earlier than depicted in the figure, depending on the unique characteristics of the incident.

Pre-incident coordination and communication strategies are essential, as outlined in Koerner.[5]

Organization of the Response

The destruction from a nuclear detonation produces both physical damage and radiation exposure. (Figure 2) While the blast, heat, and radiation zones are fairly co-incident close in, **there can be major zones where there is physical injury without radiation (upwind glass breakage injuries) and others where there is radiation with limited or no physical damage to the infrastructure (fallout areas).** The response after a nuclear detonation is organized around and within the damage zones (Table 1): Severe, Moderate, Light Damage Zone, and Dangerous Fallout zones—all based on damage or presence of fallout—and a variable zone designated >10mR/hr in which response can occur but rescue time may be limited. **The RTR system** (Radiation TRiage, TReatment, and TRansport) (Table 2) overlays a functional response on the physical damage response zones.[6]

Figure 2. Physical Damage and RTR Zones

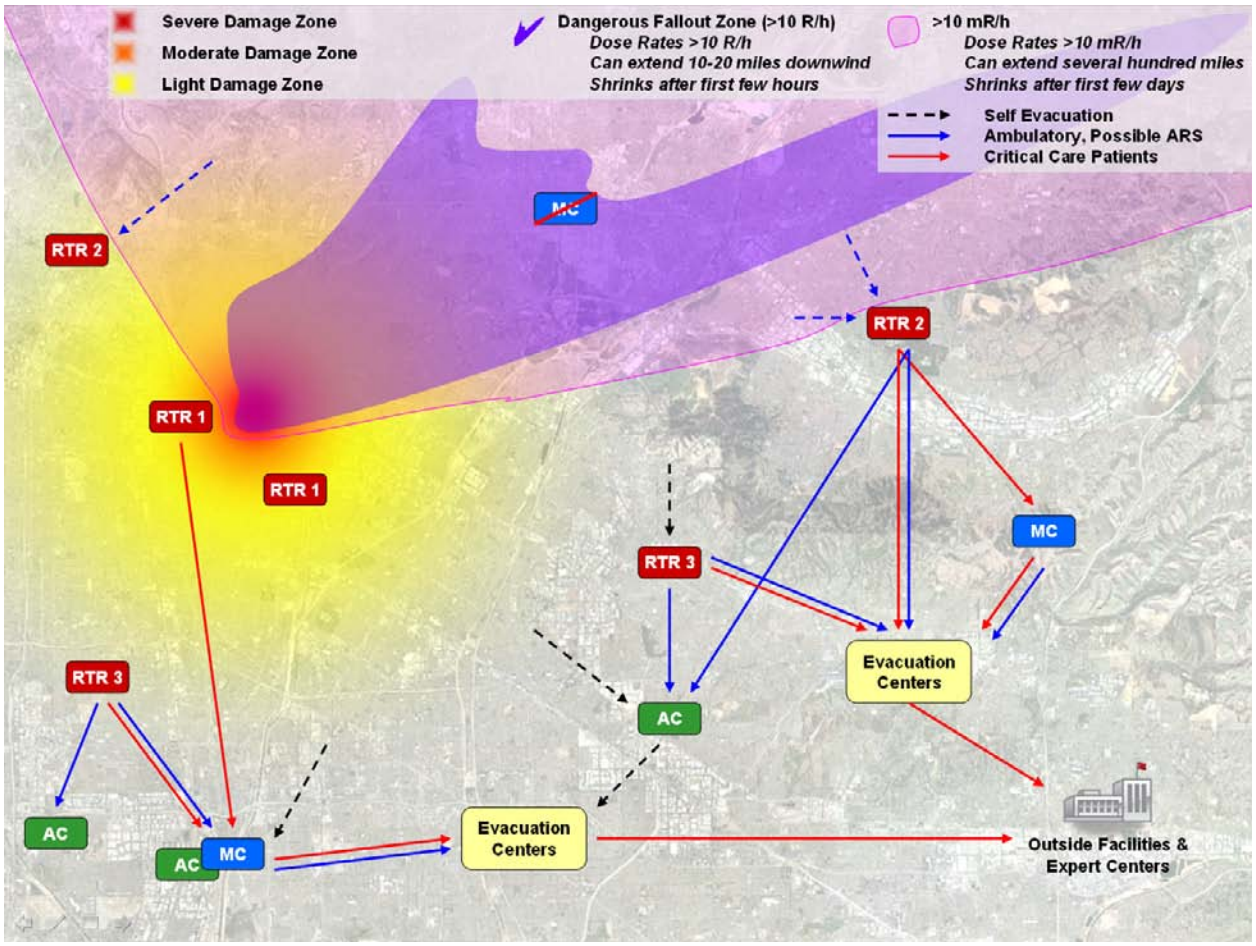
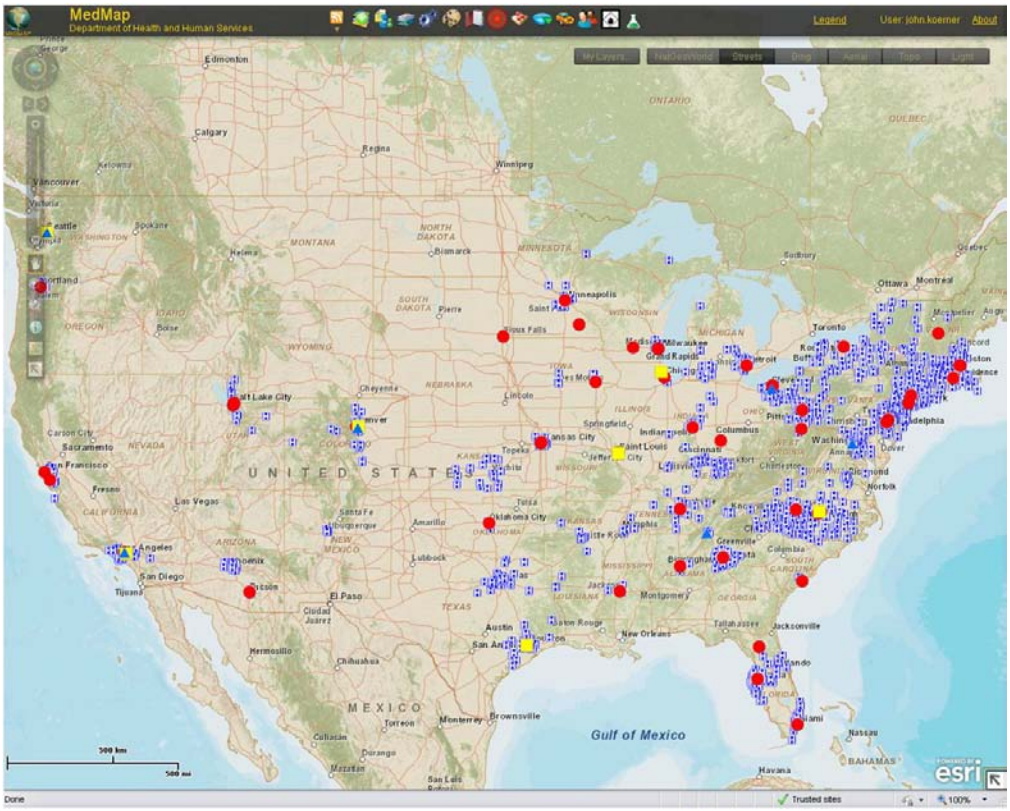


Table 1. Physical Damage Zones[7]	
Severe Damage (SD) Zone	Extensive infrastructure damage and few survivors
Moderate Damage (MD) zone	Passable, with variable to no levels of radiation, which, if present, decrease over time
Light Damage (LD) zone	Passable, with little or no radiation other than where fallout areas overlap the LD zone
Dangerous Fallout (DF) zone	10 R/h or greater – may overlap the above zones. (The DF zone shrinks rapidly as exposure from fallout decays rapidly. The "7-10 rule" indicates that fallout decays to approximately 10% after 7 hours and every 7 times that it decays to 10% (so it would be 1% at 49 hours (7 hours x7= 49 hours or ~2 days) and 0.1% at 2 weeks (2 days x 7= 14 days))
A perimeter 10mR/h (0.01 R/h) or greater	Location where time and dose for people working in that zone are monitored. This is outside the DF zone

Table 2. Functional Response System. The RTR system (Radiation TRiage, TReatment, and TRansport) system helps organize the response[6, 7] (Figure 2).	
Spontaneously forming RTR (casualty collection point) sites	• RTR1 – at or near major physical damage with radiation present; • RTR2 – no or limited physical damage and radiation present, likely near the DF zone; and • RTR3 – no or limited damage and no radiation.
Pre-designated sites (community reception centers)[8]	• Medical Care (MC) sites, including alternative medical care sites; • Assembly centers (AC), some of which may be co-located near MC sites for people who do not require medical care; and • Evacuation centers (EC)

Local planning is most effective when it is integrated across the tiers of response[9] to include the federal tier. Effective integrated planning is facilitated through the use of planning and response tools such as a resource-mapping tool developed by HHS known as MedMap.[10] MedMap (Figure 3) facilitates sharing situational awareness with local/regional responders and can show locations of healthcare facilities in relation to other overlays and demographic information. Designated local and state government partners (as defined in the National Response Framework Emergency Support Function #8)[11] can request access to MedMap through their HHS/ASPR Regional Emergency Coordinators.

Figure 3. MedMap. During an incident, selected access to MedMap will be available to assure that all responders have coordinated situational awareness.



Resource Availability

Resource scarcity is the inability of the resources—space, staff, and supplies—to meet the medical needs. The mismatch between need and available resources will vary by type of resource, location of need, and the time following detonation. Table 3 depicts the categorization of supply/demand mismatch as recommended by the Institute of Medicine (IOM).[12]

Table 3. Relationship between Resource Availability as used in this Project to IOM Standard of Care definitions. In the setting of a severe crisis there are no longer sufficient resources to treat all patients.[12-15]

Resource Availability (this series)	**IOM Standard of care**	**Level of care recommended by this manuscript**
Normal	Conventional	Normal care is provided.
Good	Contingency	"Functionally-equivalent" level of care is maintained by using resource-enhancing strategies such as substituting and conserving resources.

Fair	Crisis	Triage prioritizes those with moderate injuries because those with more severe injuries (trauma, burn, and radiation) will have higher resource requirements and worse prognosis, even with treatment.
Poor	Crisis	Those with severe traumatic, burn and radiation injuries are triaged to the expectant category.

The Scarce Resources Project for Nuclear Detonation[16, 17] (Table 3) subdivided the IOM crisis standards of care (Table 4) into 4 categories in which crisis care is subdivided into fair and poor resource availability, the latter having severe shortages that impact triage category.[18]

Table 4. Resource Availability for Nuclear Detonation and IOM Standards of Care

Incident demand / resource imbalance increases →
Risk of morbidity / mortality to patient increases →
← Recovery

	Conventional	Contingency	Crisis
Space	Usual patient care space fully utilized	Patient care areas re-purposed (PACU, monitored units for ICU-level care)	Facility damaged / unsafe or non-patient care areas (classrooms, etc) used for patient care
Staff	Usual staff called in and utilized	Staff extension (brief deferrals of non-emergent service, supervision of broader group of patients, change in responsibilities, documentation, etc)	Trained staff unavailable or unable to adequately cae for volume of patients even with extension techniques
Supplies	Cached and usual supplies used	Conservation, adaptation, and substitution of supplies with occasional re-use of select supplies	Critical supplies lacking, possible re-allocation of life-sustaining resources
Standard of care	Usual care	Functionally equivalent care	Crisis standards of care[1]

Usual operating conditions

Indicator: potential for crisis standards[2]

Trigger: crisis standards of care[3]

Austere operating conditions

1) Unless temporary, requires state empowerment, clinical guidance, and protection for triage decisions and authorization for alternate care sites / techniques. Once situational awareness achieved, triage decisions should be as systematic and integrated into institutional process, review, and documentation as possible.
2) Institutions consider impact on the community of resource utilization (consider 'greatest good' vs. individual patient needs – for example, conserve resources when possible) but patient-centered decision-making is still the focus
3) Institutions (and providers) must make triage decisions balancing the availability of resources to others and the individual patient's needs – shift to community-centered decision-making

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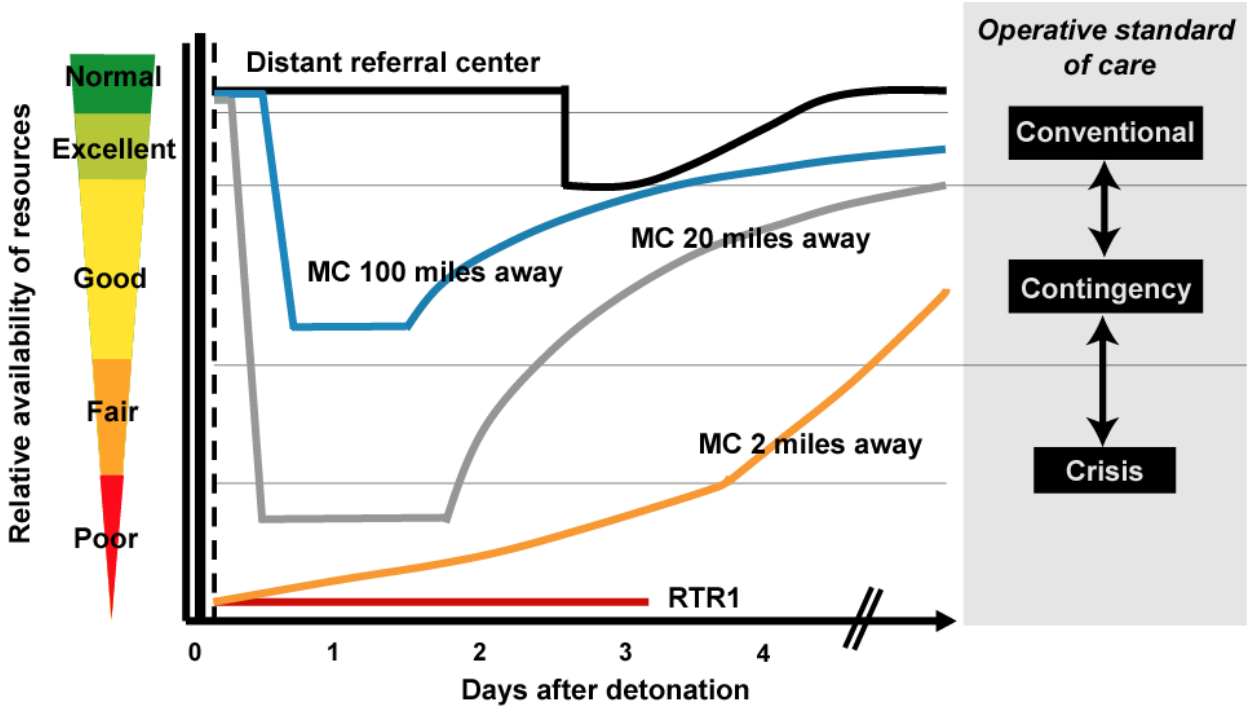
Thus, the scarce resource setting will differ in location and over time and consequently the standards of care will vary; Figure 4 is a graphic representation this concept (adapted from DiCarlo[19]).

Figure 4. Resource Availability Will Vary By Proximity to the Incident and Will Change Over Time



An RTR1 site (see Figure 2) will have poor resources—the focus is on moving patients from an RTR to more definitive assessment/care. A medical center (MC) 2 miles away will have poor resource availability but will improve to fair by the third day (assuming infrastructure is relatively intact AND that appropriate requests for resources were able to be made and fulfilled), while a MC 20 miles away will recover faster due to resupply. Even a MC center 100 miles away could be transiently resource limited These curves assume that there has been appropriate forward movement of casualties out of the immediate area and establishment of alternative care and screening sites—
Although the scarce resource setting is likely to vary based on physical location and time since the event, strategies for dealing with even transient scarcity are necessary.

Strategies for Scarce Resource Situations[12-15, 20]

- **Prepare** – stock disaster supplies and increase par levels on commonly needed items such as tetanus vaccines, laceration trays, narcotic analgesics, dressing, etc.[21]
- **Substitute** – use a clinically equivalent item or staff person;
- **Adapt** – use items or technologies to provide sufficient care (use transport ventilators or anesthesia machines instead of full-featured ventilators), use staff with similar or congruent skill-sets (specialty surgeons assisting with trauma surgeries), or adapt locations of care (performing surgical procedures outside of the operating room);
- **Conserve** – use less of a resource by lowering dosage or changing utilization practices;
- **Re-use** – after appropriate disinfection/sterilization, re-use supplies;

- **Re-allocate** – prioritize a therapy in scarce supply so that it is only given to those with a higher chance of benefit or greater need.

Some key planning and early response priorities for these different locales are outlined below.

Jurisdictional Response

Situational awareness and establishment of command/control

- Assess healthcare facility and public safety system damage and infrastructure damage (communications, transportation affecting response).
- Healthcare responses focus on provision of supplemental staff, supplies (e.g., wound dressings) and pharmaceuticals (e.g., cytokines, analgesia, intravenous fluids, and antiemetics) to hospitals, RTR sites, and pre-determined alternative care sites prior to full situational awareness.
- Pre-determined resources should be 'pushed' to affected facilities and agencies (or to regional staging areas) from suppliers, more functional healthcare systems, and jurisdictions. Preplan 'automatic' responses so that functional operations center is not necessary in the first hours after an event.

Triage

- Triage based on physical injury first and then radiation assessment.
- Radiation- assessments (including exposure information and symptom information and lymphocyte counts.

Contamination

- Emergency care takes precedence over decontamination.
- Removal of clothing removes >90% of superficial contamination.
- Decontamination and contamination containment (how are patients designated as 'clean' for shelters and what is the threshold) should be planned by community prior to the event.

Medical care

- Overflow: alternative care sites, temporary RTR3 sites may provide symptomatic care for those without serious injuries to reduce burden on healthcare facilities and reduce panic.
- Non-life-threatening but serious injuries evacuated for necessary care after first-aid (e.g., splinting or covering wound).
- Palliative care plan (supplies, location, managing community expectations).

Mental health

- Responders top priority.
- Victims, including seriously ill and expectant category.
- Communication to help reduce panic and hopelessness.

Transport

- Primarily evacuation and transport out of the area—including those in latent phase of ARS.
- Some back-fill personnel and supplies are transported in.
- May require creative solutions (4-wheel drive vehicles, buses, etc.).

- Coordination with public works likely required to clear streets of debris to facilitate evacuation of patients from RTR and close-in hospitals.

Regional/State Response

The role of the surrounding region is to support, and when needed, assume responsibility for absent command and control mechanisms. Planning requires working with coalitions outside the immediate area, as their support and assistance will be required. Some major considerations for state and regional response include the following:

Command and control

- Regional/state Emergency Operations Center (EOC) may have to take over role of 'local' EOC if command infrastructure is severely damaged

Proactive emergency declaration for state and federal resources

- Pre-scripted declarations and plans

Acute medical care

- Small healthcare facilities may become major providers of triage and care—requires planning and communication/coordination mechanism.
- Regional/statewide hospital coalitions are critical to effective response and medical demand balancing/resource management.

Emergency management assistance compacts (EMACs)

- Pre-planned interstate resource mutual aid may greatly contribute, but impact may be uncertain due to magnitude of crisis.

Regional staging area

- Forward movement of resources to these areas prior to specific assignment will cut hours to days off of usual mechanism for requests.
- Requires planning for accommodations, staff support, communications, and resources (maps, GPS for responding units)

Federal Response

A nuclear detonation will bring an unprecedented number of federal agencies to the jurisdiction. Understanding the resources available and the chains of command, as well as anticipating where and how to accommodate these agencies so that their efforts can coordinate prior to an event, are important. Some of the key players would likely be:

Federal Bureau of Investigation – Crisis management and lead investigative agency following a terrorist event.

Federal Emergency Management Agency[22] – Consequence management and gateway for resource requests via the state to the Federal Coordinating Officer for logistical requirements not able to be supplied by the state or region including personnel, communication, earth-moving equipment, urban search and rescue teams, etc.

U.S. Department of Energy – Provision of modeling and atmospheric data via Laurence Livermore National Laboratories and provision of expert technical assistance from the Radiologic Assistance Program and National Nuclear Security Agency.

- Federal Radiological Modeling and Assessment Center[23]
- Advisory Team for Environment, Food, and Health (A-Team)[24]

Nuclear Regulatory Commission provides expertise on nuclear reactors and reactor sites[23]

U.S. Department of Health and Human Services (HHS)

- Centers for Disease Control and Prevention – activation of Strategic National Stockpile[25] and provides epidemiologic assistance.
- National Institute for Health – National Library of Medicine – Radiation Emergency Medical Management (REMM) website and other resources for victim medical treatment.
- Assistant Secretary for Preparedness and Response (ASPR)[26] – National Disaster Medical System (NDMS), U.S. Public Health Service, volunteers, Disaster Medical Assistance Teams (DMATs), Disaster Mortuary Teams (DMORTs)

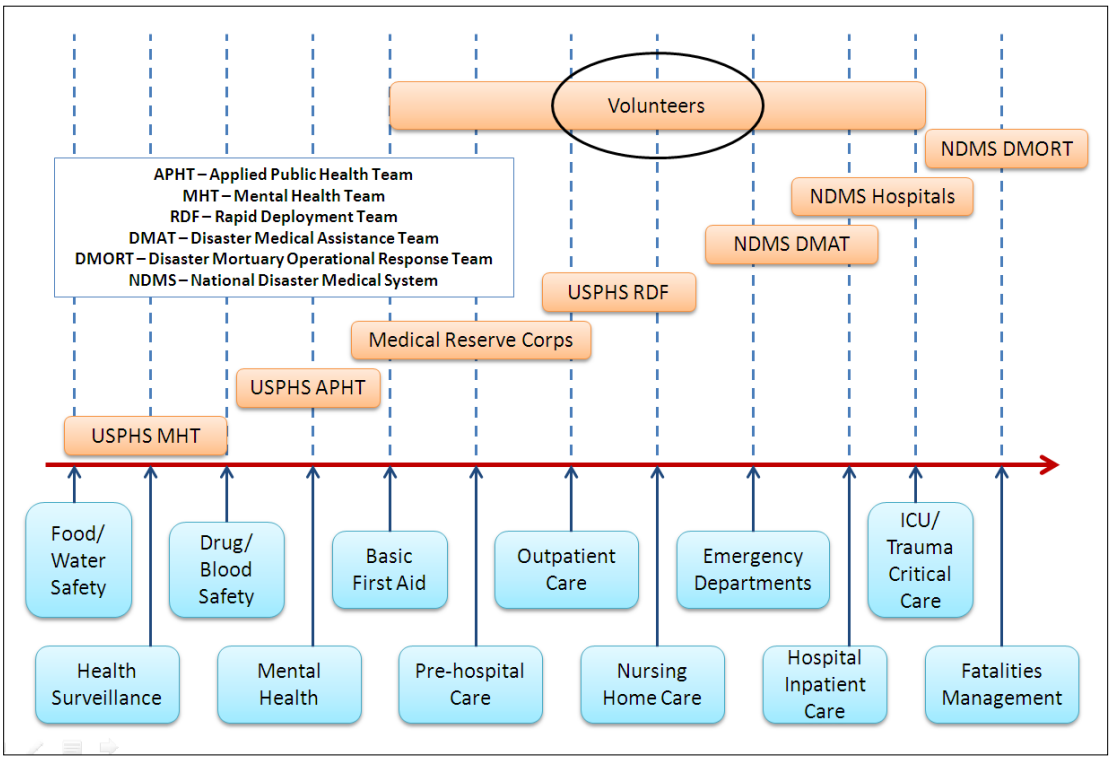
Department of Defense (DOD) –coordinates airlift capability for NDMS. DOD can provide substantial technical and personnel assistance according to needs identified by the Federal Coordinating Officer.

U.S. Department of Veteran's Administration (VA) – activation of Medical Emergency Radiologic Response Team[27] as well as VA Federal Coordinating Centers for patient movement.

Continuum of Responders

Figure 5 illustrates the spectrum of HHS staffing support to the local area and the importance of integration and coordination among a broad base of responders. This is one aspect (local staff support) of the multiple federal agencies and missions that will be engaged.

Figure 5: The Spectrum of Care & Phased Deployment



Summary
The challenges of planning for a nuclear detonation are manyfold. However, by focusing on the fundamentals of community resilience and concentrating on redundancy of command, control, and communication mechanisms, jurisdictions can build an underlying community structure that can reconstitute and gain situational awareness more rapidly after a detonation. As a planning element, developing a quantitative understanding of the local capacity for non-traditional emergency response assets (private practices, commercial labs, etc.) and coordinating them is crucial. Planning for proactive resource support from the surrounding region, state, and federal entities and the use of regional staging areas in case of a catastrophic incident will greatly shorten the time to resource availability to the end users. Assembly and evacuation center planning by healthcare facilities and the community at large will greatly mitigate bottlenecks and confusion in the hours and days after an incident. Pre-scripted mission assignments may be constructed for local, regional, or state groups to support these sites. Though a nuclear detonation will be catastrophic, the resilience of the community rests in large part on the success of these key activities during planning, exercising, and response. While one can never be perfectly prepared, and much work remains to be done, there has been substantial progress in defining needs and in developing plans, tools and resources. Coordination, communication, education, cooperation, and collaboration among the broad spectrum of government, academia, the private sector and, in particular, the general public will be needed to conduct the best possible response in the face of such a catastrophic and traumatic incident.

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Acute Radiation Syndrome: Medical Guidance and National Response

Overview

Detonation of a 10 kiloton improvised nuclear device (IND) within a U.S. city could result in hundreds of thousands of casualties, many with clinically significant bone marrow injury.[1] In addition, industrial accidents involving ionizing radiation exposure, such as those in Goiania and Chernobyl, can affect many people and require specialized medical treatment for exposure and internal contamination.[2,3]

The four known organ systems affected by ARS are the *hematopoietic, gastrointestinal, cutaneous, and neurovascular systems*. Treatment of ARS is dependent on radiation dosage and the length of time between exposure and medical intervention. Information with links to primary resources is available on the Radiation Emergency Medical Management (REMM) website. The REMM website also provides mobile electronic access on medical management and triage models for use by emergency responders and medical personnel.

Key to an effective response is understanding the manifestations and management of acute radiation exposure and matching available resources to radiation casualties after a large incident. The Radiation Injury Treatment Network (RITN)[4] is a voluntary program that can provide care for radiation injury. We describe a hospital-based surge capacity survey that highlights key points relevant locally and to a nationwide radiation casualty response.

Acute Radiation Syndrome (ARS) Management

Historically, clinical assessments after radiation exposure have focused on the four most relevant organ systems, specifically the *hematopoietic, gastrointestinal, cutaneous, and neurovascular systems*. The unit for radiation dose absorbed by an individual is the Gray, abbreviated Gy. Radiation injury depends on the dose received and the extent of the body exposed. When discussing ARS, whole-body exposure is assumed—or at least most of the body. For a nuclear detonation, it is the external radiation that is critical as there is very little significant internal exposure (from ingestion or inhalation). Generally, there may be some nausea and vomiting at whole-body dose of ~1 Gy, which might require some symptom control, but serious ARS begins at ~ 2Gy, especially for those with combined injury. However, radiation can cause damage to essentially any organ system and much of the acute damage is related to a systemic inflammatory response (Figure 1).[5]

Figure 1. Time Course of ARS Following Exposure to Radiation
As the dose of radiation increases, injury is more severe and occurs more promptly.
At the lower doses there may be initial symptoms, then a latency period (of days to a few weeks) before the major consequences occur.

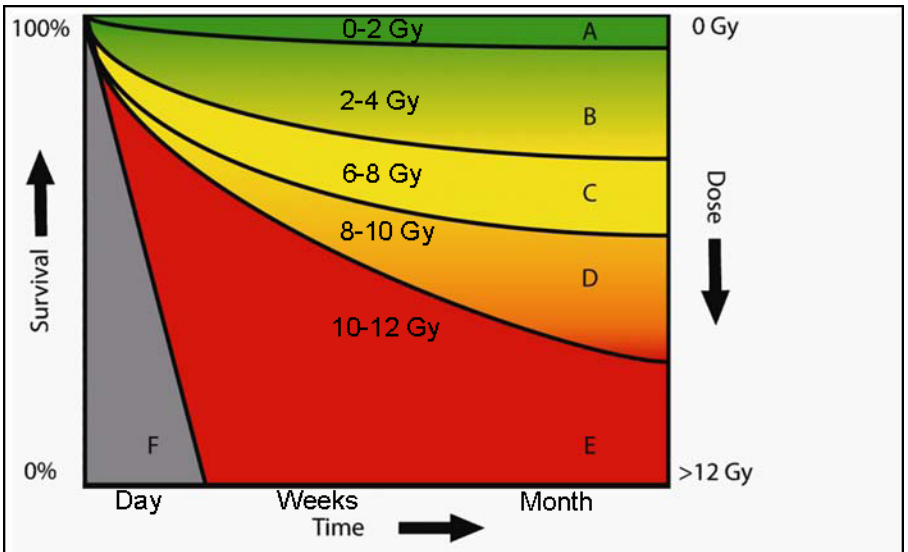


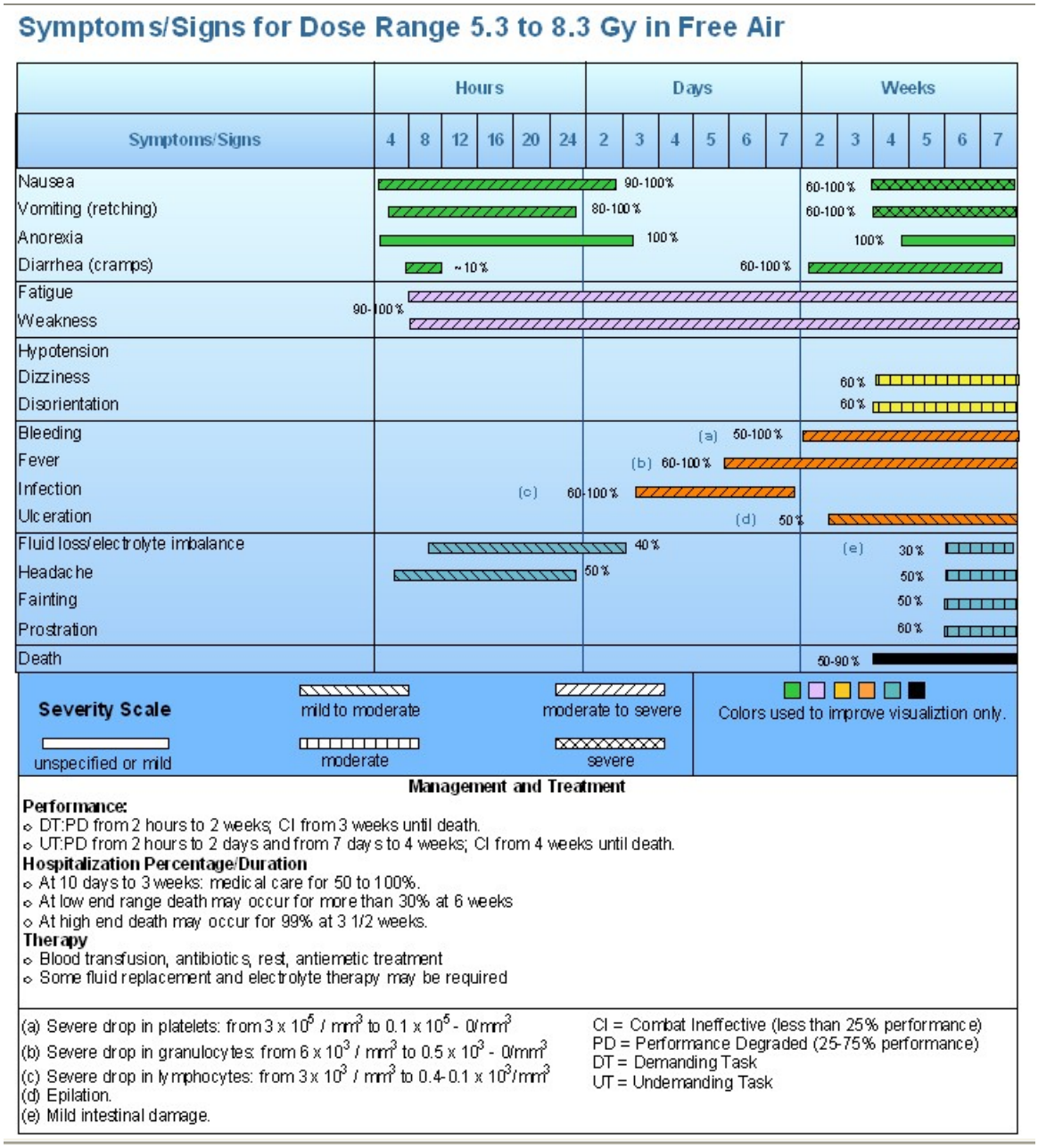
Figure 1. Spectrum of Outcomes Following Exposure to Ionizing Radiation

A. 0 to <2 Gy, no therapy needed
B. 2 to 6 Gy, onset of hematopoietic syndrome, possible cytokine and/or pharmacological intervention
C. 6 to 8 Gy, onset of GI syndrome, rescue by intensive supportive care, immune reconstitution, cellular therapy
D. 8 - 10 Gy, rescue through stem cell transplantation
E. 10 - 12 Gy, salvage through somatic stem cell regeneration
F. >12 Gy, neurovascular syndrome, multiple organ failure, no effective intervention available

Grading systems that utilize clinical and basic laboratory data to estimate radiation dose (i.e., biodosimetry) have been established by the METREPOL group[6] and the Armed Forces Radiobiology Research Institute[7] and are available on the Radiation Emergency Medical Management (REMM) website[8] (Figure 2). These systems can help determine the level of exposure and therefore guide triage and treatment.

Figure 2 is an example of the more serious consequences. *There are other figures on REMM for all the dose ranges*.

Figure 2. Time/Dose Effects in ARS Following Single Dose Whole Body Irradiation (REMM)



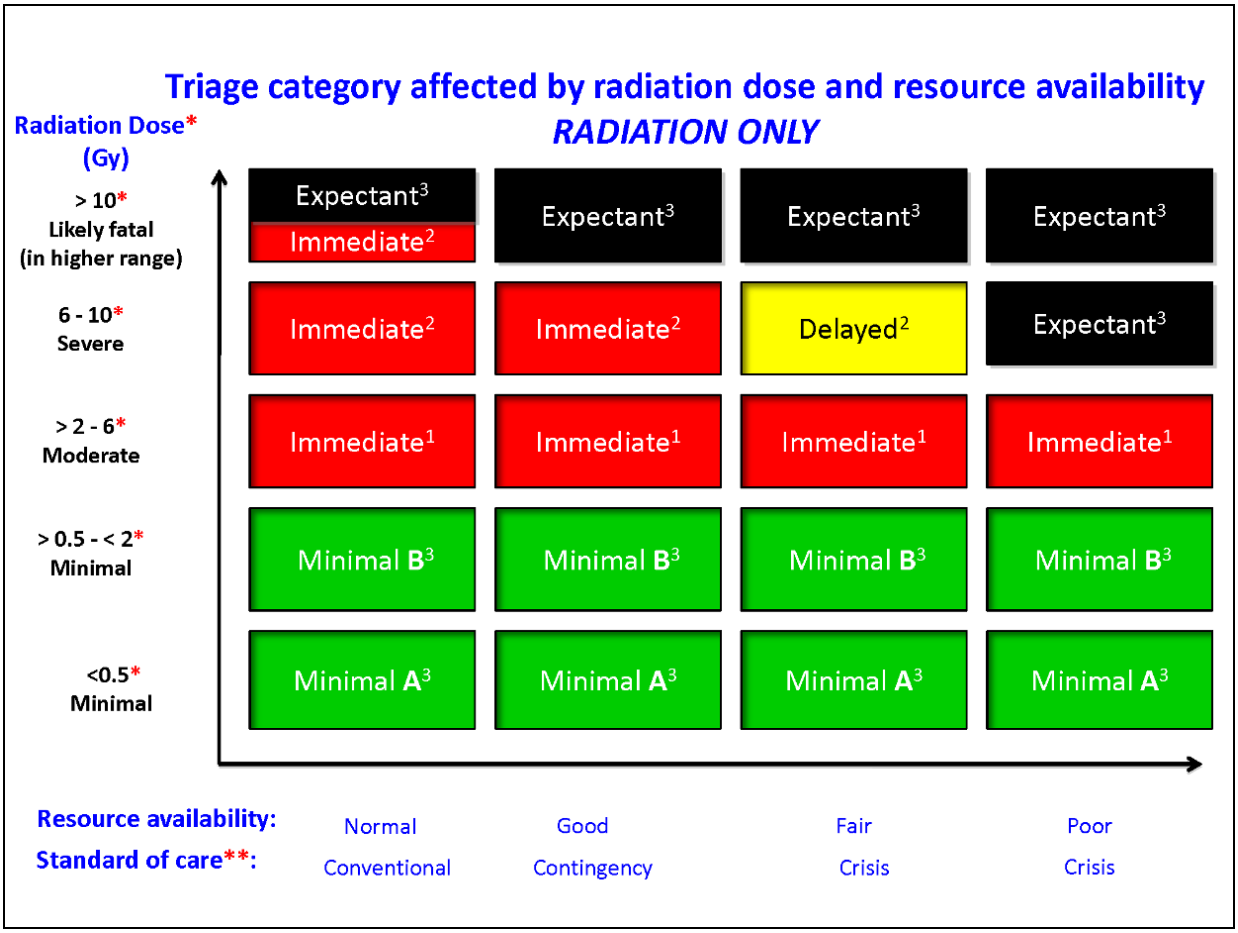
TRIAGE: In a large mass casualty setting, efficient triage of irradiated casualties is essential to identify those casualties who have received clinically significant—but not invariably lethal—doses of radiation, which range between 2-10 Gy whole-body exposure. These are the victims who need specialized and sometimes urgent care. In resource-scarce settings, symptomatic care is given if possible and life-sustaining measures should be withheld from casualties with non-survivable trauma, thermal burns, and/or radiation exposures.
Extensive triage algorithms were recently published to guide the selection of appropriate candidates for life-sustaining care in resource limited settings.[9]

Figure 3 is an example of how triage category varies by radiation dose and how it changes based on the standards of care in place at the time and location where triage is being done.

The full set of algorithms is on REMM.[10]

- Level of exposure can be determined by geographic, clinical, or laboratory means. The level of exposure can guide treatment and therefore the resources required for care.
- Exposures of 2-10 Gy of ionizing radiation are treatable if acted upon promptly.
- Combined injury- radiation plus physical trauma can have a worse prognosis.
- Re-evaluation is crucial.

Figure 3. Triage Schema Dependent on Radiation Dose and Available Resources
There are "triage cards" for radiation only and for combined injury, as well as a "triage tool" on REMM.
NOTE: TRIAGE Categories (Expectant, Immediate, Delayed, and Minimal, as used for a nuclear detonation) are described in detail in "Involving the Community" along with the ethics issues, which require community involvement.



Legend- Radiation Only

* Radiation dose received by the whole body or a significant portion of the whole body.
** Crisis standards of care IOM Letter Report 2009

Minimal B: Consider repeating both biodosimetry and clinical reassessments, especially at high end of this dose range

Minimal A. <0.5 Those with physical dose estimates based on location below 0.5 Gy need not report for medical evaluation. Joining a registry may be suggested after the incident.

The red/black split triage category for >10 Gy indicates that some victims may receive aggressive treatment at discretion of physician, especially if 10 Gy is received over prolonged time period.

Resource availability below NORMAL:

GOOD	**conditions allow for maintenance of "functionally-equivalent" care through contingency operations**
FAIR	**conditions require delaying care for severe injuries after moderate injuries**
POOR	**conditions require classifying severe injuries as expectant**

Myeloid cytokine category	G-CSF recommendation
1	G-CSF indicated.
2	G-CSF indicated, lower priority than Category 1.
3	G-CSF not indicated.

Triage category for *TRAUMA and COMBINED INJURY* affected by injury severity, radiation dose and resource availability

Injury severity	Trauma* + radiation** = Combined injury			
≥ Moderate trauma* + radiation > 2 Gy **	Immediate	Delayed / Immediate	Expectant / Delayed	Expectant

Trauma only	BURN >20% BSA worsens triage category (lowers priority) 1 level			
Severe trauma*	Immediate	Immediate	Delayed	Expectant
Moderate trauma*	Delayed	Delayed	Immediate	Immediate
Minimal trauma*	Minimal	Minimal	Minimal	Minimal

Resource availability	Normal	Good	Fair	Poor
Standard of care***:	Conventional	Contingency	Crisis	Crisis

Legend- Trauma and combined injury

* Adding > 20% total body surface area burn to trauma worsen triage priority by 1 category (puts them *lower on the priority list*).

** Radiation dose received by the whole body or a significant portion of the whole body
At higher radiation doses (>6 Gy), triage category may worsen- as on Combined Injury card

*** Crisis standards of care, IOM letter report, 2009

Trauma category	Description
Combined injury	•Radiation dose of > 2Gy to whole body or significant portion of whole body ***plus*** *moderate or severe* trauma and/or burn injury.
Severe trauma	•Stabilization requires complex treatment; •>20% chance of death even with treatment.
Moderate trauma	•Without stabilization, potential for death within hours •<20% chance of death with stabilization and treatment.
Minimal trauma	•Injuries pose no significant risk to life and limb in next 3-4 days •Limited or no treatment prior to referral in the next 3-4 days.

Determining Exposure for Triage, triage personnel will utilize: :

- Geographic (location relative to detonation and radioactive fallout);
- Clinical (signs and symptoms of radiation exposure); and
- Laboratory assesment for biodosimetry (blood cell counts, dicentric chromosome analysis) to estimate dose and the necessity for intervention.
  - Blood cell kinetics, particularly the absolute lymphocyte count, may be particularly useful for predicting clinical course. This will require serial measurements.

Acute intervention for irradiated casualties:

1) Exposure minimization (i.e., sheltering, shielding, removal of contaminated clothing if they are in fallout). Note: internal contamination is not an important issue for acute exposure in a nuclear detonation (this is different than a radiological dispersal device or nuclear power plant incident);
2) Supportive care to mitigate the morbidity and mortality of radiation exposure (e.g., hydration, antibiotics, antiemetics, skin care); and
3) Radiation medical countermeasures (MCMs), which, unlike supportive care, have the potential to alter the natural history of radiation exposure (Figure 4 and REMM[11]).

Figure 4. Consensus Guidance for Treatment of Hematopoietic Syndrome Based On Dose of Radiation (REMM)

Treatment Guidance	Whole-body Dose (Gy) What is Gy (gray)?										Event Size, ± Injury/Burn (Small event: ≤ 100 victims Mass event: > 100 victims)
	1	2	3	4	5	6	7	8	9	≥10	
NOTE: All potential treatments may not be feasible in a large size event.											
Prophylactic Antibiotics†		✓	✓	✓	✓	✓	✓	✓	✓	✓	Small/no injury
		✓	✓	✓	✓	✓	✓				Mass/no injury
		✓	✓	✓	✓	✓					Small/injury + burn
		✓	✓	✓	✓	✓					Mass/injury + burn
Cytokines/ Bone Marrow Growth Factors‡			✓	✓	✓	✓	✓	✓	✓	✓	Small/no injury
			✓	✓	✓	✓	✓				Mass/no injury
		✓	✓	✓	✓	✓					Small/injury + burn
		✓	✓	✓	✓	✓					Mass/injury + burn, if resources available
Stem-cell Transplantation (Allogeneic)§							✓	✓	✓	✓	Small/no injury
							✓	✓	✓	✓	Mass/no injury, if resources available
Stem-cell Transplantation (Autograft or Syngeneic)§				✓	✓	✓	✓	✓	✓	✓	Small/no injury
				✓	✓	✓	✓	✓	✓	✓	Mass/no injury, if resources available

- The current management of ARS does not substantially differ from the management of pancytopenia in other settings, such as after treatment with myelosuppressive chemotherapy.Myeloid cytokines[12] (granulocyte-colony stimulating factor [G-CSF; Filgrastim], granulocyte monocyte-colony stimulating factor [GM-CSF; sargramostatin] or pegylated G-CSF [pegfilgrastim] can reduce the duration of neutropenia (<500 neutrophils per mm^3), hospital length of stay, and overall costs (McVittee, personal communication).
- All patients with confirmed neutropenia are potential candidates for myeloid cytokines. Laboratory atudies suggest that *initiating myeloid cytokines within 24 hours of exposure may improve outcomes*.
- Specific indications for initiating myeloid cytokines prior to the onset of neutropenia include a projected whole body dose of 2 Gy or more based geographic information and clinical signs and/or blood cell kinetics*. These should not be used without an indication!*
- Drug should be continued for 14-21 days or until normalization of the granulocyte count.

Patients with a high likelihood of exposure to > 2 Gy based on medical history, location or blood counts, should be given cytokines within 24 hours of exposure to ionizing radiation. Continue medications for 14-21 days or until normalization of granulocyte count under expert supervision.

CAUTION: Cytokine use should be based on clinical information and not given indiscriminately to everyone with potential radiation exposure.

- This is particularly true in the context of limited supplies, when inappropriate administration may result in a casualty who could have benefited from cytokines having to go without.
- It is important to note that most of the available consensus focuses on healthy adult population. There is a paucity of data and consensus for treatments in children, the elderly, and immunocompromised individuals.

Supportive care measures are equally important. These relatively simple measures (although perhaps not so simple in mass casualty events) have been shown to improve survival in animal models of ARS:

- Antiemetics for the gastrointestinal symptom relief from nausea and vomiting (Figure 5 and REMM[8]);
- Hydration to support intravenous fluid balance due to rapid shifts of volume; and
- Antibiotics to prevent bacterial infections especially during the neutropenic period.

Figure 5. Guidance for Symptomatic Treatment and Support for Gastrointestinal Toxicities
Below is an example of ARS management. Details are on REMM
http://www.remm.nlm.gov/ars.htm

GASTROINTESTINAL SUBSYNDROME H C G 2 N = RC 2 Clear

Sign/Symptom/Test	Degree 1	Degree 2	Degree 3	Degree 4
Diarrhea - frequency	☐ 2-3 stools/d	☑ 4-6 stools/d	☐ 7-9 stools/d	☐ ≥ 10 stools/d
Diarrhea - consistency	☐ Bulky	☑ Loose	☐ Loose	☐ Watery
Diarrhea - bleeding	☐ Occult	☑ Intermittent	☐ Persistent	☐ Persistent with large amount
Abdominal cramps / pain	☐ Minimal	☑ Moderate	☐ Intense	☐ Excruciating
Vomiting	See Neurovascular System			
Nausea	See Neurovascular System			

Suggested Treatment

Checkboxes below are read-only

- ☑ Anti-diarrheal meds, e.g. Loperamide, appropriate to severity
- ☑ Measure intake/output, sequential body weights
- ☑ IV fluid and electrolyte replacement as needed
- ☑ Antibacterial agents for culture positive
- ☑ Antifungal agents for culture positive
- ☑ Antiviral agents for culture positive
- ☑ Seek etiology, ± consider surgical consultation
- ☑ Standard precautions , if needed

Radiation Injury Treatment Network (RITN)

After a mass casualty radiation incident, the ability to perform triage and provide care will depend on both the residual local infrastructure and the mobilization of resources from across the nation or even internationally. Ideally, triage centers would be organized around concentric rings, providing initial stabilization prior to transport to unaffected medical centers. Many organizations have recognized that a networked response by medical professionals can increase surge capacity and improve the quality of care.

RITN, a collaboration of 59 medical centers and hospitals with expertise in the management of myelosuppression, blood donor centers, and umbilical cord banks (Table 1, Figure 6), was established through a collaboration between the American Society for Blood and Marrow

Transplantation (ASBMT) and the National Marrow Donor Program (NMDP), with support from the U.S. Office of Naval Research. RITN has established standard operating procedures and treatment guidelines that can be used by medical professionals that are outside the RITN network, but are participating in the incident response. These guidelines have been developed based both on the medical expertise of RITN leadership and the abundant literature available in this field.[13-22]

RITN link http://www.ritn.net/

Table 1. Specific RITN Centers

Radiation Injury Treatment Network

Transplant Centers			
AL - University of Alabama at Birmingham	P/A	NDMS	HPP
AZ - University Medical Center	P/A	NDMS	HPP
CA - UCSF Medical Center	P/A		
CA - City of Hope National Medical Center	P/A	NDMS	HPP
CA - Stanford Hospital and Clinics	P/A	NDMS	HPP
CO - Presbyterian/St. Lukes Medical Center		NDMS	HPP
FL - H. Lee Moffitt Cancer Center	P/A	NDMS	
FL - Shands Hospital at the University of Florida	P/A		HPP
FL - University of Miami		NDMS	HPP
GA - Northside Hospital			HPP
IA - University of Iowa Hospitals and Clinics	P/A	NDMS	HPP
IL - Rush University Medical Center			
IN - St. Francis Hospital and Health Centers		NDMS	HPP
KS - University of Kansas Medical Center		NDMS	HPP
MA - Dana Farber/Partners Cancer Care	P/A		HPP
MA - Massachusetts General Hospital		NDMS	HPP
MI - Barbara AnnKarmanos Cancer Center			
MN - Mayo Clinic Rochester	P/A	NDMS	HPP
MN - University of Minnesota BMT Program	P/A	NDMS	
MO - Barnes-Jewish Hospital at Washington			HPP
MO - The Children's Mercy Hospital	Ped	NDMS	
MS - University of Mississippi Medical Center	P/A	NDMS	HPP
NC - UNC Hospitals	P/A	NDMS	HPP
NC - Wake Forest Univ Baptist Medical Center			HPP
NC - Duke University Medical Center	P/A	NDMS	HPP
NH - Dartmouth-Hitchcock Medical Center			
NY - Strong Memorial Hospital	P/A	NDMS	
NY - Memorial Sloan-Kettering Cancer Center	P/A		HPP
NY - Mount Sinai Hospital	P/A	NDMS	HPP
NY - Westchester Medical Center		NDMS	HPP
OH - Cincinnati Children's Hospital Medical Center	Ped		
OH - Cleveland Clinic Foundation		NDMS	HPP
OH - University Hospitals of Case Medical Center		NDMS	HPP
OK - Oklahoma Univ. Medical Center & Childrens Hospital	P/A	NDMS	
OR - Oregon Health & Science University	P/A	NDMS	HPP

Transplant Centers			
PA - Children's Hospital of Philadelphia	Ped	NDMS	HPP
PA - Temple University		NDMS	HPP
PA - University of Pennsylvania Medical Center		NDMS	HPP
PA - Western Pennsylvania Cancer Institute		NDMS	
RI - Roger Williams Medical Center		NDMS	HPP
SC - Medical University of South Carolina		NDMS	HPP
SD - Avera McKennan Transplant Institute			HPP
TN - Vanderbilt University Medical Center		NDMS	HPP
TX - M.D. Anderson Cancer Center	P/A		HPP
TX - Texas Children's Hospital	Ped	NDMS	HPP
UT - LDS Hospital		NDMS	
UT - Primary Children's Medical Center	Ped	NDMS	HPP
UT - University of Utah	P/A	NDMS	HPP
WA - Seattle Cancer Care Alliance	P/A		
WV - West Virginia University Hospitals		NDMS	HPP
WI - Children's Hosp of WI & Midwest Children's CC	Ped	NDMS	HPP
WI - Froedtert Memorial Lutheran Hospital		NDMS	

Donor Centers
CA - City of Hope National Medical Center
CO - Colorado Marrow Donor Program
MD - C.W. Bill Young Marrow Donor Center
MI - NMDP operated donor center
TN - Blood Assurance
WA - Puget Sound Blood Center

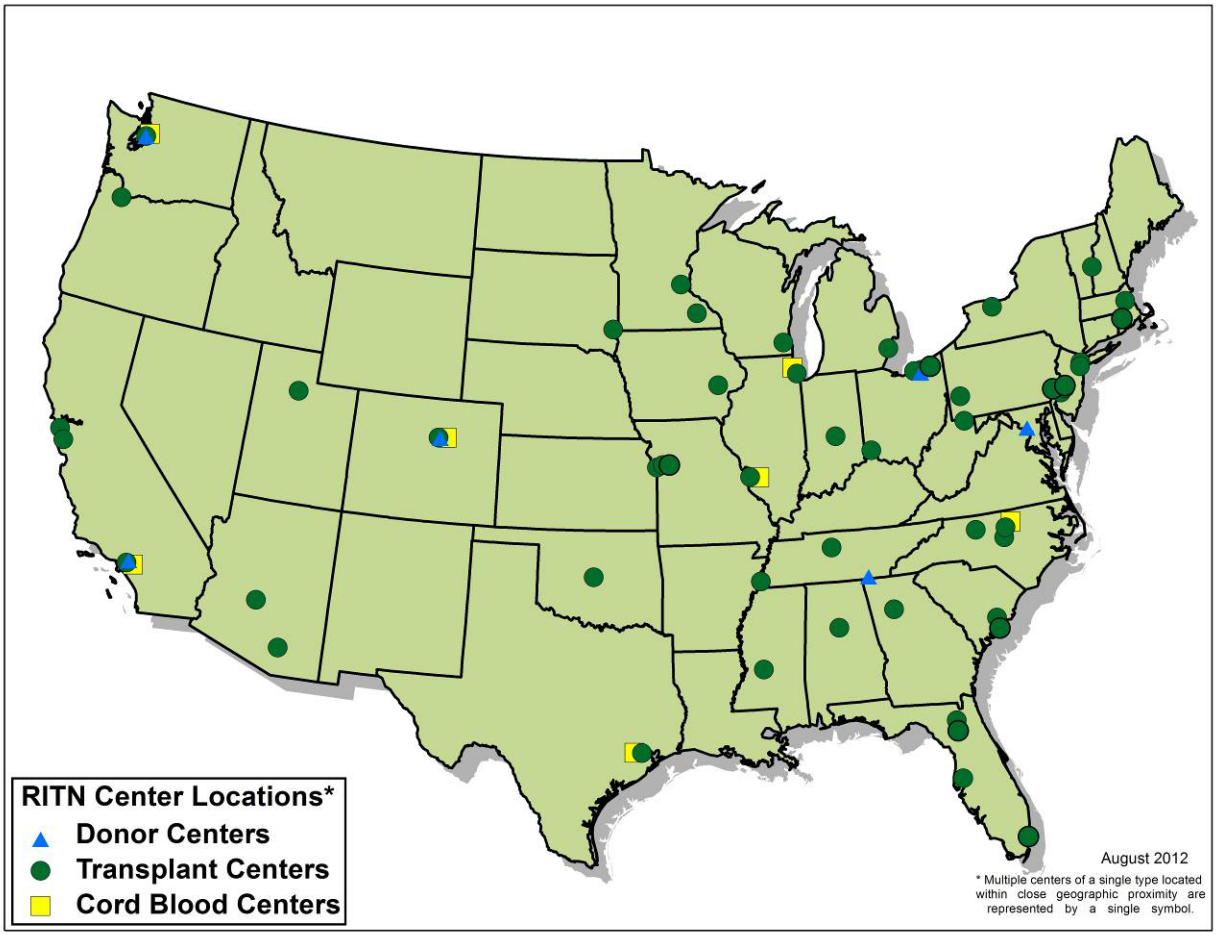
Cord Blood Banks
CA - StemCyte International Cord Blood Center
CO - University of Colorado
IL - ITxM Cord Blood Services
MO - St. Louis Cord Blood Bank
NC - Carolinas Cord Blood Bank
TX - MD Anderson
WA - Puget Sound Blood Center

TC	52
DC	6
CBB	7
Total	65
Total NDMS Centers	38
% TCs that are NDMS	73%
Total HPP Centers	38
% TCs that are HPP	73%

Ped = Pediatric patient only facility
P/A = Pediatric and adult capable facility
NDMS = National Disaster Medical System Center
HPP = Hospital Preparedness Program
If no capability is annotaed the facility is adult only

As of 31 AUG 2012

Figure 6. National Map of the Radiation Injury Treatment Network (RITN)
Arrows refer to a possible incident and how victims could flow from one city to the network.



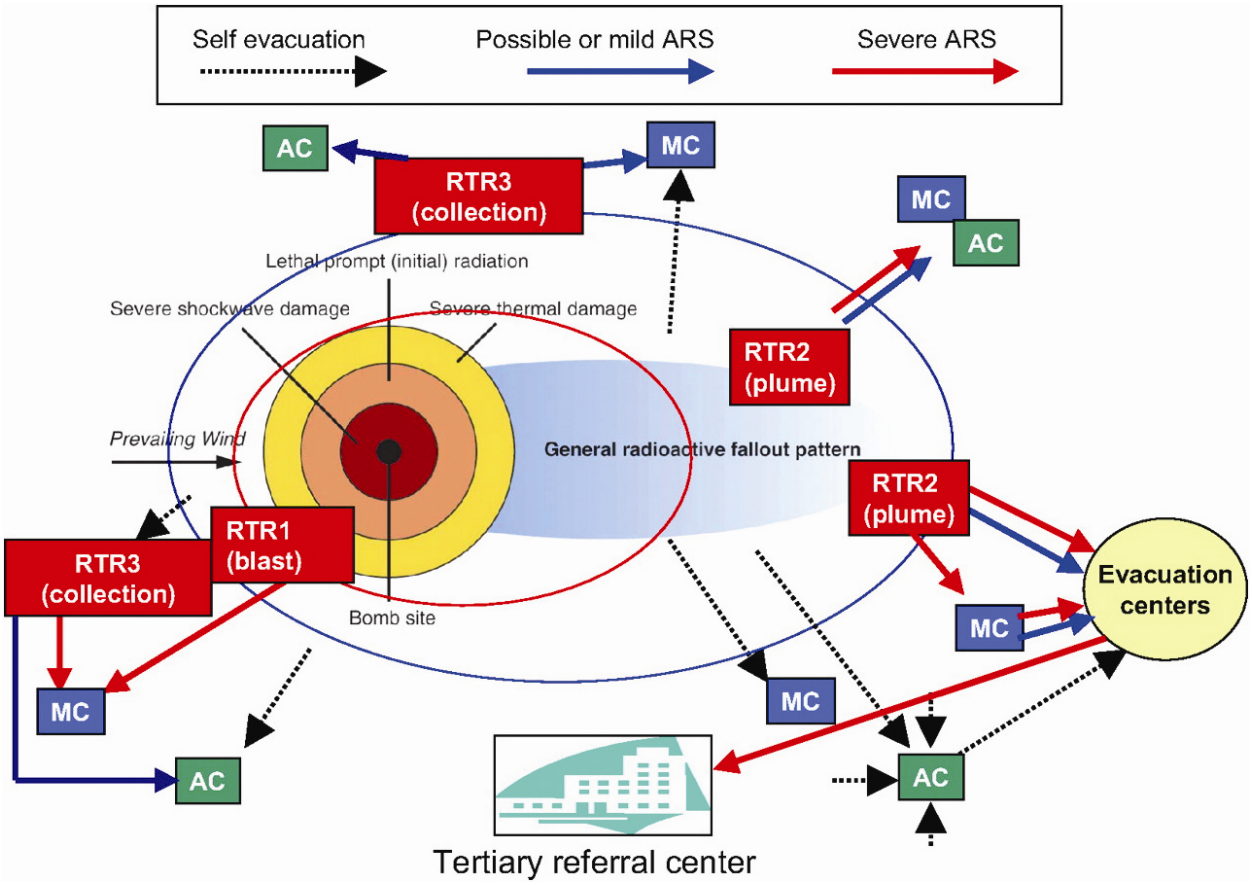
RITN has two primary goals:

1) Provide facilities and staff for intensive supportive care in the aftermath of a marrow toxic incident; and
2) Educate hematologists, oncologists, stem cell transplant practitioners, nursing and support staff about their potential involvement in the response to such an incident.

RITN centers *are not first responders, nor are they decontamination facilities*. Initial decontamination and the treatment of life threatening injuries would have to be completed prior to RITN involvement (Figure 7). Transport of casualties from the incident site would be organized through the National Disaster Medical System (NDMS).[23] RITN centers have existing infrastructure and expertise for managing casualties with bone marrow toxicity. Most of these casualties would require supportive care, either as in-patient or out-patient, and would not undergo hematopoietic cell transplantation. A small fraction of casualties may sustain irreversible bone marrow injury, and therefore require an unrelated marrow or cord blood match from the Be the Match Registry® operated by the NMDP. As of December 2010, the Be

the Match Registry® contained over 9 million potential hematopoetic cell donors and more than 185,000 cord blood units, the largest source of hematopoeitic cell donors in the world. The registry is a national resource—a "genetic safety net" in a time of a radiological/chemical crisis.

Figure 7. Schematic for Triage and Response to a Large-Scale Radiation Event Developed By the Office of the Assistant Secretary for Preparedness and Response

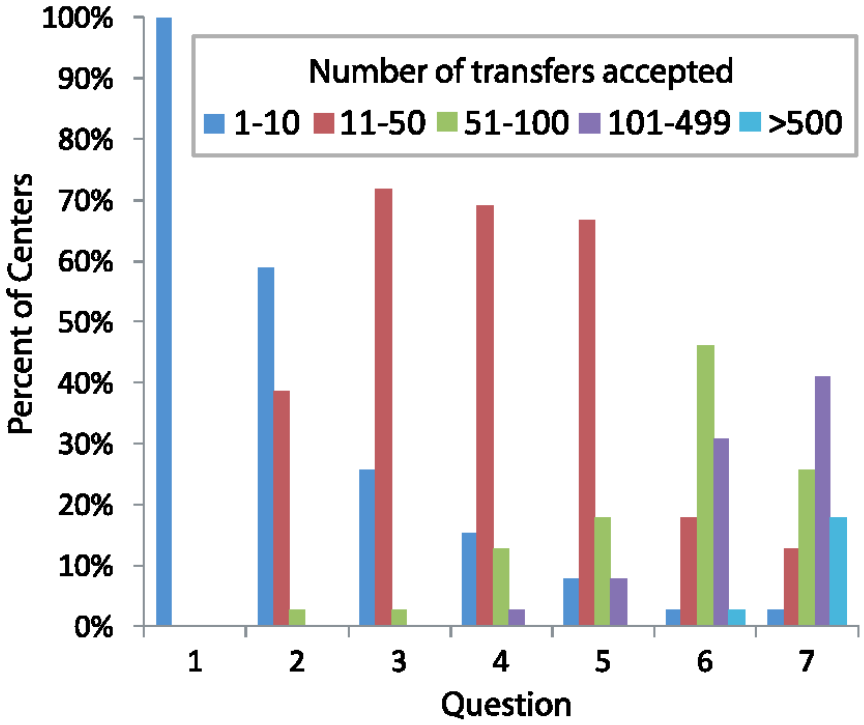


Triage centers are located in concentric rings around the affected area, providing initial stabilization and decontamination (RTR1 - RTR3), more extensive Medical Care (MC), and rapid screening of unexposed or minimally exposed individuals at Assembly Centers (AC). Patients who require further care are evacuated to referral centers in unaffected regions.[24]

Maximizing Surge Capacity

In April 2011, RITN performed a survey to determine the willingness of RITN centers to voluntarily accept irradiated casualties across a range of hypothetical circumstances. The number of casualties accepted by centers increased markedly with the 1) utilization of partner hospitals to offload existing patients and/or irradiated casualties, or 2) clearly-defined austerity measures. These austerity measures included the treatment and housing of casualties in non-traditional sites (Figure 8).

Figure 8. RITN Survey of the Medical Centers and Their Ability to Increase The Numbers Of Victims That Could Be Accommodated Based On Different Scenarios



1. How many patients could you receive in your existing BMT unit with no changes?
2. Above with modest changes (e.g. early discharges)?
3. Above with aggressive changes (e.g. aggressive discharges, delayed admissions)?
4. Above with spill over into other areas of your hospital?
5. Above with some alterations in standards of care?
6. Above and utilizing additional hospitals in your community?
7. Above and austere emergency treatment facilities (e.g. dormitories) with major alterations in standards of care?

Local/regional planning is the primary responsibility of state and local governments. No clear guidelines have been established by the federal government for establishing alternate care sites at distant locations from a mass casualty incident. Utilizing such sites and thereby modifying the normal standards of care raise a host of legal, financial, and ethical issues for medical centers asked to accept casualties.[9, 25-34] Not surprisingly, self-imposed changes in standards of care had very little effect on capacity (Figure 8). This suggests that specific guidelines for alterations in standards will be necessary to effectively expand capacity.

Concerns and Future Plans

A catastrophic incident, such as an IND detonation, would overwhelm the capacity of the health care system, even at a national level. The need for international cooperation in the face of such an incident is clear. While there are clearly defined processes for some aspects of response (e.g., emergency use authorization for drugs in the national stockpile), work is ongoing in the following critical areas:

- Details of how payment will be worked out and the willingness of hospitals to receive patients, even with existing Centers for Medicare & Medicaid Services codes for reimbursement.
- Legal protection, which is largely a local issue and varies by state.[34]
- Clearly established guidelines for alternate standards of care for medical centers that may be asked to receive injured casualties.[9, 10, 25, 35]
- New approaches to rapid dosimetry in a mass casualty setting to complement hematology and cytogenetics.
- Novel medical countermeasures to reduce morbidity and mortality to complement medical management as described above. The concept of "dual-utility" is emphasized using drugs/agents that have routine clinical use so that resources are available as is experience with the agent.
- Further expansion of the RITN network, as well as, integration with NDMS and local government efforts, which will be essential to optimize the efficient triage, transport and management of irradiated casualties after a mass casualty incident.

Authors

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Nuclear Fallout Protection in a Nutshell – What to Do, What Not to Do, and Why

Overview:
Nuclear fallout will occur significantly from a ground-burst and minimally from an air-burst. The most acutely hazardous fallout particles are generally visible as fine sand-sized grains and are deposited within about 20 miles. There are two principal protective action recommendations that may be implemented to protect the public from fallout—taking shelter and evacuation. The best initial action immediately following a nuclear explosion is to take shelter in the nearest and most protective building or structure and listen for instructions from authorities. You should have at least 10 minutes before fallout arrives. Go below grade if that option is available or to the center of the shelter structure and shelter for 12-24 hours.

Evacuation has been recommended as an action after having sheltered in place for at least 12 hours, but can be done prior to the detonation if advanced warning of the incident is available. Overall, people should immediately take shelter in a safe location and listen for further instruction by authorities.

Introduction
Ours is not a nation uninitiated into the fears and concerns of nuclear attack. Those of us who grew up during the Cold War remember the angst associated with Soviet nuclear-tipped intercontinental ballistic missiles (called ICBMs), "duck-and-cover" school drills, and fallout shelters. The predictions were dire: whole cities would be wiped from the face of the Earth; millions would be annihilated; and a "nuclear winter" would follow, as predicted by astronomer Carl Sagan.

The Cold War domestic civil defense approach consisted of preparedness measures through public education, and readiness with heavy emphasis on both public and private build-it-yourself fallout shelters and stockpiling. Fallout shelters made sense because a) the threat was serious and perceived as imminent, and b) satellite and radar warning systems would generally provide sufficient notice to hasten into a pre-constructed private or pre-designated public shelter. Post-attack emergency response was not a serious idea.

Fortunately, the Cold War specter of strategic thermonuclear war and "mutually assured destruction," with the possibility of hundreds of nuclear strikes on major cities and the majority of the United States covered with fallout is greatly diminished. However, the possibility of nuclear attack still exists through terrorist use of a low yield nuclear device.

This paper addresses one of the more significant causes of morbidity and mortality following the detonation of a small nuclear device (approximately 10 kilotons) in an urban area—highly radioactive fallout—and the effectiveness and implementation of protective strategies, such as sheltering in place.

Fallout Basics

Radiation from a nuclear explosion falls into 2 categories: 1) initial nuclear radiation (prompt radiation and neutron activation), which originates from the explosive event and the early fireball, and 2) residual radiation which is largely associated with fallout. Both prompt and fallout radiation can cause health effects and the severity increases as the dose increases (as discussed in the paper on Acute Radiation Syndrome in this manual). . The exposure pathway of greatest concern up to several days after the incident is external irradiation from fallout(and not ingested or inhaled radiation) In the first hour, fallout dose rates in the hundreds of R/hour should be expected, and may be 1000 R/hour (10 Gy/h) or higher in localized areas.

UNITS: R/hr is technically Roentgen's per hour but is often used interchangeably with rad/hour or rem/hour [rem is used for radiation protection as it accounts for the type of radiation, eg., neutrons, x-rays or particle}. Gy, or Gray is the preferred international unit [and Sievert is the unit for radiation protection]. **Therefore, 100 rad = 1 Gy, and 100 rem = 1 Sv.**

Fallout is generated when the dust and debris excavated by the explosion is combined with radioactive fission products produced in the nuclear explosion and drawn upward by the heat of the event. This cloud rapidly climbs through the atmosphere, potentially up to 5 miles or higher, forming a "mushroom cloud" from which highly radioactive particles coalesce and drop back down to earth as they cool. It is important to note that Hiroshima and Nagasaki did not have significant fallout because their detonations occurred at altitude (air-burst) and the fission products did not have the opportunity to mix with excavated earth, as in a ground-burst. The majority of the radioactivity in fallout comes from fission products, or the radionuclides produced as a result of uranium or plutonium nuclei splitting apart in the nuclear fission reaction.

The hazard from fallout comes from being exposed to the ionizing radiation the particles give off after they have settled on the ground and roofs, *not from breathing the particles*. Radiation levels from these particles will drop off quickly, with *most (~55%) of the potential exposure occurring within the first hour and 80% occurring within the first day*. Although it is highly dependent on weather conditions, the most dangerous concentrations of fallout particles (i.e., potentially fatal to those outside) occur within 10 to 20 miles downwind of the event and are clearly visible as they fall, often the size of sand, table salt,[1] or ash.[2]

This rule states that for every sevenfold increase in time after detonation, there is a tenfold decrease in the radiation rate, as shown in Table 1.[3] **After about 24 hours (and in most cases 12 hours), even the highest early dose rates have diminished to the point where exposures may be incurred without suffering acute radiation effects.**

Table 1. Example dose rate decay from early fallout as a function of time after a nuclear explosion (adapted from Glasstone[3])

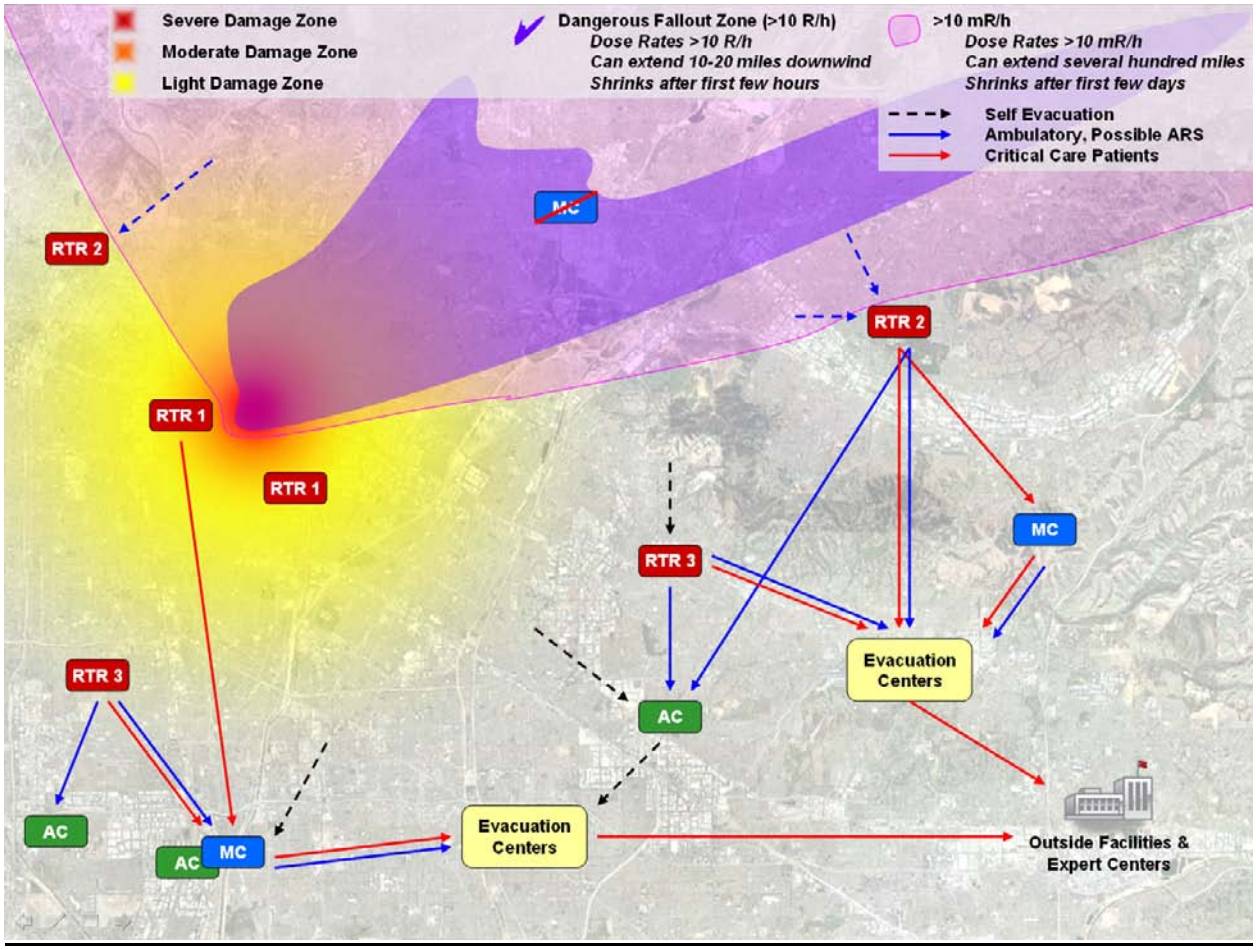
Time (hours)	Dose Rate (R/h)	Time (hours)	Dose Rate (R/h)
1	1,000	36	15
1.5	610	48 (2 days)	10
2	400	72 (3 days)	6.2
3	230	100 (~ 4days)	4.0
5	130	200 (~ 8 days)	1.7
6	100	400 (~ 17 days)	0.69
10	63	600 (~ 25 days)	0.40
15	40	800 (~ 33 days)	0.31
24	23	1,000 (~ 42 days)	0.24

While fallout particle sizes range from centimeters to submicron, most of these smaller particles will remain in the upper atmosphere for days or weeks.

- The most acutely hazardous fallout particles are generally visible as fine sand-sized grains and are deposited within about 20 miles.
- The lack of apparent fallout should not suggest the lack of hazardous radiation.[4]
- Predicting where lethal fallout will deposit cannot be done reliably in the short time after a detonation although there will be a good estimate of what is called the dangerous fallout zone (Figure 1).
- Therefore, protective guidance should apply widely, regardless of meteorological observations or early plume model results.
- Fallout deposition on areas where survivors are likely to be found (outside the more severely damaged areas) may be expected to begin in about 10 minutes.[5]

As shown in Figure 1, there are 3 damage zones: Severe, where there will be mostly fatalities, Moderate, where there will be many survivors, and Light, where most injuries will be from glass or accidents. The Dangerous Fallout Zone has a potentially high enough dose to cause the acute radiation syndrome (discussed by Chao) and there is a larger fallout zone for which care will be needed regarding food, water and evacuation. The various spontaneously-forming emergency response sites (RTRs) indicate the type of injuries, and the various predetermined medical response sites and evacuation centers are also indicated.

Figure1. Physical Damage and RTR Zones.



Protective Action Guides and Protective Action Recommendations

A protective action guide (PAG) is "the projected dose…from an unplanned release of radioactive material at which a specific protective action to reduce or avoid that dose is recommended".[6] The PAGs can be found on REMM: *www.remm.nlm.gov/pag.pdf.*

A protective action recommendation (PAR) is a *recommended action* to reduce or avoid that dose.

- At low dose rates (1-5 rem), a decision should be made whether the cost and risk of the protective action is warranted by the projected collective dose to the affected population. This makes sense far downwind, but not closer in.
- At high doses (> 100 rem) protective actions are always warranted. The difficulty lies in identifying the protective action that results in the lowest overall risk to the population under the circumstances.

Shelter and Evacuation

There are two principal PARs that may be implemented to protect the public from fallout: *taking shelter* and *evacuation*.[4] Either can be executed on an individual basis (by self-

evacuation) or facilitated in an organized fashion at any time before or after the incident. The timing and execution of protective actions are critical to their effectiveness. In nuclear terrorism scenarios, no advance notice is presumed that would afford time to either shelter properly or evacuate from the target (e.g., city center).

Immediate evacuation has serious drawbacks as a protective action in the early hours after detonation:

- The high initial dose rates from fallout mean that early evacuation can cause the highest exposures;
- It will be difficult to predict which areas will be impacted by fallout and attempted evacuations could move people into or through areas of higher contamination;
- Cars offer little protection from fallout and those evacuating on foot would have no protection; and
- All evacuations take time. Moving any number of people even a few miles, especially with damaged infrastructure, obstructed roadways, and jammed highways, will take many hours.

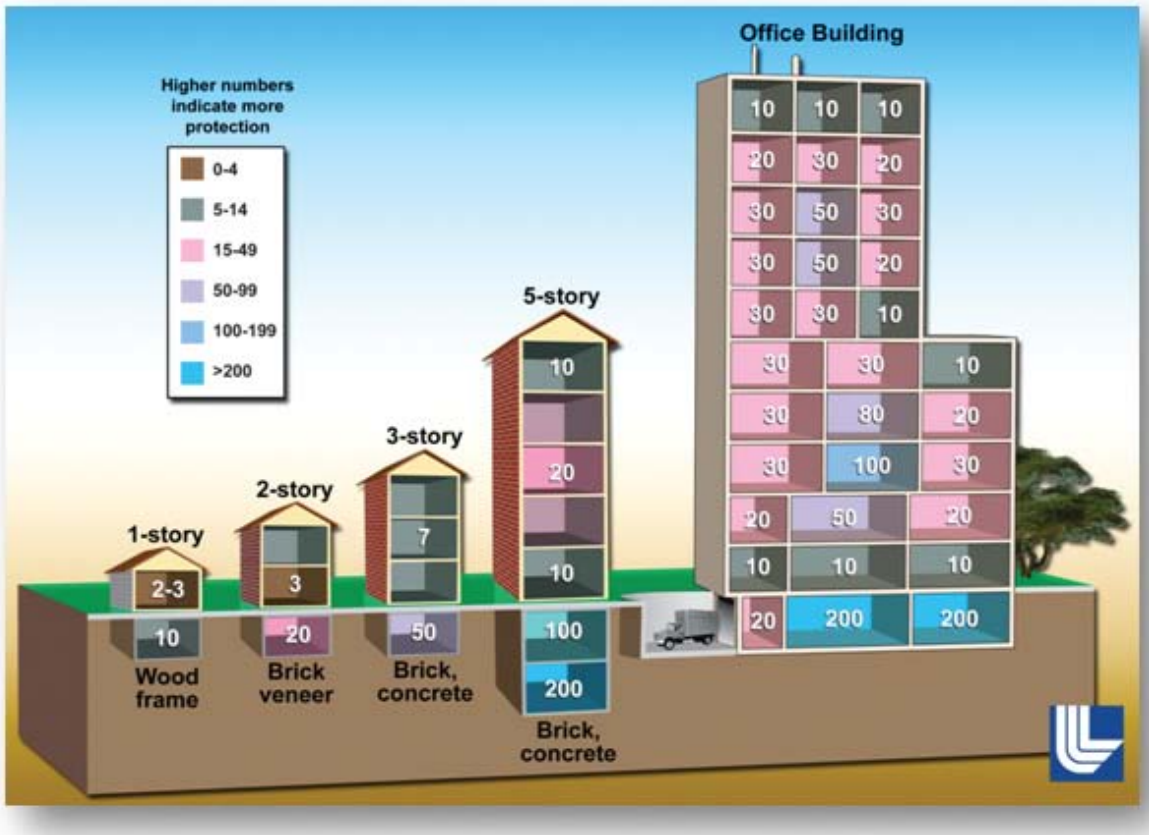
Sheltering can be done easily, especially when people are already in some form of structure at the time of the incident.

- If an individual is caught outside, they should seek adequate shelter immediately. It is important to be sheltered when the fallout arrives.
- Radiation is best attenuated by dense material (earth, concrete, stone), and dose is reduced by increasing distance from the source and reducing the time spent exposed.

Although any shelter will provide some protection and reduction of dose, some shelter locations can provide superior protection and should be sought out to prevent adverse effects within the dangerous fallout zone. Generally, below grade (e.g., a basement or underground garage) is better than above grade, large buildings are better than small, and heavy concrete or masonry walls are better than wood. Shelters such as houses with basements, large multi-story structures, and underground parking garages, or tunnels, can generally reduce doses from fallout by a factor of 10 or more (see Figure 2). These structures would generally provide "adequate" shelter. Single-story wood frame houses without basements and vehicles provide only minimal protection and are not considered adequate shelter. The worst situation is being caught outdoors when fallout arrives or choosing to go outdoors in the early hours when fallout is most radioactive.

Shelters such as houses with basements, large multi-story structures, and underground parking garages or tunnels, can generally reduce doses from fallout by a factor of 10 or more. These structures would generally provide *adequate* shelter.

Figure 2. Fallout Protection Factors for Various Structures.
Image courtesy of: Lawrence Livermore National Laboratory
The larger the PF number the greater the protection. For example 10 means 1/10th the exposure compared to no protection and 100 means 1/100 (1%).



Conclusion

<u>What to Do</u>: Because the fallout radiation hazard is so high early after the detonation and within about 20 miles of ground zero, and because the deposition of fallout is unpredictable, taking immediate shelter in an adequate shelter is the unequivocal recommendation of the federal government.[4]

Seek early adequate shelter for 12-24 hours, followed by informed evacuation

- It is important to be in the shelter when the fallout arrives.
- Fallout arrival times vary with weather, but if you are outside of the building collapse area, you should have at least *10 minutes* before fallout arrives.
- Adequate shelters are locations that place as much earth, building materials, or distance between the occupants and horizontal surfaces that will accumulate fallout (including roofs). Examples of adequate shelters include basements, usually against a basement wall; multi-story brick or concrete structures (towards the center of the structure);

office buildings (central core or underground sections); multistory shopping malls (away from roof or periphery); and tunnels, subways, and other underground areas.

- If you are outdoors or in a car, seek the nearest adequate shelter.
- Note: Even an inadequate shelter will provide some protection.

The best initial action immediately following a nuclear explosion is to take shelter in the nearest and most protective building or structure and listen for instructions from authorities. You should have at least 10 minutes before fallout arrives. Go below grade, if that option is available, or to the center of the shelter structure. Shelter for 12-24 hours.

What to Avoid: The worst thing a survivor can do is to get caught outdoors when fallout arrives, or choose to go outdoors when fallout is fresh. You cannot predict where fallout will deposit, or how radioactive it will be.

Avoid all hazards, not only fallout. Relocate if your shelter is threatened by fire, building collapse, or other immediate threats. Immediate medical needs of life threatening injury would also take precedent over fallout protection.

Avoid Immediate and/or uniformed evacuation

- Survivors should plan on sheltering for at least 12 hours.
- Unless threatened by other hazards or medical necessity, survivors should not leave adequate shelter on their own; wait for officials to facilitate evacuation.

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Preparing the Home for Sheltering In Place Following a Nuclear Detonation

Overview:
Every American family should prepare their home for the possibility of disaster.[1] This is especially important for a nuclear detonation, since you may be advised to "shelter in place" in order to reduce your exposure to radiation.[2] Individual and family preparedness can aid the response to a radiological incident by decreasing the likelihood of injury, reducing the sense of panic and the pressure on the overall response so responders can focus the injured. The following steps (compiled largely from www.ready.gov/america/index.html and emergency.cdc.gov/radiation/shelter.asp) can help you prepare your home for any disaster, including a nuclear detonation:

1. Psychological preparation
2. How to choose a safe room
3. Recommended emergency supplies
4. How to maintain your safe room

Psychological preparation for a disaster means acknowledging that there is a possibility a nuclear explosion can happen and that there are protective actions one can take to reduce serious injury. One such protective action is to choose a safe room. The safest room in a house is a basement or a room with as few windows as possible.

Step 1: Become Psychologically Prepared

In this context, psychological preparation means being motivated to create a safe room and to anticipate and resolve potential obstacles to remaining in it following a nuclear detonation. To be prepared psychologically, individuals must recognize that nuclear terrorism is possible; understand key protective actions; and put plans in place to support these actions. Simply put, people need to know how to select a safe room and/or seek adequate shelter, and anticipate how to fill physical and psychological needs so that they can remain there until it is safe to leave.

People are more likely to prepare a safe room when they have credible information from multiple sources about the value of a safe room in reducing exposure to fallout and the subsequent radiation injuries. Social science research has demonstrated that individuals are more motivated to prepare for emergencies when those who have made preparations share what they have done.[3, 4] The more that people see, hear, and talk about safe rooms, the more likely they are to create them. Moreover, since safe rooms afford protection for a wide range of hazards, highlighting the aspects that are especially important for fallout protection can reinforce general all-hazard education activities.

However, being motivated to create a safe room is only one part of psychological preparedness. It is equally important to address psychological issues that could interfere with people's willingness to remain in a safe room. Following a disaster, there is a universal urge to connect with friends and loved ones to check on their welfare and make sense of what has

happened. Parents, in particular, will feel a strong emotional pull to immediately reunite with their children and bring them home.[5] In the case of fallout, rushing to pick up children may jeopardize the health of both the child and the parent. Therefore, it is important that parents have confidence that schools have identified adequate shelters and supplies to ensure their children's safety. They also need to know the school's plan and contingency plans for reuniting with their children. If these measures are in place, parents are more likely to remain in their safe room or at least wait an hour or more for radiation levels to fall. Similarly, confidence that adult loved ones will shelter is also important. In the event that people are unable to communicate by phone or email, worry may cause them to leave shelters in order to physically check on their loved ones. Knowing that a loved one is in a home that has a safe room and will stay there may help reduce anxiety and fear.

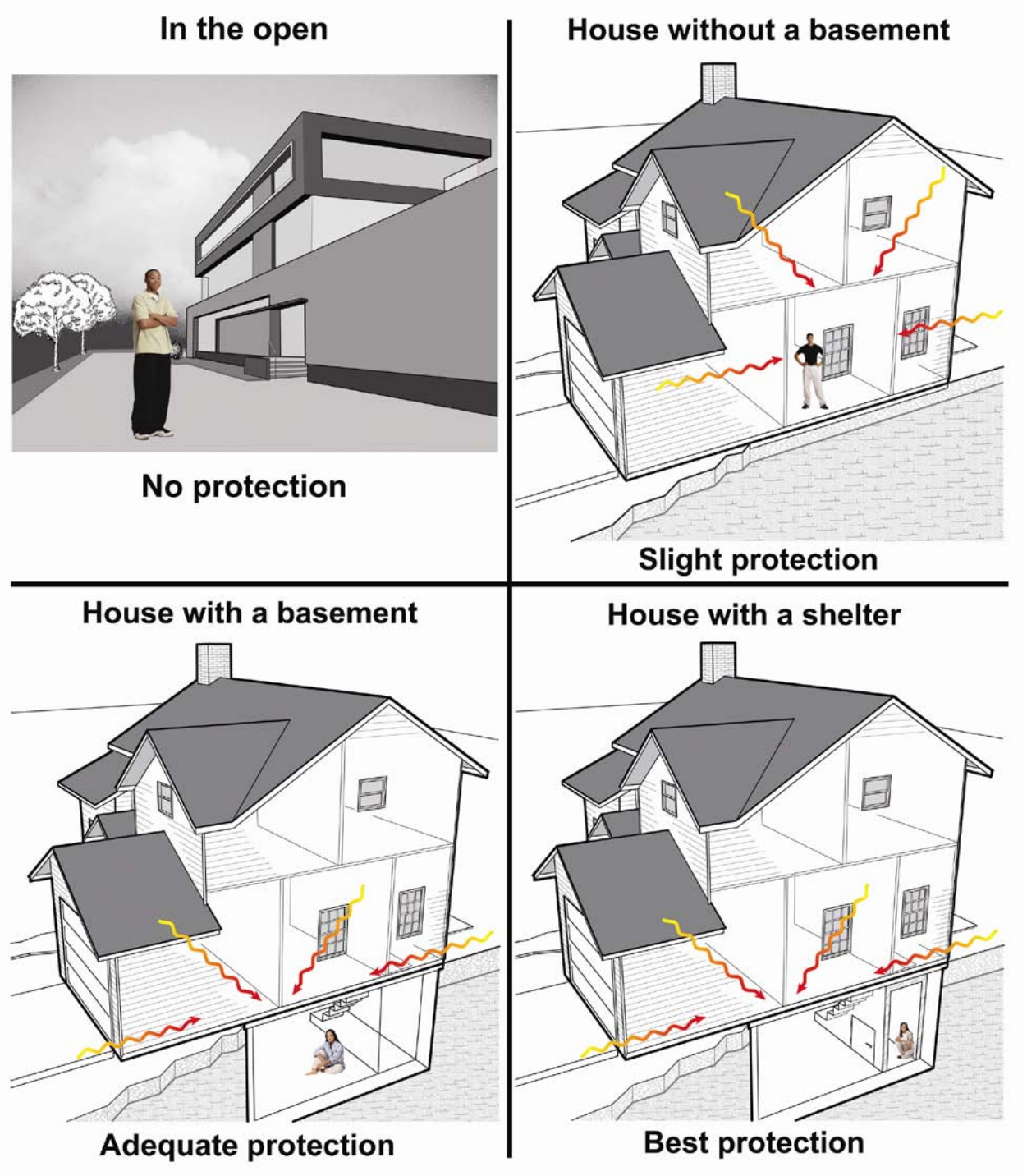
From a psychological perspective, knowing what to expect—even if it is painful—is less terrorizing than surprise. For example, knowing that cell phones may not work initially due to network congestion, a damaging electromagnetic plus, or loss of a cell tower can minimize surprise. Similarly, keeping a hand crank radio, in anticipation of electrical blackouts, can foster a sense of connectedness with the outside world and help people feel less alone.

During emergencies, people often find that they experience physical and psychological signs of distress. These can range from insomnia to excessive worry or depression. Psychological first aid or similar approaches teach people the basic skills for supporting each other during stressful times.[6-10] There are free courses available online that can be completed in as little as 60 minutes. Some basic understanding of how to keep yourself and those around you calm can foster better decision making during a radiological event and help ensure survival.

Step 2: Choose A Safe Room[1, 11, 12]

The safest place in your home following a nuclear detonation incident is a centrally located room or basement with as few windows as possible. The rooms in your home that give the highest fallout protection are the ones that put the most earth, building material, and distance between you and the fallout (the radioactive particles that may land on the roof and ground outside your home). Figure 1 illustrates this principle. Store emergency supplies in this area. If you have pets, prepare a place for them to relieve themselves in the safe room. Pets should not go outside following a nuclear detonation because they may track radioactive materials into the room.

Figure 1. The Rooms in Your Home That Give the Highest Fallout Protection Are the Ones That Put the Most Earth, Building Material (and Distance) Between You and the Fallout
Illustration courtesy of Lawrence Livermore National Laboratory (LLNL)



Step 3: Gather Supplies[1, 11]

Gather the necessary supplies for a closed-in stay of up to 3 days in your safe room. Tables 1 and 2 contain a list of some supplies to consider. (For a full list, see http://www.ready.gov/america/getakit/index.html)

Table 1. Recommended Safe Room Supplies		
Item	Amount	Comments
Communications		
Battery-operated or hand-crank radio	1	In case electrical power is out, a battery-operated radio will allow you to listen to emergency messages. You may consider keeping another radio in your car.
Extra batteries	2 sets	Make sure the batteries are not expired.
A telephone or cell phone	1	Although cell phone or ground phone service may be interrupted, there is still a chance that you will be able to use a phone to call outside for information and advice from emergency services. SMS (text) messages are more likely to get through than voice. *(Note: If electrical power is out, old model phones (landlines) may be useful since they get power from the phone lines.)*
List of critical phone numbers	1	This may include family members, workplace, colleagues, schools, doctors, pharmacies, places of worship, or other people/places that play a role in your everyday routine and health maintenance.
Emergency plans	1	If your school, civic organization, or workplace has emergency plans, it would be good to keep copies in your safe room.
Protection		
Face masks or dense-weave cotton material	Enough for everyone	Gather material that snugly covers your nose and mouth and is specifically fit for each member of the family. Do whatever you can to make the best fit possible for children.
Duct tape and heavy plastic sheeting	Enough to seal room	If a radioactive plume is passing over your home, these items may be used to seal the door to your shelter and to seal any vents that open into your shelter for a *very* short period of time. *(Note: This may not be necessary, and is certainly not recommended for more than a few hours.)*
Food and Water		
Water	3 gals per person	Each person in the household will need about 1 gallon of water per day; plan on storing enough water, per person, for at least 3 days. Include additional water for pets.
Food with a long shelf life	Enough for 3 days	Examples of this include canned, dried, and packaged food products. Choose foods your family will eat and don't forget comfort foods.
Pet food	Enough for 3 days	If you have pets, keep a 3-day supply of pet food.
Baby formula	Enough for 3	If you have an infant, store enough extra formula for at least 3 days.

Table 1. Recommended Safe Room Supplies		
Item	Amount	Comments
	days	
Paper plates, paper towels, and plastic utensils	Enough for 3 days	Store disposable dishware and utensils because you will not have enough water to wash dishes and because community water sources may be contaminated.
Manual can opener	1	
Medical and personal supplies		
Prescription or other medication	Enough for 3 days	Have 3 days' worth of your current prescription (or non-prescription) medicines in a childproof bottle; label with the name and expiration date of the medicine. *Discuss with your doctor the best way to obtain this small amount of extra medicine*.
First aid kit	1	You can purchase a first-aid kit or prepare one yourself. (*See Table 2 for list of recommended first aid supplies.)*
Extra eyeglasses	1	
Contact lenses and cleaning supplies	Enough for 3 days	
Toiletries	Enough for 3 days	Keep a supply of soap, hand sanitizer, toilet paper, deodorant, disinfectants, feminine supplies, and other personal hygiene items.
Clothing and bedding		
A change of clothes and shoes	1 change	Remember to include underwear, socks, sturdy shoes or work boots, and winter or summer clothes as needed.
Bedding	1 set per person	Store sheets, blankets, towels, and cots for use during the time that you cannot leave your safe room.
Waste management		
Plastic bags	Enough for 3 days	Because you may not be able to leave your safe room for several days, you will need to collect your waste in plastic bags until it can be removed.
Newspapers, litter, or other material for pets to relieve themselves	Enough for 3 days	Pets should not go outside following a nuclear detonation because they may track radioactive materials into the room.
Other		
Flashlight	1	Electrical power may be out for several days.
Batteries	2 sets	
Games, books, and other entertainment	Enough for 3 days	Because you may be in your safe room for several days, keep items on hand to occupy your family during that time. Children are likely to get bored if they have to stay in one place for long periods. Think of activities that they will enjoy doing while in the shelter—finger painting, coloring, playing games, etc.

Table 2. First Aid Kit Minimum Recommended Supplies	
Item	**Amount**
Sterile adhesive bandages	1 pkg
Sterile gauze pads in 2 inch and 4 inch sizes	1 pkg
Adhesive tape	1 roll
Sterile rolled bandages	1 pkg
Scissors	1
Tweezers	1
Needle	1
Thermometer	1
Eye wash solution	1 bottle
Moist towelettes	1 pkg
Antiseptic ointment	1 tube
Tube of petroleum jelly or other lubricant	1 jar
Soap or hand sanitizer	1 bottle or pkg
Sterile latex or vinyl gloves	2 pairs
Safety pins	1 pkg
Aspirin or aspirin-free pain reliever	1 bottle or pkg
Anti-diarrheal medication	1 bottle or pkg
Laxatives	1 bottle or pkg
Antacids for stomach upset	1 bottle or pkg

Step 4: Maintain The Safe Room[1, 11]

Make sure that all family members know where the shelter is and what it is for. Caution them not to take any items from that area. Routinely check supplies as suggested in Table 3.

Table 3. Safe Room Maintenance	
Frequency	**Action**
Weekly	Verify that cell phones or other communication devices are fully charged
Every 6 months	Check all supplies
	Replace expired medications
	Replace expired food
	Replace expired batteries
	Replace all of the water in your safe room to keep it fresh
	Replace clothes that no longer fit or are unsuitable for seasonal weather

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Involving the Community: Operationalizing a Playbook, Engaging Regional Emergency Coordinators, and Considering Ethical Issues

Overview

Planning for the medical and public health response to the detonation of an improvised nuclear device in a U.S. city is a complex process of coordinating and integrating resources, organizations, and capabilities from the full spectrum of federal, regional, state, local, tribal, and territorial responders. As the federal lead for medical and public health preparedness and response, the Department of Health and Human Services (HHS) Office of the Assistant Secretary for Preparedness and Response (ASPR), in conjunction with its partners and stakeholders, has developed the *State and Local Planners Playbook for Medical Response to a Nuclear Detonation*[1] (the Playbook) as a web-based, interactive guide for planning. This chapter describes the genesis and use of the Playbook, how to contact and work with HHS Regional Emergency Coordinators (RECs), as well as an approach to addressing the ethical issues for communities conducting such planning.

Given the complexity of planning and preparing for an IND, this modifiable Playbook has been created for regional, state, local, tribal, and territorial planners to facilitate their efforts so localities can add details to these documents as they develop their own plans. The Action Steps of the Playbook provide users with a detailed list of actions and issues specific for that particular phase of the incident. Planners have the option of downloading an electronic copy of the text itself or using the interactive version online. The web-based version allows users to go directly to a specific phase or action issue. Lastly, the Playbook examines the ethical decisions related to triage after a nuclear explosion with a scarcity of resources. It provides models on how to categorize patients ethically when conducting triage and examines patient's needs versus condition-based issues.

Background

The predicted structural damage and the morbidity and mortality following the detonation of a 10 kiloton (kT) improvised nuclear device (IND) in a U.S. city is enormous. Careful pre-incident deliberate planning can help to more efficiently and fairly utilize already scarce resources and maximize lives saved.[2,3] Effective planning can improve coordination of various response assets and ensure vertical and horizontal integration of the response from the community level to and through the federal, regional, and state levels. HHS is the coordinating agency for the federal Public Health and Medical Emergency Support Function (ESF) #8[4] under the National Response Framework[5] and the associated Nuclear/Radiological Incident Annex.[6] As such, ASPR has the responsibility to coordinate and conduct planning for the federal health and medical response to an IND detonation.

To meet this responsibility, ASPR has created an ESF #8 playbook for the anticipated federal response to an IND detonation. The IND Playbook is part of a suite of playbooks created to address each of the 15 National Planning Scenarios.[2] ASPR is in the process of coalescing these scenario-based playbooks into an All-Hazards Playbook that will reflect general similarities in

response actions and have annexes to address the details unique to each scenario. The playbooks provide strategic guidance for ESF #8 response and inform senior leadership by describing response operations that will require complex coordination of numerous entities and assets in a time-phased manner. The playbooks' sections focus on a spectrum of anticipated planning requirements and operations including:

- Scenario
- Concept of Operations
- Action Steps/Issues
- Pre-Scripted Mission Assignment Sub-Tasks
- Essential Elements of Information

Addressed are the core emergency response functions (management, command and control, logistics, planning, and operations) and ESF #8 operational activities and capabilities to provide for life-saving emergency medical care and support, restoration of the public health and medical infrastructure, patient evacuation and return, veterinary medical assistance, fatality management assistance, and human service and at-risk population needs.[7]

Community Planning and the Playbook

The Federal Emergency Management Agency (FEMA) has produced guidance to facilitate the integration of state, local, tribal, and territorial planning with the anticipated federal response. *Comprehensive Preparedness Guide 101*[8] describes ways to align community planning with the broader response should that community become overwhelmed and require additional assistance. In order to assist state and local medical planners in their own IND response planning and ensure that those plans link and integrate with the anticipated federal response, ASPR coordinated a group of experts from across multiple disciplines to adapt the ESF #8 IND Playbook and develop a guide[9]—the ASPR *State and Local Planners Playbook for Medical Response to a Nuclear Detonation.*[1] The key principles of the medical and public health response to a nuclear detonation and other planning factors are summarized in the Background section of the Playbook and include:

- Concept of Operations using Damage Zones
- Number and Spectrum of Injuries
- Decontamination
- Response Worker Safety
- Triage
- Scarce Medical Resources and Standards of Care
- Organization of Medical Response
- Radiation TRiage, TReatment, and TRansport Response Organization System (RTR)
- Summary and Intent of Anticipated Operations
- Certain Response Considerations

Organization of the Playbook

The Playbook is intended to be scalable and customizable based on a specific jurisdiction's capabilities, requirements, and needs and will be periodically improved and updated to reflect

the most current knowledge, lessons learned, and changes in capabilities. The Action Steps section (see Figure 2) of the Playbook provides sequential guidance to coordinate the medical response to a nuclear detonation at all levels. It is written in plain language intended to better align jurisdictional planning methods and capabilities with the ESF #8 Playbook. The section provides detailed time-phased, sector-oriented approaches to response activities with linked references.

For each time phase and sector, the Playbook highlights issues and provides action items to consider. The sectors used in the playbook include:

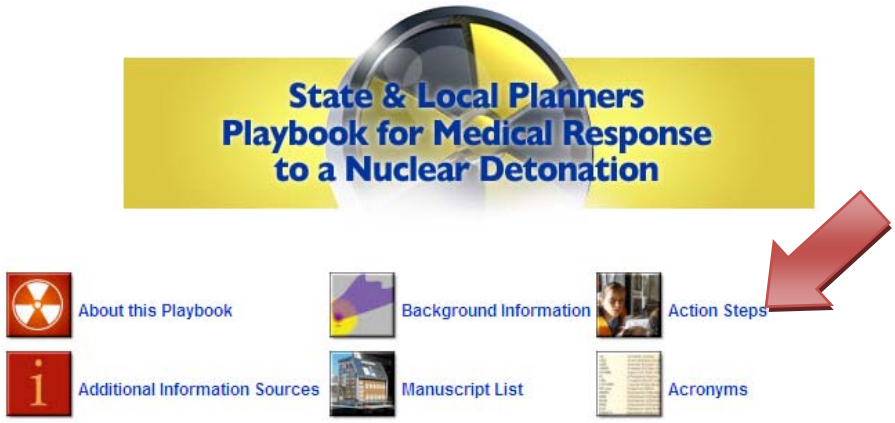
- General Readiness Planning and Emergency Management
- Emergency Medical Services (EMS)
- Health and Facility Response, Public Health
- Medical System Response
- Evacuee Medical Care and Fallout-related Illness
- Recovery

Playbook User Guide

To use the Playbook, planners have the option of downloading an electronic copy of the text itself or using the interactive version on-line. The downloadable version can be printed to provide a checklist for planners. The interactive web-version allows users to go directly to the specific response phase and sector they are interested in viewing. For instance, an Emergency Manager with limited medical or public health experience may be interested in medical and public health planning factors for coordination during Phase 2 of the response. From the home page, that person would:

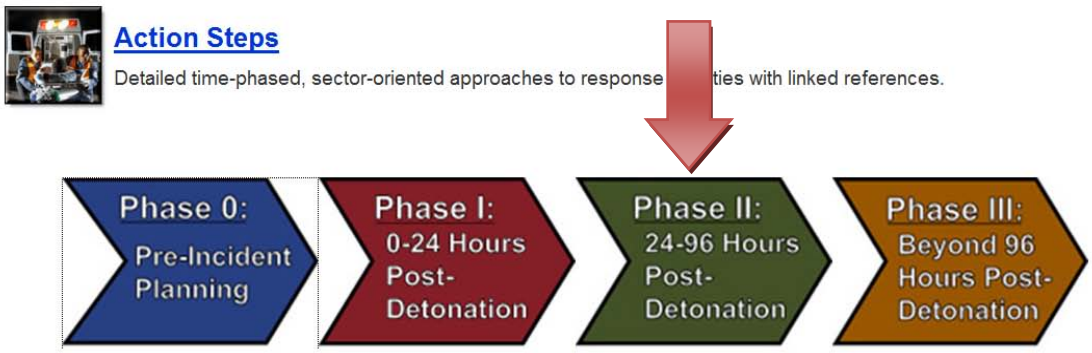
1. From the opening screen, click the "Action Steps" link (note, clicking the icon will bring you to the Action Steps Overview),

Figure 1. Playbook Opening Screen



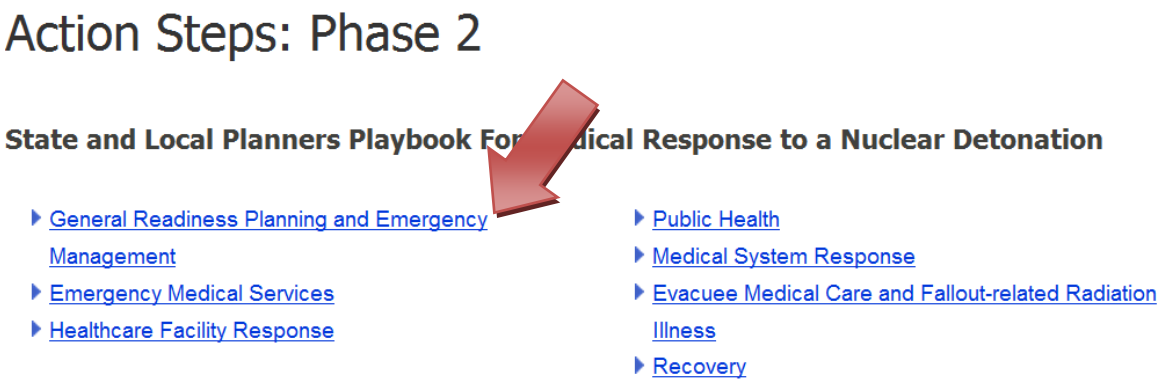
2. Click on the “Phase 2” button (Figure 2),

Figure 2. Action Steps – Time Phase



3. Click the “General Readiness Planning and Emergency Management” link (Figure 3),

Figure 3. Action Steps Phase II – Sector Selection



4. This brings the user to a detailed list of specific actions and issues (Figure 4) that includes requirements for coordination, situational awareness, communication, security, and more. Additionally, it links information sources and references to provide additional information to substantiate a given recommendation.

Figure 4. Action Steps Phase II – List of Specific Actions and Issues

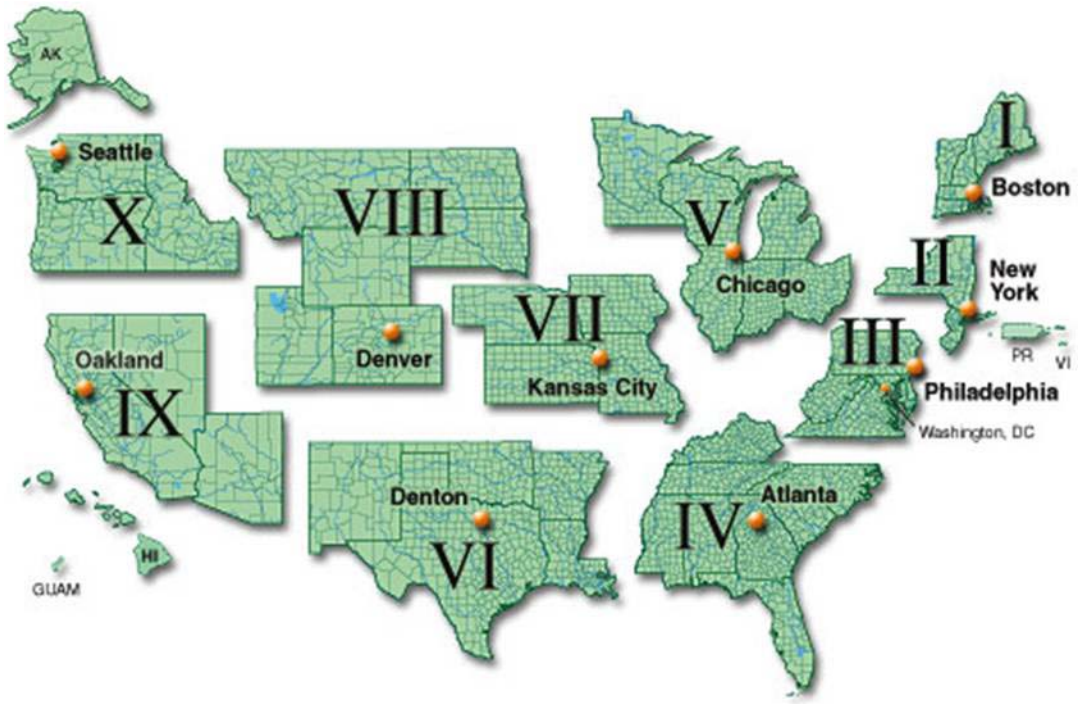
Phase II: 24-96 hours post-detonation IN ADDITION to what has been started on Day 1		
Line number	**Actions/Issues**	**Information Source**
	General Readiness Planning and Emergency Management	
II-1	Maintain situational awareness and define the damage and fallout zones in collaboration with USG and other Federal partners	IS #2
II-2	Obtain situational awareness support from DHS and HHS. On-site measurements of radioactivity and prediction of levels for every 6 hours. Provide assessment of low level radiation in the down-wind fallout zones (not likely to require radiation injury treatment).	
II-3	Utilize MedMap in coordination with HHS and DHS to assess medical assets	IS #4
II-4	Assign available law enforcement (and National Guard) to assist at transportation routes, staging areas, assembly centers and within damage zones for property protection.	
II-5	Have JPIC provide frequent communication with the public in a coordinated manner with Federal messages	

The webpage is intuitive and allows users to easily navigate the guidance and understand the similarities and differences of the phases and sectors. Planners should be able to identify existing response or other capabilities that may address a specific issue or action item. For example, existing capabilities may include plans for Points of Dispensing to distribute antimicrobials for a biological attack, which may be modified to address requirements for Community Receptions Centers (CRC); designation of locations unlikely to be damaged for alternative care sites (e.g., community health centers or similar locations); or evacuation plans that can be revisited to address the unique damage and contamination patterns anticipated for an IND detonation.

The Regional Emergency Coordinators

Regional Emergency Coordinators (RECs) are the primary point of contact for state public health departments and emergency management agencies to assure the coordination and integration of a federal response relating to ESF #8. Jurisdictional planners will find the RECs to be a crucial link for assistance or coordination regarding IND or other planning efforts. The U.S. and territories are organized into 10 regions (Figure 5).[10] RECs serve as ASPR's primary representatives in each of the ten regions plus the District of Columbia.

Figure 5. FEMA regions
(Region IX includes American Samoa, Commonwealth of the Northern Mariana Islands, Republic of the Marshall Islands and Federated States of Micronesia)



The main role of the RECs is to build relationships with federal, regional, state, local, tribal and territorial officials and health care representatives (partners and stakeholders) in order to conduct planning for effective federal emergency response for all hazards, and to facilitate coordinated preparedness and response activities for public health and medical emergencies. This is accomplished in a variety of ways to include:

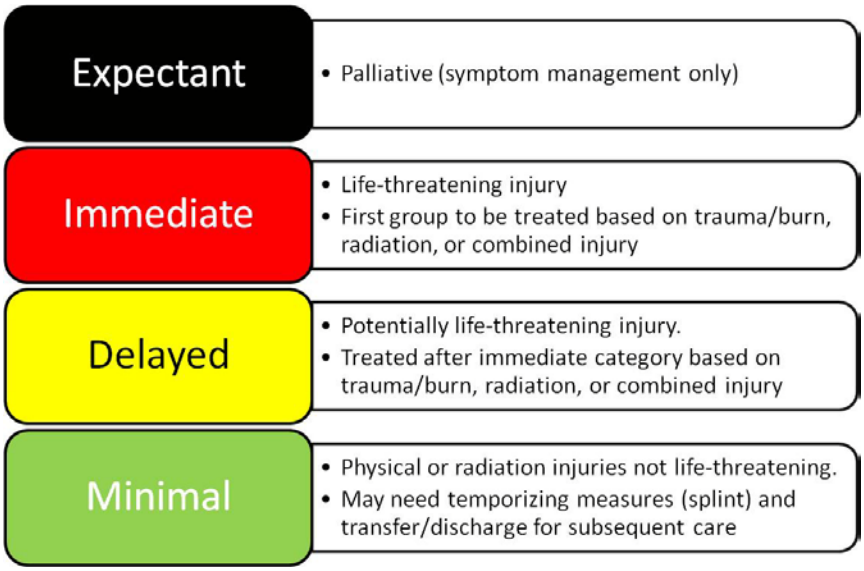
- Enhancing cross discipline integration among public health and medical and emergency management partners;
- Providing situational awareness to headquarters;
- Responding to events and providing command and control for deployed Departmental resources and assets; and
- Providing exercise support to stakeholders.

For more details regarding the ASPR REC program and for contact information, please go to www.phe.gov/Preparedness/responders/rec/Pages/default.aspx.

Incorporating Ethical Decision Making Into Planning
Saving lives is the primary mission in planning and response to an IND and triage is a major driver of that mission. Success in this mission will be strongly impacted by the anticipated scarce resource environment and requirements for certain trade-offs and decisions that will be

necessary to achieve the best possible outcomes. Perhaps the most difficult issue for medical decision making is triage under chaotic circumstances by physicians and other triage personnel untrained in this aspect. The four victim triage categories applicable to the scarce resources setting are in Figure 6 (adapted from Coleman[11]). The categories are slight modifications of the categories used in non-scarce resource settings, for example, minimal may need medical care but not immediate life-saving care. *Triage cards and system are included in the Acute Radiation Syndrome chapter in this manual.* For more detailed information see Murrain-Hill (Chapter 10).

Figure 6. Triage Categories for Nuclear Detonation: Scarce Resources Setting (This is a modification of triage categories from "standard systems" to accommodate the mass casualty, scarce resource nuclear detonation setting.)



The order of triage depends on the medical condition and the scarcity of resources, as discussed in Coleman[11] and Coleman.[12] and illustrated in the chapter by Chao in this manual. As resources become increasingly scarce, the resource-rich order of "always sickest first" may be modified by goals of fair treatment.[3, 13]

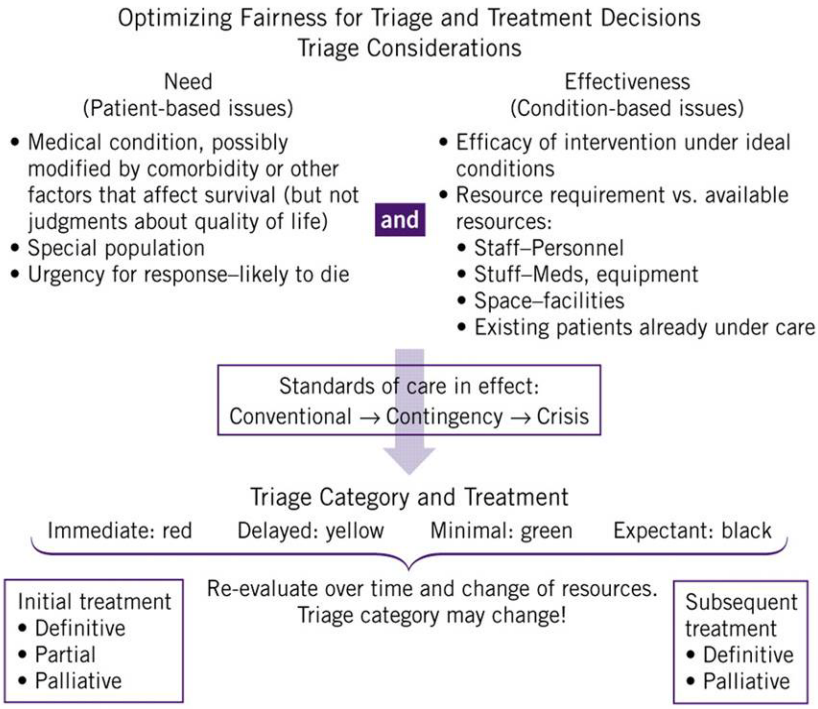
Fairness is the key factor in ethical decision-making.[13] The importance of community- and region-wide participation in planning is critical to establishing a response that will be judged as fair. Figure 7, below, is somewhat complex, but illustrates the issues that go into a triage decision:

1. "Need" is based on the medical condition; and
2. "Effectiveness" determines whether the need can be met under the circumstances. This depends on the efficacy of the intervention and on the resources available to deliver it.

For example, someone with severe abdominal injury who is critically ill and requires extensive surgery and blood transfusions might be the "sickest" and therefore would ordinarily be the first to receive medical care (Immediate). This might save the life 80% of the time in normal

circumstances. However, in a setting with insufficient resources, there may be no blood supply or operating room available, thus no effectiveness of operating. The patient would receive pain medicine, if available, and be triaged to Delayed. If the person also had extensive radiation (combined injury), he or she would be triaged to Expectant and receive palliative care. As more resources arrive, re-evaluation might be changed from Delayed or Expectant to Immediate.

Figure 7. Optimizing Fairness for Triage and Treatment Decisions. The Medical Need Depends On the Person's Clinical Condition (Whether Resulting From the Nuclear Detonation Or Not)



The scarce resources manuscript series from *Disaster Medicine and Public Health Preparedness*[11, 13] discusses this in detail. Ideally, community preparedness would include discussion and consensus regarding the conditions that would change a person's priority for treatment (e.g., previously comatose).

To initiate discussion and attempt consensus building prior to a nuclear event, public health officials and disaster response professionals are encouraged to begin compiling information—through focus groups or opinion polling—about the interests and preferences of various communities related to the utilization of scarce medical resources. Focus groups participants can include specialized populations in a specific geographic area with similar disease conditions, social characteristics, or religious beliefs. These group discussions can be useful in developing a cache of information, building consensus where possible, and providing immediate direction for local hospitals regarding clinician training and dissemination of information to the public.

Conclusion

Given the complexity of planning and preparing for an IND, a modifiable Playbook has been created for regional, state, local, tribal, and territorial planners to facilitate their efforts.[1] The RECs form the link between the state/local planners and responders and the federal ESF #8 response. Localities can add details to these documents as they develop their own plans.

Plans should reflect the assumption that medical resources in the region surrounding a nuclear detonation will be scarce, at least for the first few days. The subsequent inability to meet patients' needs will require medical triage to be modified from the usual "sickest first." These are very challenging decisions, and best discussed well in advance.

Authors

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Communicating About a Nuclear Detonation

Overview

The fear and confusion following a nuclear detonation can lead people to take action that may inadvertently put them in harm's way. Lack of understanding of radiation, its effects, and how it is measured can enhance the short- and long-term anxiety. Communicating a clear and effective message is a challenge, yet it is critical for reducing panic and saving lives. Response requires pre-scripted messages, expert spokespersons, credible experts, and rapid restoration of an effective communications infrastructure.

One challenge after a detonation will be making sure the communication infrastructure remains sound after the incident. Officials must ensure there alternate avenues of communication are in place in case there is significant damage to the infrastructure. Planners must consider the allocation of resources to supply information to these outlets and which outlets to use to gather situational awareness information.

Background

After a nuclear detonation, public safety depends on the ability to quickly communicate appropriate safety measures. Empowering people with information to protect themselves and their families can save thousands of lives. People will be affected in different ways and will have different information needs depending on their proximity to the blast and fallout plume. (Details in Chapter 3, Figure 2).

> ***Blast Damage and Dangerous Fallout (DF) Zones:*** People in these areas need life-saving information. Anyone who might be in the path of the radioactive plume must quickly get inside and stay inside to avoid a potentially fatal dose of radiation.
>
> ***Surrounding Area:*** People in this area will be concerned for their immediate health and safety and will want to know what they should do. The surrounding area will also be faced with concerns about contaminated people and vehicles entering their communities. These communities will also serve as reception communities for evacuees.
>
> ***National and International Communities:*** People in other parts of the nation and across the world will be seeking information and trying to get in touch with loved ones who may be in affected areas. There will be concern about a second attack. This is an opportunity to provide situation and response updates, educate the population about appropriate safety measures, and address concerns about the perceived health and other risks of those outside the affected areas.

Key goals of health officials and clinicians will be to remove contamination and control its spread, thereby preventing internal contamination and the need to use stockpile pharmaceuticals, and minimizing medically unnecessary self-referrals to hospitals and other critical facilities. Effective communications will drive accomplishment of these goals.

Messaging About Protective Actions And Radiation

Messages prepared, tested, and practiced in advance are fundamental to conveying clear, consistent information and instructions during an emergency. Many of the questions the public will have after a nuclear detonation can be anticipated and answered in advance.

When anticipating questions, planners must keep in mind both the broad audiences (listed above) as well as audiences with special communication needs (e.g., non-English speakers, hospital and nursing home staff and patients, the homeless population, etc.). To some extent, each audience will have specialized information needs, and messages should be able to be tailored to meet those needs.

In a nuclear incident, people will be primarily concerned with protecting themselves and their families. Protective action messages should provide simple, direct instruction to people in the affected areas about how to do this.

Audience research provides the following recommendations for messages:

Immediate Lifesaving Message

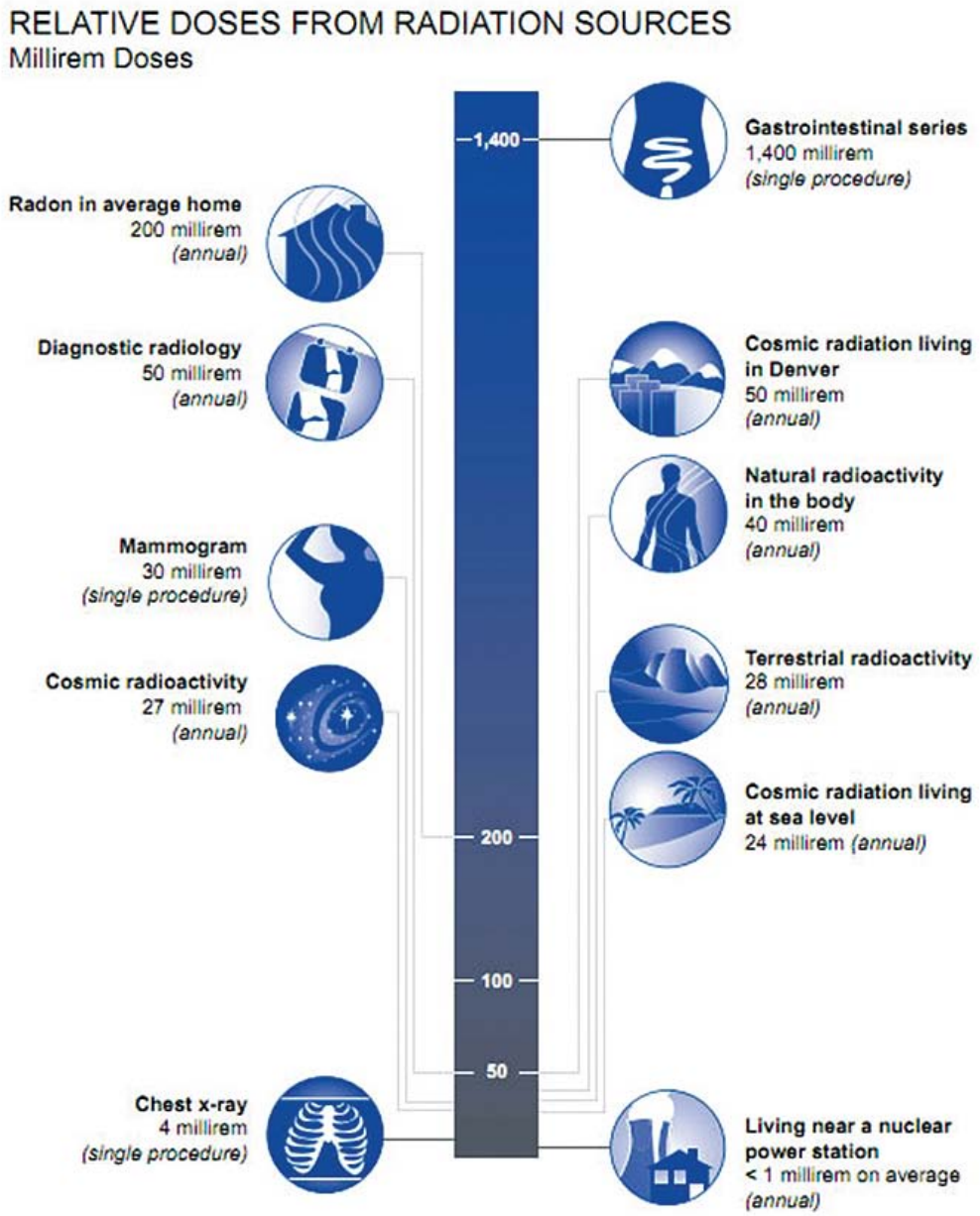
- A nuclear explosion has occurred at [Location] here in [City].
- You can survive a nuclear explosion if you take the right actions.
- Quickly Get Inside, Stay Inside and Stay Tuned.
    - **Quickly Get Inside**
        - Go inside the nearest building. (Preferably brick or concrete, but any building is better than being outside).
        - Go to a basement or the middle the building. You want to stay as far away from the outside of the buildings as possible.
        - If you are in a car, find a building immediately. Cars do not provide good protection from radiation but are better than no shelter
    - **Stay Inside**
        - Stay where you are.
            - The radiation outside may be fatal.
            - Remember, your friends and family have been instructed to stay inside too.
            - Staying inside, where you are, is best for everyone.
        - Plan to stay inside for at least 12 to 24 hours or until you are instructed to do otherwise. Radiation levels are extremely dangerous after a nuclear explosion, but the levels drop rapidly.
        - Staying inside can save your life.
    - **Stay Tuned**
        - Instructions will be updated as we gather more information.
        - Unless instructed otherwise, stay inside.

- Write short, concise, and simple messages.
- Use directive and authoritative language.
- Provide prioritized instructions and directions in each message.
- Provide information for a variety of environments.

- Create a message to encourage people not to leave their homes to check on loved ones in schools, daycares, and elder-care facilities.
- Avoid or define unknown terms and phrases.[1]

To help people understand information about the radiation threat, it is important to put the levels being detected in the context of the radiation we live with every day. Recent experience with the U.S. response to the Japanese nuclear plant emergency highlighted the public's desire for information about "how much" radiation they might be exposed to and how that compared with other radiation exposures. Figure 1 is a useful illustration for helping to accomplish this task

Figure 1. Relative Doses from Radiation Sources
Source: U.S. Environmental Protection Agency



Notes of caution:

- Some individuals may find the comparisons to other radiation exposures to be minimizing their concerns.
- Expert spokespersons should be available to discuss radiation and risk at a sophisticated level and be able to explain and/or counter partial or incorrect information that may be in the media.

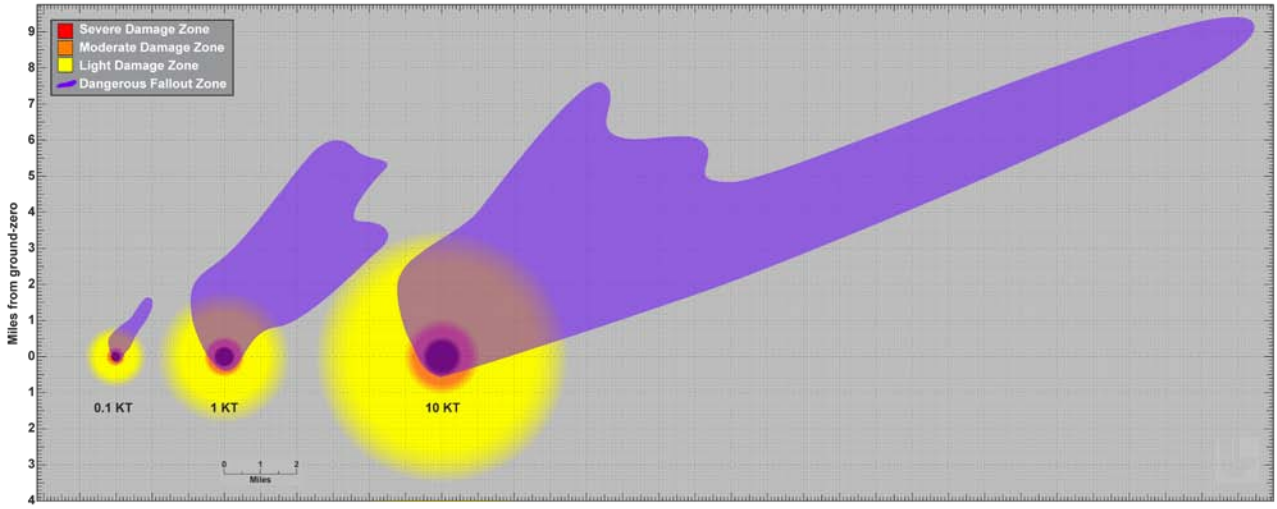
Communications Infrastructure

A key concern following a nuclear detonation incident will be the integrity of the communications infrastructure. How will officials communicate messages to affected audiences? The difficulty that will inevitably follow a nuclear detonation drives home the importance of pre-event preparedness. Officials anticipate the following infrastructure issues.[2]

***Blast Damage Area*:** In the physically damaged areas (see Figure 2) there will be minimal, if any, ability to send or receive communications. All communications capabilities will be destroyed or severely hindered from the blast damage to the communications systems. Electrical, phone, and cellular systems will be down, and an electromagnetic pulse (EMP) will devastate electronics in the physically damaged area and possibly beyond. Televisions, computers, cell phones, and personal digital assistants (PDAs), such as BlackBerry devices, may also be impacted. Phones or PDAs that do withstand the EMP impact will likely be in the hands of survivors, because the person possessing it is sufficiently sheltered underground. However, this deep shelter could render the cell phone or PDA useless until a survivor finds a way to the surface, which could subject him or her to life-threatening radiation exposure. It may be days before communications capabilities are reestablished.

Figure 2. Nuclear Detonation Impact Zone and Action Area

After a nuclear detonation, people in the blast damage zones will have limited or no communications abilities. *However, the majority of treatable injuries will be in the zones that will likely have intact infrastructure including light damage zone and dangerous fallout zones.*



Source: *Planning Guidance for Response to a Nuclear Detonation*[2]

Along with commercial systems, public safety systems in this area (e.g., land and mobile radio and 911 call centers) may also suffer communications failures. Although these systems are typically more robust and less susceptible to failure than their commercial counterparts, they will be severely damaged or degraded in the blast and surrounding areas. These systems are critical to emergency responders for life-saving and rescue operations and must be restored as quickly as possible.

As part of the federal response to a major disaster, the Federal Emergency Management Agency (FEMA) will activate the Communications Annex of the National Response Framework, Emergency Support Function #2, to coordinate with the private sector, state, and local entities in restoring the commercial communications infrastructure and public safety and emergency responder networks.[3] Industry continually monitors its own networks for outages and reduced capabilities and will usually begin recovery operations relatively quickly. Commercial providers typically have transportable restoration capabilities (e.g., cellular on wheels and cellular on light truck) strategically located around the country to minimize response times. With proper planning and preparedness, public safety and emergency responder networks can be augmented and/or temporarily restored through assets that the state, National Guard, and surrounding localities may be able to provide. As part of the federal response, FEMA can typically have communications assets on the ground in the contiguous 48 states within 24-48 hours after an incident.

Surrounding Area: The surrounding area may include surrounding communities, counties, bordering states, and people in the path of the radioactive plume, including the dangerous fallout zone. After a nuclear detonation, there is the potential for cascading effects along transmission lines in this area caused by EMP, which may extend hundreds of miles from the detonation site. This could mean electrical, phone, and Internet outages. *The EMP should have limited, if any, effect on electronic devices in the surrounding area and DF zone outside of the blast damage zone. Electronic devices may only require resetting switches and circuit breakers.* Reception communities may not have significant infrastructure issues, but connectivity will be essential for them to adequately prepare for receiving potentially thousands of evacuees.

National and International Communities: In any major national emergency, a sudden increase in the need for information and human connectivity can severely stress and sometimes exceed the capacity of the communications infrastructure. This will hinder the ability to communicate into or out of the physically damaged areas, the regional DF zone, and possibly the surrounding vicinity. Planners must know what types of systems are available to enable responder communications in case normal communications methods are unavailable.

Communication Channels

In a nuclear denotation, every available information outlet must be used to gather information about the health and safety issues the community and responders face; to provide guidance to affected populations; and to address health, economic, safety and other concerns of people across the country and throughout the world. **Information outlets include electronic**

billboards, 911 systems, short-wave radio, siren warning systems, radio, television, newspapers, flyers, public announcement (PA) systems, text messages, and social media and other websites. Planners must consider the allocation of resources to supply information to these outlets and which outlets to use to gather situational awareness information.

Radio broadcasts may be the most effective means to reach people closest to the nuclear explosion. Emergency Alert System, National Oceanic and Atmospheric Administration (NOAA) weather radio broadcasts, reverse 911 systems, flyers, PA systems, short-wave radio, and siren warning systems may be useful in rapid dissemination of emergency information in the affected area. Although additional outlets, particularly electronic outlets, are more likely to be useful away from the blast site, these outlets should be considered in emergency communications plans.

A 2011 Pew Research Center report found that 84 percent of adults in the United States own a cell phone, a relatively stable number since mid-2008.[4] Among this population, 56 percent reported receiving local news and information on their mobile devices. This equates to nearly half of all American adults (47 percent). Approximately 70 percent send text messages daily—an average ten messages per day.[5] Recognizing this trend, the U.S. government is currently building a library of public health text messages that can be used during disasters by local responders and health departments and the entities with the capacity to send emergency text messages to people in the affected area.

Table 1. Social Media Usage (2010). Social media usage is also increasing for all ages groups, although people ages 18-29 continue to be the largest group of social media users.[6]

Age	Percent Using Social Media
19-29	86% (up from 16% in 2001)
30-49	61%
50-64	47%
Over 65	26%

These figures suggest that disaster communications plans should include use of social networks in disaster response. In addition to serving as information outlets, these internet sites also provide responders with situational awareness during the disaster response and recovery.

Planners should also enlist community and national organization partners, including faith-based organizations, to support communications efforts in a nuclear emergency response. Given the magnitude of the communication task in such a response, partners can serve as force multipliers—providing information between organization members and emergency response agencies. Most people look for confirmation from five sources before evacuating an area,[7] and trusted partners can provide this confirmation, encouraging evacuation as well as compliance with other health and safety actions.

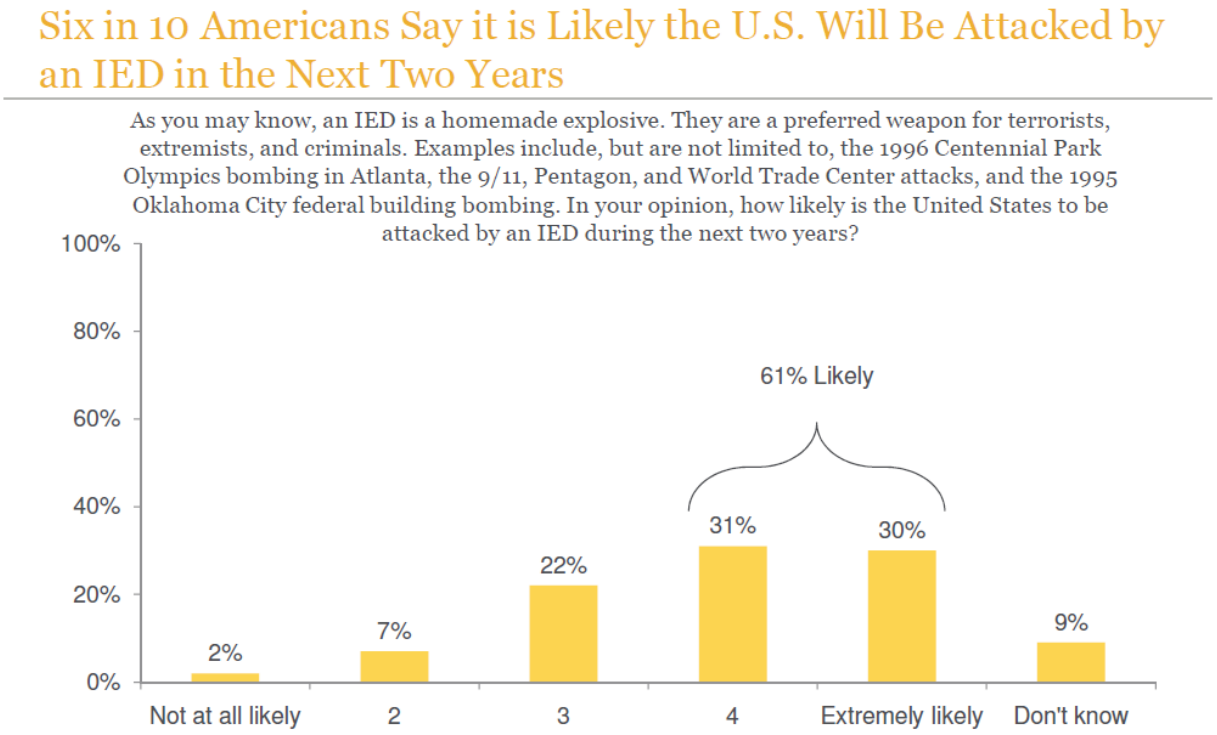
Table 2. Communication Channels by Target Audience
**All of these communication channels can and should be approached with partners who can amplify the message and serve as force-multipliers for emergency responders.*

Public Information Target Audience	Suggested Communication Channels*
Blast Damage Zone	Radio Short-wave radio NOAA weather radio Public announcement (PA) systems Flyers Siren warning systems NOAA weather radio Door-to-door Monitor social media for situational awareness
Dangerous Fallout Zone	Radio Short-wave radio NOAA weather radio Regular radio Public announcement (PA) systems Siren warning systems Electronic billboards Flyers 911 systems Monitor social media for situational awareness
Surrounding Area	Radio Television Newspapers Text messaging systems Electronic and hard-copy billboards Social media Websites Flyers
National and International Communities	Social media Television Newspapers Magazines Websites

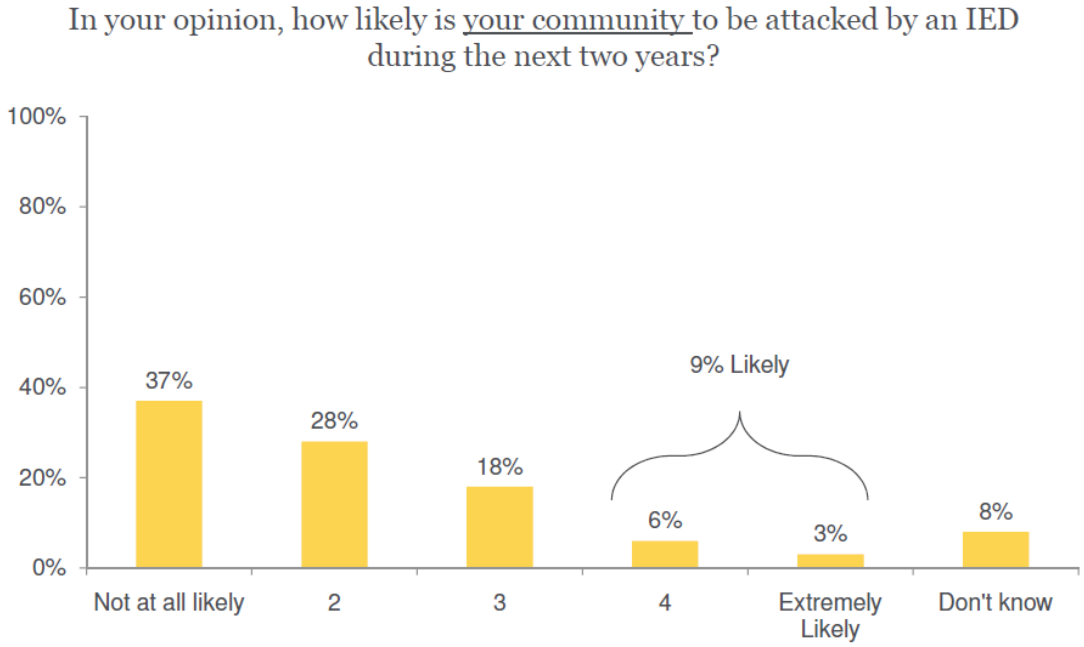
Challenges to Preparedness and Opportunities for Planning

Given the critical need to communicate rapidly and effectively following an improvised nuclear device (IND) incident, pre-event planning is essential. However, significant challenges exist. In a Gallup panel (Figure 3) including more than 25,000 individuals from across the country, 61 percent of people believed an improvised explosive device would be used in an attack on U.S. soil in the next two years; however, only 9 percent believed it would happen in their community. One of the greatest challenges to getting the public to prepare for any type of terrorist incident is finding ways to motivate a public who believes the threat is real, but does not believe it will impact them.[8]

Figure 3. Perception of Local Impact
Printed with permission from Gallup



Likelihood of an Attack on Community Using IED



In addition, there is a legacy of public emergency preparedness campaigns, such as the Cold War's "duck and cover" and the more recent "plastic sheeting and duct tape," that leave the public confused or even skeptical of preparedness messages. Many people do not believe that a nuclear detonation is survivable. This sense of futility, fatalism, and hopelessness severely impacts the public's desire and ability to absorb information and follow instructions.[9] Many people do not own or have access to emergency radios, which may lead to problems communicating protective actions and safety information.

Opportunities to educate the public about radiation and IND preparedness do exist, including:

- Taking advantage of other pre-incident education campaigns, such as National Preparedness Month or FEMA's Radiological Emergency Preparedness (REP) Program educational campaign around nuclear power facilities.
- Thinking All-Hazards. The key protective action message 'Get inside, Stay inside, Stay tuned' applies to more than just nuclear detonations. This type of all-hazards messages can apply to any emergency situation where people need to get off the streets and listen for instructions before taking action. Response to a nuclear detonation has similarities to sheltering for tornadoes.
- Focusing on target audiences and community leaders, who are the people most likely to act on the information and influence those around them. Target audiences may include grade school students who can bring the information home to their families, religious leaders who can inform their congregations, business owners who can help encourage their employees to be prepared, and first responders who can educate their communities.

In conclusion, communications will be a driving factor in the response to a nuclear detonation. Planning and preparedness are essential for effective messaging and a resilient communications infrastructure in such an emergency.

Additional Communication Resources:

U.S. Environmental Protection Agency: *Communicating about Radiation Risks*. nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=500025HA.txt

U.S. Department of Health and Human Services: *Tools for the Media and Public Health Communicators: Public Health Emergency Response: A Guide for Leaders and Responders* and *Communicating in the First Hours: Initial Communication With the Public During a Potential Terrorism Event.* www.phe.gov/emergency/communication/Pages/default.aspx

Centers for Disease Control and Prevention: *A Primer on Health Risk Communication.* www.atsdr.cdc.gov/risk/riskprimer/vision.html

U.S. Department of Health and Human Services: *Nuclear Detonation Preparedness: Communicating in the Immediate Aftermath.* www.remm.nlm.gov/NuclearDetonationPreparedness.pdf

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[3] Radiation Protection Division, U.S. Environmental Protection Agency

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The Federal Response Structure and Plans: NRF, NIMS, ESFs and Directives

Overview

Standardized terminology and organizational structure are key elements of an effective and coordinated response. The overall federal response is described in the National Response Framework (NRF)[1] and is organized into 10 Federal Emergency Management Agency (FEMA) Regions[2] with agency responsibility outlined in the Emergency Support Function Annexes.[3] The National Incident Management System (NIMS)[4] outlines structure, terminology, and procedures with the Incident Command Structure (ICS)[5] organizing the five components: command, operations, planning, logistics, and finance/administration. Development of these systems was originally mandated by Homeland Security Presidential Directive #5 (HSPD-5) – Management of Domestic Incidents.[6]

The NRF is a guide produced by the U.S. Department of Homeland Security and approved by the Executive Office of the President to direct communities, states, the federal government, and private-sector and nongovernmental partners to respond to all hazards. Contained in the NRF guide are Emergency Support Function Annexes. These annexes list the Emergency Support Functions (ESF) and the capabilities, roles, and responsibilities each agency or group provides during response operations which is supported by FEMA Regions.

The federal response to an IND detonation requires many agencies and resources to ensure an appropriate medical and public health response. At this time, the HHS Assistant Secretary for Preparedness and Response (ASPR), in collaboration with subject matter experts and partner agencies (e.g., CDC, NIH, and the National Library of Medicine), developed the *ESF #8 – Improvised Nuclear Device Playbook (IND Playbook)* and the *State and Local Planner's Playbook for Medical Response to a Nuclear Detonation*

The National Response Framework – How the Nation Responds to All Hazards

The medical and public health response to a nuclear detonation will require numerous resources, comprehensive planning, effective communication, and novel approaches to addressing an incident of this scale. Guidance on the nation's approach to conducting response efforts is detailed in the National Response Framework (NRF).[1] The Nuclear/Radiological Incident Annex (NRIA)[7] to the NRF addresses the unique responsibilities and coordination requirements for the scope of potential accidental or deliberate releases of radiological material or a nuclear detonation. Agency roles, responsibilities, and authorities are specifically described for each type of incident. Additionally, an integrated concept of operations and unique organization, notification, and activation processes and specialized incident-related actions are discussed.

The NRF is a guide produced by the U.S. Department of Homeland Security and approved by the Executive Office of the President to direct communities, states, the federal government, and private-sector and nongovernmental partners to respond to all hazards. It is built on key response principles with overall goals of a collaborative response structure that is applicable during large or small incidents:

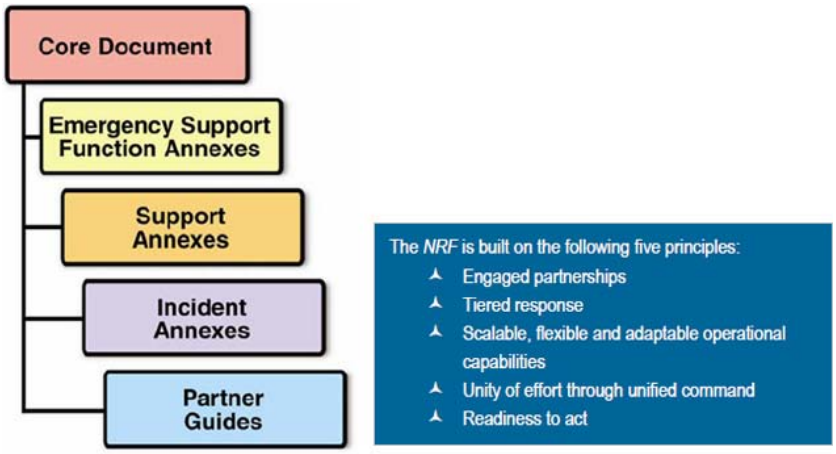
- Engaged partnerships
- Tiered response
- Scalable, flexible, and adaptable operational capabilities
- Unity of effort through unified command
- Readiness to act

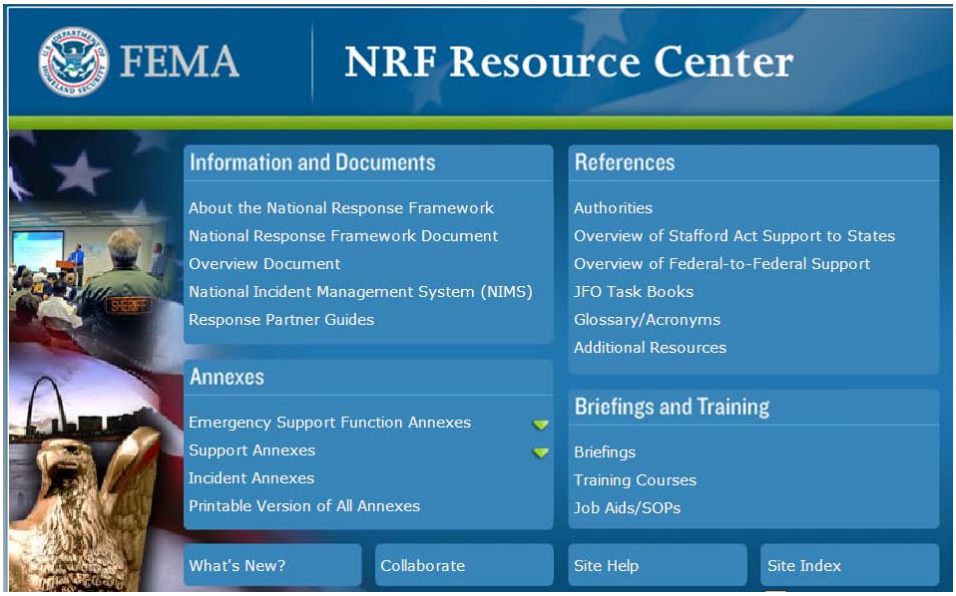
The National Response Framework[1]

The NRF and its list of annexes fully explain the principles that guides national response, roles and responsibilities, response actions, response organizations, and planning requirements to achieve an effective national response to any incident that occurs. A visual structure of the NRF is shown below in Figure 1.

Figure 1. Structure of the National Response Framework[1]

These components are nonspecific and applicable to all hazard incidents and emergency and non-emergency situations to ensure all municipalities develop similar response structures in an effort to integrate response across all levels of government.





Emergency Support Functions

Contained in the NRF guide are Emergency Support Function Annexes.[3] These annexes list the Emergency Support Functions (ESF) and the capabilities, roles, and responsibilities each agency or group provides during response operations. Table 1 describes the roles and responsibilities of ESF partners. Tasks of the Department of Health and Human Services (HHS) fall under ESF #8.

Table 1. Roles and Responsibilities of the ESFs

Emergency Support Function	Scope	Coordinator	Primary Agency
ESF #1 – Transportation	Aviation/airspace management and control	DOT	DOT
	Transportation safety		
	Restoration/recovery of transportation infrastructure		
	Movement restrictions		
	Damage and impact assessment		
ESF #2 – Communications	Coordination with telecommunications and information technology industries	DHS/NCS	DHS/FEMA
	Restoration and repair of telecommunications infrastructure		
	Protection, restoration, and sustainment of national cyber and information technology resources		
	Oversight of communications within the federal incident management and response structures		
ESF #3 – Public Works and Engineering	Infrastructure protection and emergency repair	DOD/USACE	DOD/USACE/ DHS/FEMA
	Infrastructure restoration		
	Engineering services and construction management		
	Emergency contracting support for life-saving and life-sustaining services		
ESF #4 – Firefighting	Coordination of federal firefighting activities	USDA/FS	USDA/FS
	Support to wildland, rural, and urban firefighting operations		
ESF #5 – Emergency Management	Coordination of incident management and response efforts	DHS/FEMA	DHS/FEMA
	Issuance of mission assignments		
	Resource and human capital		

Emergency Support Function	Scope	Coordinator	Primary Agency
	Incident action planning		
	Financial management		
ESF #6 – Mass Care, Emergency Assistance, Housing, and Human Services	Mass care	DHS/FEMA	DHS/FEMA
	Emergency assistance		
	Disaster housing		
	Human services		
ESF #7 – Logistics Management and Resource Support	Comprehensive, national incident logistics planning, management, and sustainment capability	DHS/FEMA/ GSA	DHS/FEMA/ GSA
	Resource support (facility space, office equipment and supplies, contracting services, etc.)		
ESF #8 – Public Health and Medical Services	Public health	HHS	HHS
	Medical		
	Mental health services		
	Mass fatality management		
ESF #9 – Search and Rescue	Life-saving assistance	DHS/FEMA	DHS/FEMA/ DOD/USCG/ DOI
	Search and rescue operations		
ESF #10 – Oil and Hazardous Materials Response	Oil and hazardous materials (chemical, biological, radiological, etc.) response	EPA	EPA/DHS/ USCG
	Environmental short- and long-term cleanup		
ESF #11 – Agriculture and Natural Resources	Nutrition assistance	USDA	USDA/DOI
	Animal and plant disease and pest response		
	Food safety and security		
	Natural and cultural resources and historic properties protection and restoration		
	Safety and well-being of household pets		
ESF #12 – Energy	Energy infrastructure assessment, repair, and restoration	DOE	DOE
	Energy industry utilities coordination		
	Energy forecast		
ESF #13 – Public Safety and Security	Facility and resource security	DOJ	DOJ
	Security planning and technical resource assistance		
	Public safety and security support		
	Support to access, traffic, and crowd		

Emergency Support Function	Scope	Coordinator	Primary Agency
	control		
ESF #14 – Long-Term Community Recovery	Social and economic community impact assessment	DHS/FEMA	DHS/FEMA/ USDA/HUD
	Long-term community recovery assistance to states, local governments, and the private sector		
	Analysis and review of mitigation program implementation		
ESF #15 – External Affairs	Emergency public information and protective action guidance	DHS	DHS/FEMA
	Media and community relations		
	Congressional and international affairs		
	Tribal and insular affairs		

FEMA Regions

FEMA operates the regional support structure by managing regional offices. States are divided into 10 regions, which enables FEMA to better coordinate emergency response efforts (see Figure 2). Each region contains a Regional Response Coordination Center (RRCC), which is designed to become response headquarters during or in anticipation of a major incident. The centers are staffed by response personnel in order to fulfill the goals of ESF guidance.[1]

Figure 2. FEMA Regions

National Incident Management System (NIMS)
From the NRF key principles emerge the core principles found in NIMS. NIMS outlines the management structure for response to a large or small specific emergency by establishing unified concepts, terminology, and procedures. It is a template that allows first responders (e.g., police, firefighters, or emergency planners) from various jurisdictions (local, state, tribal, government and non-government organizations) to effectively work together during an all-hazard response.[1]

The Concepts of NIMS
Interoperability and compatibility—balance of flexibility and standardization

Flexibility and scalability:

- Adjustable national framework
- All levels can work together to respond to domestic incidents, regardless of their cause, size, location, or complexity
- Applies across all phases of incident management—prevention, preparedness, response, recovery, and mitigation

Standardization:

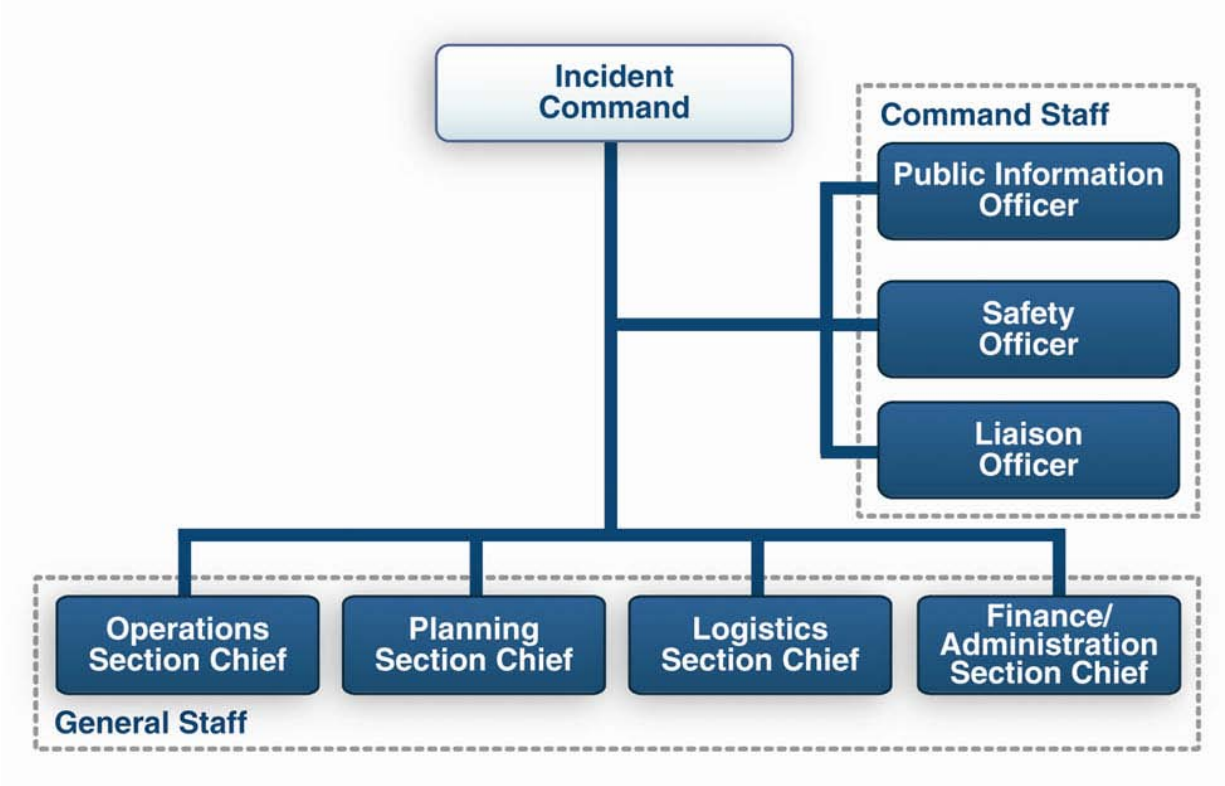
- Organizational structures
- Titles of organizations and positions are standardized

The response to all hazards is unified due to the NIMS concepts, which are built on a widely used organizational structure called the Incident Command System (ICS). NIMS and ICS share common components such as:

- Preparedness;
- Communications and Information Management;
- Resource Management;
- Command and Management; and
- Ongoing Management and Maintenance.

ICS is the combination of facilities, equipment, personnel, procedures, and communications operating within a common organizational structure, designed to aid in domestic incident management activities (see Figure 3). It is used for a broad spectrum of emergencies, from small to complex incidents, both natural and manmade, including acts of catastrophic terrorism. It is divided into five functions: Command, Operations, Planning, Logistics, and Finance. This structure was designed for use by federal, state, local, and non-government organizations while managing incidents.

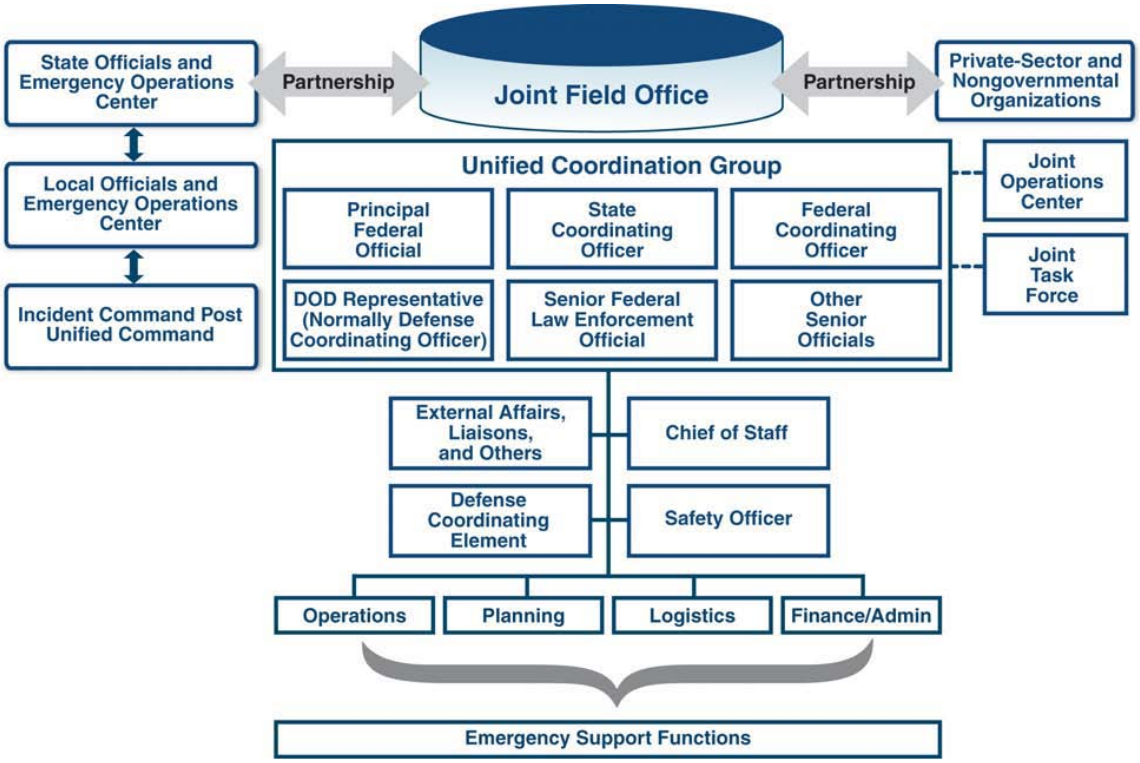
Figure 3: Incident Command Structure



Joint Field Office (JFO)

The Joint Field Office (JFO) is the federal incident management structure (Figure 4). It is a temporary multiagency coordination center established at, or near, the incident site to provide a central location for coordination of federal, state, local, tribal, nongovernmental, and private-sector organizations with primary responsibility for incident oversight, direction, and/or assistance to effectively coordinate protection, prevention, preparedness, response, and recovery actions. The JFO is not designed for tactical incident response despite utilizing the ICS structure. The JFO focuses on providing support to on-scene efforts and conducting broader support operations that may extend beyond the incident site.[1]

Figure 4: The Structure of the Joint Field Office



The Federal Response Structure Applied To Improvised Nuclear Device (IND) Response Plans
The medical and public health response to an IND is complex and will require numerous resources. The NRIA of the NRF describes specific response activities, capabilities, and responsibilities carried out by coordinating and cooperating agencies to support the state, tribal, and local activities during the response. In the NRIA, HHS responsibilities through ESF #8 – Public Health and Medical Services include coordination of population monitoring; certain laboratory analyses; guidance and technical assistance for population decontamination and internal contamination monitoring; provision of medical countermeasures from the Strategic National Stockpile (SNS); coordination of fatality management; and provision of medical surge. Responders and planners can use tools developed by HHS and based on the NRF, NIMS, and ESF guidance to navigate through response planning complexities. The HHS Assistant Secretary for Preparedness and Response (ASPR), in collaboration with subject matter experts and partner Agencies (e.g., CDC, NIH, and the National Library of Medicine) developed the following:

- *ESF #8 – Improvised Nuclear Device Playbook (IND Playbook)* to provide guidance for executive decision makers within the HHS in the event of an actual radiological terrorist attack in a U.S. city. Specifically, it outlines key measures and options to aid the HHS Secretary in making essential decisions and directing the HHS response to a radiological attack. The IND Playbook provides specific linkages between HHS and ESF #8 response capabilities (e.g., medical and public health coordination, guidance and technical assistance, patient movement, deployable assets and teams) and the overall planned federal response as it is outlined in the NRF guidance.

- As an adjunct to the ESF #8 IND Playbook and to assist with the integration of state and local IND response planning, the *State and Local Planner's Playbook for Medical Response to a Nuclear Detonation* [8] was developed. The State and Local Planners Playbook is an interactive resource offered as a guide to assist local, state, regional, tribal and territorial medical and public health planners and other subject matter experts in preparing for a nuclear detonation. It provides sequential guidance and specific action steps to coordinate the medical response to a nuclear detonation and detailed time-phased, sector-oriented approaches to response activities with linked references. It is intended to assist emergency management planners and provide a linkage to overall federal medical and public health planning efforts.

Conclusion

The ESF guidance lists the specific agency responsible for particular responsibilities and capabilities whereas the NRF driven concept of operations (CONOPS) describes the steps required to perform medical and public health services. HHS guidance from ESF #8 resulted in the development of "Action Steps" which are sequential response steps and highlight the collaborative, interagency and multi-jurisdictional operational activities and capabilities outlined in the NRF, in the HHS/ASPR IND Playbook, and the IND State and Local Playbook. These action steps were developed to guide emergency management leaders from pre-incident to tasks 96 hours after the incident. They were designed for response to a radiological detonation but can be applied to manage the medical and public health response to all hazards.

Authors

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Population Monitoring After a Nuclear Detonation

Overview

Following any large scale radiation disaster, the evacuated, sheltered, or otherwise affected members of the public would require monitoring for external and/or internal contamination, and decontamination, if indicated. In addition, the potentially-affected individuals should be identified so that epidemiologic data can be collected. These data will be used to identify vulnerable populations (e.g., children, pregnant women), those at risk of overexposure, and those with high levels of contamination. These persons may need dose reconstruction, biodosimetry/bioassay, medical treatment, and inclusion into long-term health and medical monitoring programs and registries. These vital activities are part of a process called population monitoring.

Process

The general process of population monitoring is described in detail in the Department of Health and Human Services (HHS) Centers for Disease Control and Prevention (CDC) guide on population monitoring.[1] Considerations that are particularly applicable to a nuclear detonation scenario are discussed in detail in the federal *Planning Guidance for Response to a Nuclear Detonation*.[2]

The primary considerations regarding screening and monitoring of the population after a nuclear detonation are described below.

1. **Identification of individuals who are in immediate danger and require emergent medical stabilization**. Near the incident site, this monitoring need is accomplished as part of the medical triage process.
    a. Management of serious injury takes precedence over radiological decontamination.
    b. Radioactive contamination is not immediately life threatening.

2. **Detection and removal of contamination.** In most cases, external decontamination of skin and clothing can be self-performed (i.e., showering or washing with water and changing into clean clothes) if straightforward instructions are provided.
    a. External decontamination removes fallout particles and other radioactive debris from clothes and the external surface of the body.
    b. Plastic bags are useful for containing contaminated clothing and moist wipes are useful for cleaning the skin when water is scarce.
    c. Internal decontamination, if needed, requires the administration of medications or therapies to reduce the amount of radioactivity in the body.

3. **Prevention of acute radiation syndrome and acute local radiation injury**. Population monitoring personnel should offer or recommend gross external decontamination, such as brushing away dust or removal of outer clothing and cleaning of the skin. Cross-contamination issues (e.g., from transport vehicles) are of secondary concern, especially

in a nuclear emergency where the contaminated area and the potentially-impacted population are large.

4. **Maintaining flexibility and scalability**. Population monitoring and decontamination activities should remain flexible and scalable to reflect the available resources and competing priorities.

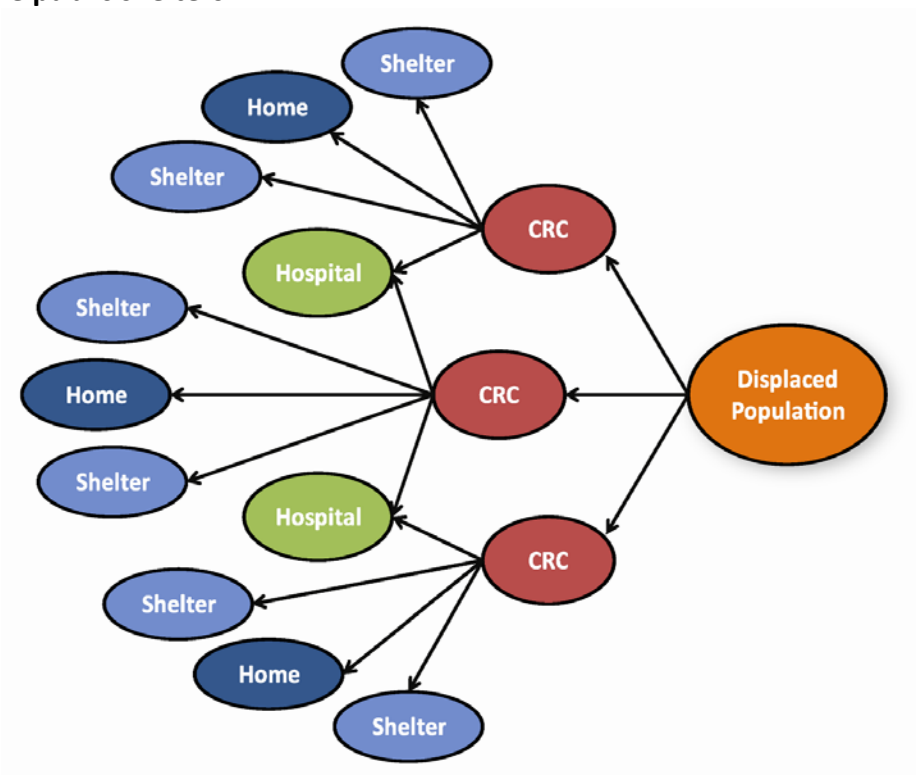
In the immediate phase of the response and in areas surrounding the damaged zone:

- Any responder actions to assist with screening and decontamination of people, pets, or vehicles should not restrict or inhibit necessary evacuation procedures.[2]
- Radiation monitoring and assistance with decontamination can be done at any location of opportunity or at ad hoc facilities set up by emergency response organizations to facilitate washing.
- An ample supply of clean replacement clothing, plastic bags, and moist wipes should be available and would be a valuable resource at these ad hoc facilities.[2]

Community Reception Centers

The focus of this article is on population monitoring activities that take place away from the impacted area at locations referred to as Community Reception Centers (CRC).[1] The displaced population who arrive in a host community are directed to CRC locations for assistance before they proceed to stay with family or friends or seek temporary housing at public shelters that local communities establish to receive and care for this population (Figure 1).

Figure 1. Community Reception Centers are set up in unaffected host communities to provide population monitoring services before people move on to temporary housing. Each CRC can serve multiple public shelters.



As stated in the National Response Framework (NRF) – Nuclear/Radiological Incident Annex, "decontamination of possibly affected victims is accomplished locally and is the responsibility of state, tribal, and local governments."[3] It is prudent to assume that after a large-scale nuclear emergency, the burden of providing population monitoring services in host communities away from ground zero will fall primarily on local resources. Therefore, it is necessary for local communities to include population monitoring after a radiation emergency as part of their all-hazard preparedness planning.

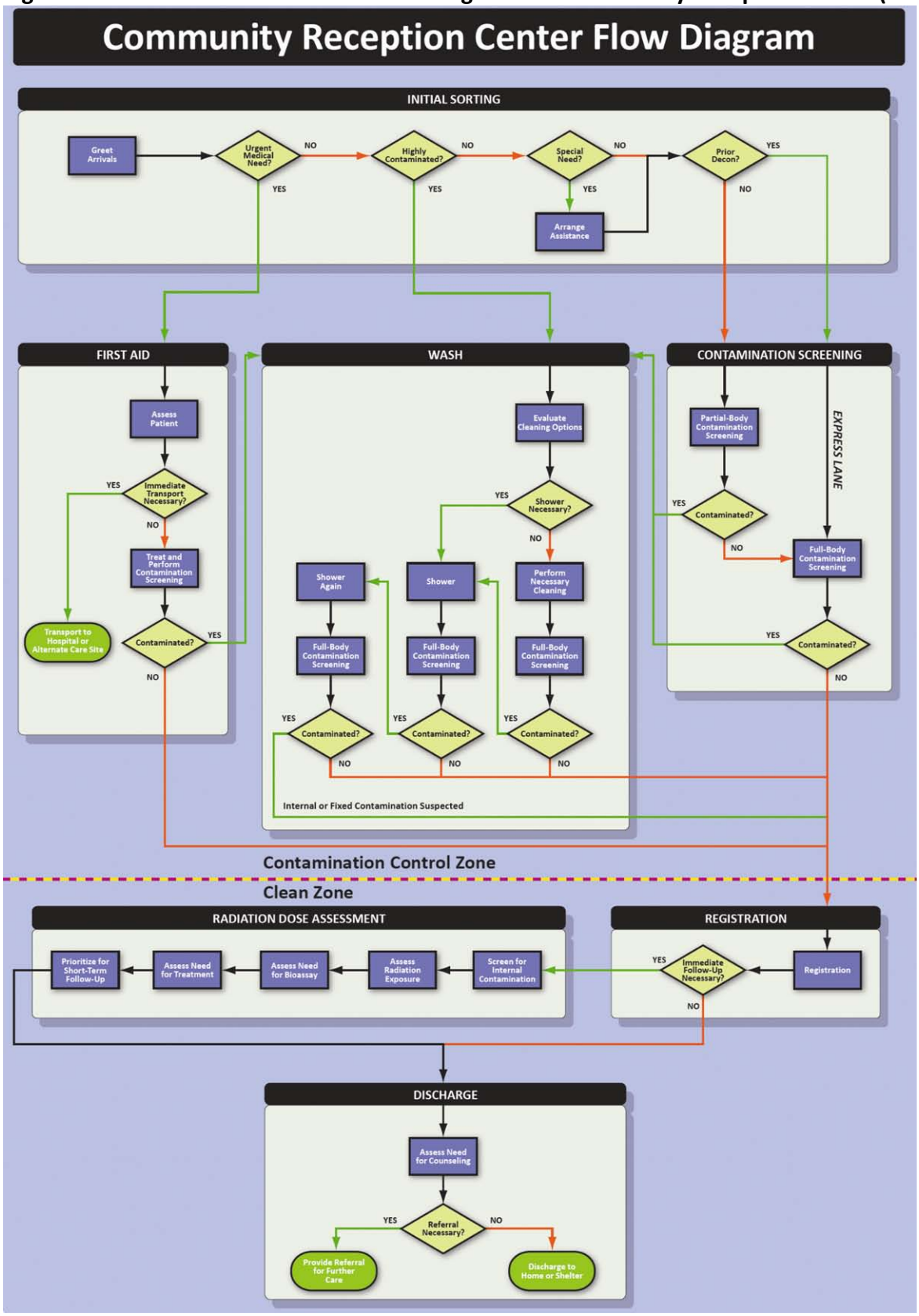
Community Receptions Centers are opened within 24 to 48 hours after a radiation emergency (or sooner if resources are available) in locations outside the affected areas. The basic services offered at a CRC include:

- Screening people for radioactive contamination;
- Assisting people with washing or decontamination;
- Collecting epidemiologic data and registering people for long-term follow up; and
- Prioritizing individuals for further care.

CRCs are modeled closely after points of dispensing (POD) sites, which many public health departments across the United States have already incorporated into their response plans for biological threats. Establishing and operating a CRC is a community effort involving local emergency management, law enforcement, and public health agencies, as well as other local response and volunteer organizations. In addition to providing vital services to people who need them, establishing CRCs helps reduce the potential burden on hospitals and maximize scarce medical resources. As discussed earlier, another important benefit is supporting the operations of public shelters.

CDC and Oak Ridge Institute for Science and Education (ORISE) have developed a standardized CRC model that is modular and can be adapted to the needs and resources of each community. The process flow diagram for CRC is shown in Figure 2. A similar diagram for a pet-friendly CRC is available from CDC.[4]

Figure 2: The Standardized Process Flow Diagram of a Community Reception Center (CRC)



In addition, CDC and ORISE have developed an interactive web-based training program that allows users to explore a CRC in a virtual space. This product is called the *Virtual Community Reception Center (vCRC)* and includes a step-by-step description of the CRC process, embedded videos to describe the screening and decontamination process, and a variety of support resources such as job aids, job action sheets, posters, and forms, which users can customize and include in their CRC plans.[4]

Establishing a Registry

A registry of the affected population will need to be established as early as possible. Immediately after an incident, it may be possible to collect only limited essential information, such as name and contact information. As time and resources permit, additional information relevant to exposure or contamination status of the individuals can be collected. In the short-term, this information is used to contact people who require immediate medical follow-up. As appropriate, some individuals may need long-term health monitoring. There are many example registration tools available.[4-7] Jurisdictions can adopt a registry tool unique to their own requirements and tracking systems.

Epidemiology data

If resources are available at the CRC, pertinent information can be collected to assist in monitoring the health status of the affected population, identifying the most important health needs, and counting persons with illnesses and radiation contamination. Epidemiology can also be used to identify risk factors for radiation exposure and contamination and identify ways public health officials can help to reduce those risks. This information, combined with results from radiation contamination assessments and laboratory testing, may enable public health officials to assess population- and individual-level radiation exposure, contamination, and the potential for associated health effects; identify populations most likely to need medical care and treatment; and study long-term health effects. Table 1 provides a sample of the type of detailed data that could be collected at a CRC following a radiation emergency. A more complete question bank is available from CDC.[4]

Table 1. Sample Data Elements That Could Be Collected at the CRC.

A more complete question bank and example forms are available from CDC[4]

Contact Information	**Contamination Assessment**
Name	Contamination detected?
ID Number	Contamination detected in the breathing zone (face/neck)?
Date of birth	Decontamination performed?
Home and alternate address	Contamination detected on the body after decontamination?
Home and mobile phone	Any open wounds or embedded pieces of material?
E-mail address	Radionuclides detected and dose/dose-rate measured
Demographics	**Medical Assessment**
Age, Sex	Signs and symptoms consistent with acute radiation syndrome

If female, pregnancy status	Past medical history, including cancer
Race and ethnicity	Disposition (i.e., sent home, referred to medical facility)

Exposure Assessment
Location at incident time and thereafter (i.e., within evacuation or fallout zone)?
Length of time within evacuation or fallout zone?
Shielded or sheltered while in evacuation or fallout zone?
First responder at the incident site?

Staffing
CRCs are staffed by local government employees, as well as organized volunteers such as members of the Medical Reserve Corps.[8] As indicated earlier, CRCs are modeled closely after PODs, and their staffing parallels that of PODs. An important difference is the need for radiation detection equipment and trained radiation protection personnel who can operate and interpret the screening results, as well as resources to assist with decontamination.

Table 2 provides an example of a fully-staffed CRC with all modules in operation at a host community to provide population monitoring services to a displaced population or concerned citizens in that community. These estimates were developed using the Community Reception Center Simulation Tool for Evaluation and Planning (CRC-STEP), a simulation program that uses Arena® simulation software (Rockwell Automation, Milwaukee, WI) to estimate CRC throughput. In this simulation, it was assumed that 50% of the people reporting to the CRC have either self-decontaminated or had prior assistance with decontamination before arrival, and only 1% of the population is contaminated on arrival. The CRC throughput will vary depending on specific circumstances, available staffing and instrumentation, specific screening procedures and service times. CRC-STEP allows users to plan ahead by running various simulations to optimize the CRC set up and provides a tool for planning CRC drills and testing CRC procedures.

Table 2. Example Showing Resources and Throughput for a Fully-Staffed CRC Using the Community Reception Center Simulation Tool for Evaluation and Planning (CRC-STEP) [1]
All input parameters and default assumptions can be tailored by the user to specific situations.

CRC Throughput: 500 people per hour			
Staffing		**Arrivals**	
Radiation screening	18	Prior decon	50%
Decontamination	2	Contaminated	1%
Medical	2		
General	33	**Time Spent in CRC**	

[1] More information about this simulation tool is available from the CDC's Virtual Community Reception Center (vCRC) Web site.[4]

Total	55	Average	18 min
		Minimum (uncontaminated)	12 min
Instrumentation			
Portal monitor	2	Maximum (internal contamination)	60 min
Hand-held	14		

A key and limiting resource for CRC operations is the insufficient number of radiation staff trained to operate radiation detection equipment and interpret the results. While the number of radiation protection staff employed by local and state governments is extremely limited, there are tens of thousands of radiation professionals who can be encouraged to volunteer and be organized and credentialed in a state volunteer registry. The Conference of Radiation Control Program Directors and CDC have been working to promote this sensible, practical, and cost-effective approach to address the critical local and state staffing needs for population monitoring after a radiation emergency.[9]

If a nuclear incident occurs anywhere, most communities throughout the country will be involved in the public health response to that emergency. Planning for population monitoring is an important element of local response. Local and state emergency management and public health planners can use the available guidance documents, planning and training tools to better prepare their communities.

KEY POINTS

- Population monitoring refers to a set of actions for expeditious screening of a population potentially exposed to radiation or contaminated with radioactive material, providing assistance with decontamination, evaluating information related to their exposure history, and registering people for subsequent follow-up.
- Because of the anticipated large number of displaced persons and the widespread geographic distribution of this population, we recommend that communities throughout the country incorporate population monitoring in their response plans.
- Population monitoring activities should remain flexible and scalable to reflect the prioritized needs of the affected individuals and the availability of resources at any given time and location.
- Community Reception Centers (CRCs) are locations where local response agencies provide population monitoring services.
- State and local agencies should plan to accommodate the needs of pets and service animals in CRCs. Contaminated pets can present a health risk to their owners, especially children who pet them.
- Operation of public shelters after a nuclear detonation depends heavily on the successful implementation of population monitoring activities at these Community Reception Centers.
- There are a number of resources available to local and state planners to plan, train, and prepare for population monitoring.

Authors

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The findings and conclusions in this publication are those of the authors and do not necessarily represent the official position of the Centers for Disease Control or the Oak Ridge Institute for Science and Education.

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Radiation/Nuclear Medical Countermeasure Research and Product Development Efforts for Public Health Emergencies

Overview

Medical response for radiological and nuclear incidents, including a nuclear detonation, a radiological dispersal device, a radiological exposure device, or a nuclear power plant accident, involves supplies for treating trauma and burns; drugs for relief of nausea, pain, and infection; and medical countermeasures (MCMs) for radiation injury. Diagnostic assessment is critical to medical management. Rapid and accurate biodosimetry tools are needed to estimate absorbed dose from radiation for useful clinical assessment and triage. Innovative diagnostic approaches, including point-of-care and high-throughput biodosimetry tools, are being identified, optimized, and validated to provide enhanced response capability for triage applications, field-deployable laboratories, and reference laboratories. A range of existing and developing technologies are being considered for incorporation into a Radiation Laboratory Network (RadLN), also referred to as Integrated Clinical Diagnostics System (ICDS), although this network is not yet developed to a point of implementation. The approaches to MCMs, including biodosimetry capabilities, and to RadLN development, involve a continuum of activities from basic science to technology and drug development to preclinical and clinical assessment, all in a context of guidelines and review by the U.S. Food and Drug Administration (FDA).

MCMs have the following characteristics:

- Protectors – given before exposure to radiation to lessen effects;
- Mitigators – given after exposure to reduce severity of effects before clinical manifestation; or
- Treatments – given after clinical manifestation of effects. An MCM such as a myeloid cytokine for the hematological syndrome can be both a mitigator and a treatment.

Few treatments have been approved by the FDA but some MCMs approved for other medical indications might be useful and could be used under an Emergency Use Authorization (EUA).

Background

Leading the U.S. Government's (USG) effort to develop and gain Food and Drug Administration (FDA) approval of medical countermeasures to mitigate radiation injury and save lives in a public health or terrorist emergency are components of the U.S. Department of Health and Human Services (HHS): the National Institutes of Health (NIH), particularly the National Institute of Allergy and Infectious Diseases (NIAID) [1-6] and the Office of the Assistant Secretary for Preparedness and Response (ASPR), including the Office of Policy and Planning (OPP)[7] and the Biomedical Advanced Research and Development Authority (BARDA). [5-6] NIAID supports the development of the research infrastructure and the advancement of basic science in radiobiology that is built on basic radiation biology research programs. These programs include

those in NIH's National Cancer Institute, as well as programs in the Department of Defense, Department of Energy, and National Aeronautics and Space Administration. The product development of radiation/nuclear MCMs, including biodosimetry methods and devices, is through a series of grants, cooperative agreements, and product-development support contracts. OPP works through the Public Health Emergency Medical Countermeasures Enterprise (PHEMCE) [8] to develop civilian MCM requirements and policy initiatives. BARDA supports the advanced product development, FDA-approval, and acquisition of MCMs through contracts with developers and companies. [5-6]

Exposure to ionizing radiation causes a spectrum of injuries that can be minor or lead to death. The damage occurs to DNA, cellular organelles, cells, tissues, and organs, with the extent of damage depending on the absorbed dose. Radiation-induced injury can occur due to exposure to an external radiation source (e.g., an improvised nuclear device [IND] detonation or a radiation exposure device) or by exposure from internal contamination with radionuclides (ingested, inhaled, or received through a wound) dispersed from a radiological dispersal device or a nuclear power plant accident. Acute Radiation Syndrome (ARS) is an acute illness caused by irradiation of a substantial portion of the body. The more radiosensitive tissues are affected first, and as the absorbed dose increases, additional tissues and organs are involved, leading to ARS (with component sub-syndromes, e.g., hematopoietic, gastrointestinal, cutaneous, central nervous system) and delayed effects of radiation exposure ([DEARE], including pneumonitis, lung or kidney fibrosis, and increased risk of cancer) (see Table 1). ARS management is discussed in the chapter by Chao (#4).

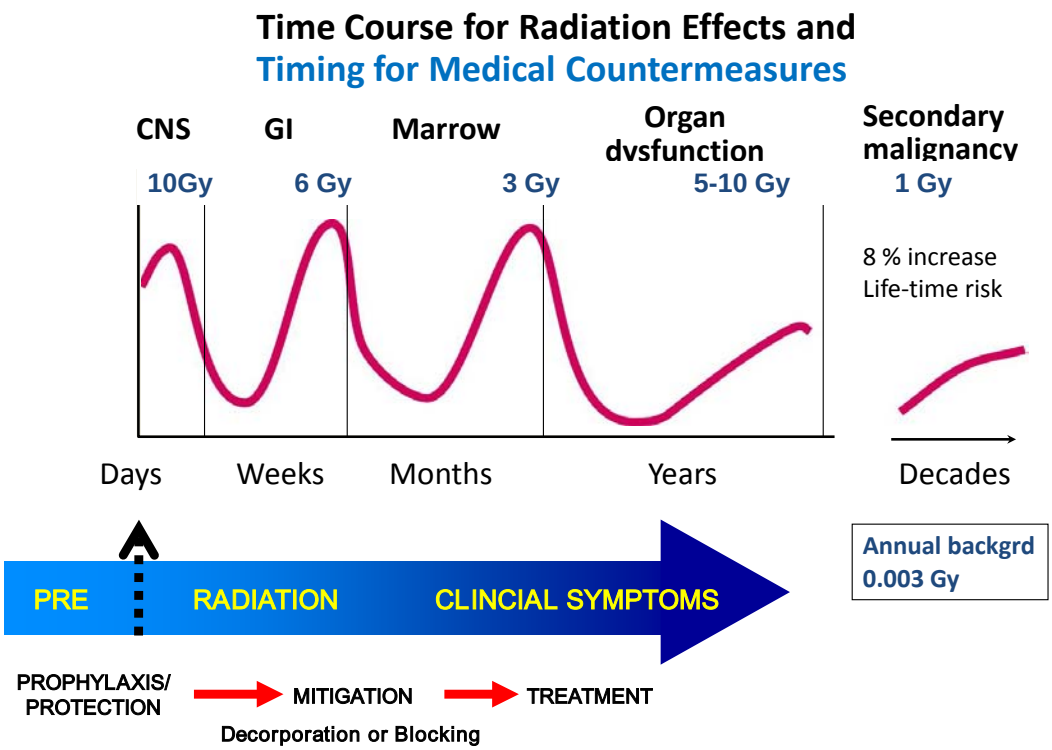
Table 1. Expected health outcomes as a function of absorbed radiation dose.

Acute Radiation Syndrome: Dose-Dependent Effects in Humans (adapted from[9])		
Dose Range, Gy	**Manifestation of Illness**	**Prognosis (without therapy)**
0.5 – 1	Slight decrease in blood cell counts	Almost certain survival
1 – 2	Early signs of bone marrow damage	Highly probable survival (>90%)
2 – 3.5	Moderate to severe bone marrow damage	Probable survival
3.5 – 5.5	Severe bone marrow damage, slight GI damage	Death within 3.5 –6 wk (~50% of victims)
5.5 – 7.5	Pancytopenia and moderate GI damage	Death probable within 2-3 wk
7.5 – 10	Marked GI and bone marrow damage,	Death probable within 1-2.5 wk

	hypotension	
10 – 20	Severe GI damage, pneumonitis, altered mental status, cognitive dysfunction	Death certain within 5-12 d
20 – 30	Cerebrovascular collapse, fever, shock	Death certain within 2-5 d

The time course for radiation effects are illustrated in Figure 1 which includes the definition of MCMs based on when they are administered. Radiation mitigators are the major focus of NIAID and BARDA research programs.

Figure 1.



MCMs can be characterized as follows:

- Protectors – given before exposure to radiation to lessen effects;
- Mitigators – given after exposure to reduce severity of effects before clinical manifestation; or
- Treatments – given after clinical manifestation of effects. An MCM such as a myeloid cytokine for the hematological syndrome can be both a mitigator and a treatment.

A few MCMs for radiation-related indications are FDA-approved—decorporation and blocking agents that facilitate removal or blocking cellular uptake thereby reducing the effects of internalized radionuclides—but currently no MCMs are FDA-approved to treat individuals with ARS or DEARE (see Table 2). Some MCMs approved for other medical indications might be useful to treat ARS[9] or DEARE; these could be used under an Emergency Use Authorization (http://www.fda.gov/emergencypreparedness/counterterrorism/ucm182568.htm). *Indeed, a key approach to MCM development is for a "dual utility" drug that has a routine use in medical care. This will enhance availability and also ensure that medical personnel are familiar with its use.*

Table 2. Approved radiation medical countermeasures.

- Decorporation agents
  - Calcium diethylenetriaminepentaacetate (ca-DTPA)
  - Zinc DTPA (Zn-DTPA)
  - Prussian Blue
- Blocking agents
  - Potassium iodide (KI) tablets and liquid solution
- Radioprotectants
  - Amifostine (approved indication is for head and neck cancer patients
- Antineutropenic agents
  - Granulocyte colony-stimulating factor (G-CSF) and pegylated G-CSF (approved indication is chemical-induced neutropenia)

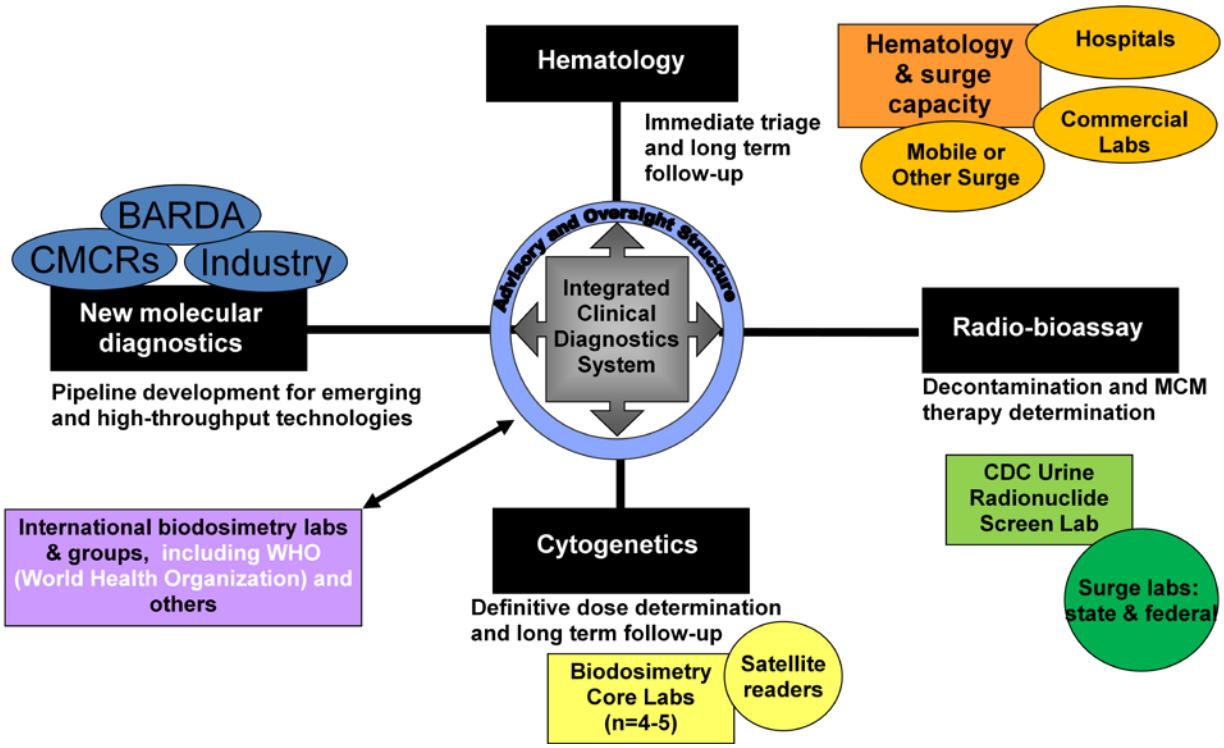
Diagnostics

For efficient employment of medical resources, prompt and effective treatment of exposed individuals, and for optimum use of radiation MCMs to be dispensed to those who need them, first responders and medical teams must be able to make accurate radiation dose assessments. Two of the most reliable biological effects of radiation are DNA damage and leukocyte depletion (lymphocyte depletion kinetics), which can be estimated based on hematological parameters [10-11] or chromosomal aberration assays (the dicentric chromosome or micronucleus assay) (http://www.remm.nlm.gov/ars_wbd.htm#lymphocyte). The diagnosis of ARS is currently based on the patient history, prodromal signs and symptoms (including the onset of emesis), hematology (blood counts) and manual or semi-automated laboratory-based cytogenetic assays. Diagnostics can be expedited by potentially combining cytogenetic laboratories within a Radiation Laboratory Network (RAD-LN) (or Integrated Clinical Diagnostics System (ICDS)) and the development and acquisition of novel biodosimetry tools supported through the NIAID/BARDA pipeline. Environmental radiation dosimeters can be used to measure the exposure that a victim could have received in the area of the dosimeter, even though they do not directly determine absorbed dose to the person. Internal contamination is primarily a risk for radiological dispersal devices (RDDs) or nuclear power plant incidents.

Nuclear detonations are not considered to provide a great risk of internal contamination, as the particle size of fallout is often too large to be internalized through inhalation[12] and contamination through food sources can be avoided. The Centers for Disease Control and Prevention (CDC) have a radiobioassay laboratory that can assay for internal radioactive contaminants.[13] Assistance in assaying for internal radioactive contamination could also be obtained from experts in nuclear medicine and radiation safety.

Figure 2 (from Grace et al[6]) is a conceptual approach to developing laboratory capabilities for radiation exposure and internal contamination assessments. The Rad-LN is a concept under development by multi-agency experts coordinated by ASPR with other HHS and federal partners.[6] The Rad-LN would provide increased cytogenetic dicentric chromosome assay (DCA) capabilities, enhanced capacities for the CDC Radiobioassay Laboratory, and hematology surge capacities by networking labs (including commercial diagnostic laboratories), increasing mobile capacity, providing certified protocols and guidance, and leveraging international collaboration. Because techniques such as cytogenetics are routinely done in hospitals, regional and state networks can help provide surge capacity with some training in the DCA and exercising as demonstrated in Connecticut.[14] The proposed Rad-LN could also serve as a test bed for assessment and inter-laboratory comparison for novel biodosimetry devices and potential biomarkers and as a node for ensuring adequate oversight, balancing investment, and optimizing or improving existing capabilities.

Figure 2. Components of Radiation-Laboratory Diagnostics (modified from Grace et al[6]).



No biodosimetry assays or devices to determine if individuals were exposed to radiation or radionuclides are currently FDA-approved. Current laboratory triage techniques such as the

rate of lymphocyte depletion kinetics can provide an early estimate of dose but require serial readings over several days to be more accurate (See REMM [11]). DCA has been the gold standard for assessment of absorbed dose in radiation accidents for decades and is currently the tool of choice for estimating radiation dose. However DCA is labor-intensive and time-consuming, and strategies are needed to increase assay throughput for efficient use in a mass-casualty scenario. Rapid and accurate biodosimetry methods that can be used in a mass-casualty incident are needed for immediate triage, medical management, and risk assessments.

Medical countermeasure developmental activities

The mission space is extensive and includes MCMs for ARS mitigation, radionuclide decorporation, and biodosimetry (Table 3). The types of MCMs that are currently being researched, evaluated, and developed are listed in Table 4.

Table 3. Radiation Countermeasure Mission Space

- ARS/ DEARE
  - Hematopoietic ARS
    - Neutropenia
    - Thrombocytopenia
    - Anemia
    - Lymphopenia
  - GI ARS
  - CNS injury
  - Cutaneous injury
  - Lung injury
  - Kidney injury
  - Combined radiation injury
- Biodosimetry Methods and Devices
- Radionuclide Threats
  - Am-241
  - Co-60
  - Cs-137
  - I-131
  - Ir-192
  - Po-210
  - Pu-238/239
  - Sr-90
  - U-235
- Late Effects
  - Carcinogenesis
  - Cardiovascular disease
  - Cataractogenesis

Table 4. Radiation/Nuclear Medical Countermeasures

- Mechanisms of Action
  - Anti-oxidants
  - Anti-inflammatories
  - Anti-apoptotics
  - Growth factors and cytokines
  - Cell-based therapies
  - Others
- Radiation Syndromes
  - Acute radiation syndromes (HE, GI, CNS)
  - Delayed effects of radiation exposure (skin, lung, kidney, others)
- Radionuclides
  - Blocking agents
  - Decorporation agents

Technologies that are high-throughput, rapid, simple, field-rugged, and inexpensive are currently under development for biodosimetry. Ccandidate technologies employ the following techniques:

- Genomics
- Proteomics
- Metabolomics
- Lipidomics
- Glycanomics
- Electron paramagnetic resonance
- Optical spin resonance
- DNA damage assay
- Micronucleus assay
- Dicentric assay

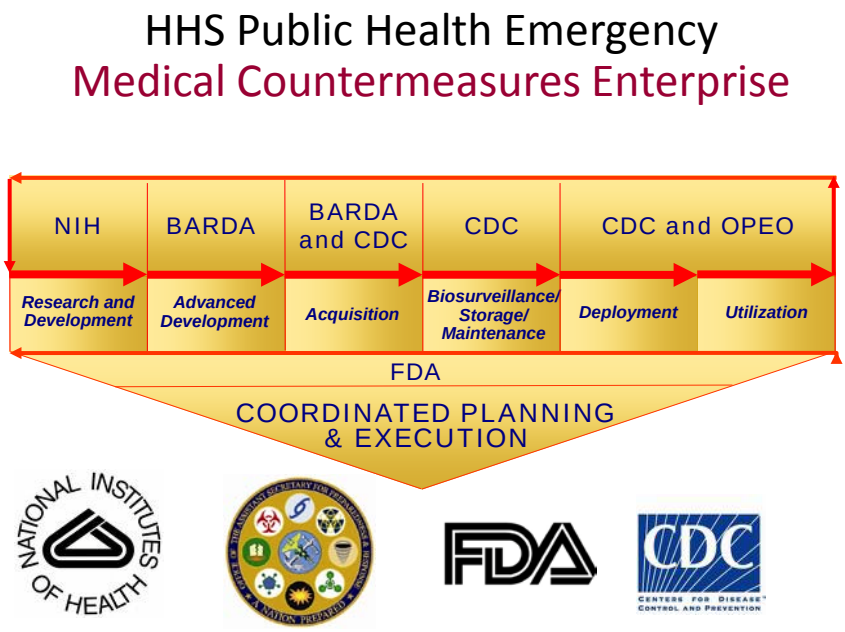
Pursuing biomarker validation and FDA clearance of biodosimetry systems for clinical diagnostic use is challenging. Inherent biomarker variables must be addressed including (1) genetic and epigenetic influences; (2) temporal and inter-individual variability of expression; (3) variance of baseline expression; and (4) other confounders (e.g., current medications or supplements, radiation treatment for cancer, age, gender). Additionally, operational issues must be addressed, including (1) sample collection, transport, tracking, and processing in an incident response; (2) assay detection limits; and (3) patient tracking. Technologies currently under development for radionuclide decorporation have one or more of the following desirable features:

- Effective and safe for decorporation of multiple radionuclides;
- Route of administration appropriate for mass casualties—oral, dermal patch, metered dose inhaler;
- Oral formulations (ease of distribution and administration in mass-casualty incident and for at-risk populations, including formulations suitable for children);
- Enhance pulmonary clearance (increase mucociliary motility); and
- Chelation capability in molecules with oral absorption, higher potency, or wider range of radionuclide decorporation efficacy than for currently available MCMs

Multi-clinical/medical utility and models of distribution/stockpiling. Given the cost and complexity of drug development, novel approaches to drug development and distribution are considered as detailed in Coleman et al.[15] In particular, medical countermeasures with ongoing utility in the absence of a mass-casualty incident are particularly desirable—"multi-clinical or medical use" products.[16] Similarly, laboratory networking can be dual-utility with hematology, cytogenetics, drug/toxin assay, nuclear medicine/radiation safety and emerging biomarker tests used for managing diseases such as cancer.

Science-based discovery, development, and delivery. The components of the Public Health Emergency Medical Countermeasures Enterprise participate in a procedural continuum, coordinated by the ASPR with the help of its Office of Policy and Planning (Figure 3). As drugs and diagnostics are developed, the delivery and "concept of operations" are modified to take advantage of these improvements.

Figure 3. Continuum from research and development through deployment and utilization. The MCMs (including diagnostics) are based on basic and applied science.



Conclusion

The health and medical response to a radiological/nuclear incident requires close alignment and coordination of the medical countermeasure technologies that are developed and deployed with the logistical and operational requirements and considerations. The ASPR, with the help of its Office of Policy and Planning, fosters this alignment and coordination through the PHEMCE. NIAID and BARDA foster development of MCMs in this context based on novel, high-quality scientific discovery and rigorous product and clinical development programs to achieve FDA approval.

Authors

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Strategic Framework for Providing Radiation Sickness Medical Countermeasures and Supplies in a Scarce Resources Setting: Local, Regional and Federal Resources

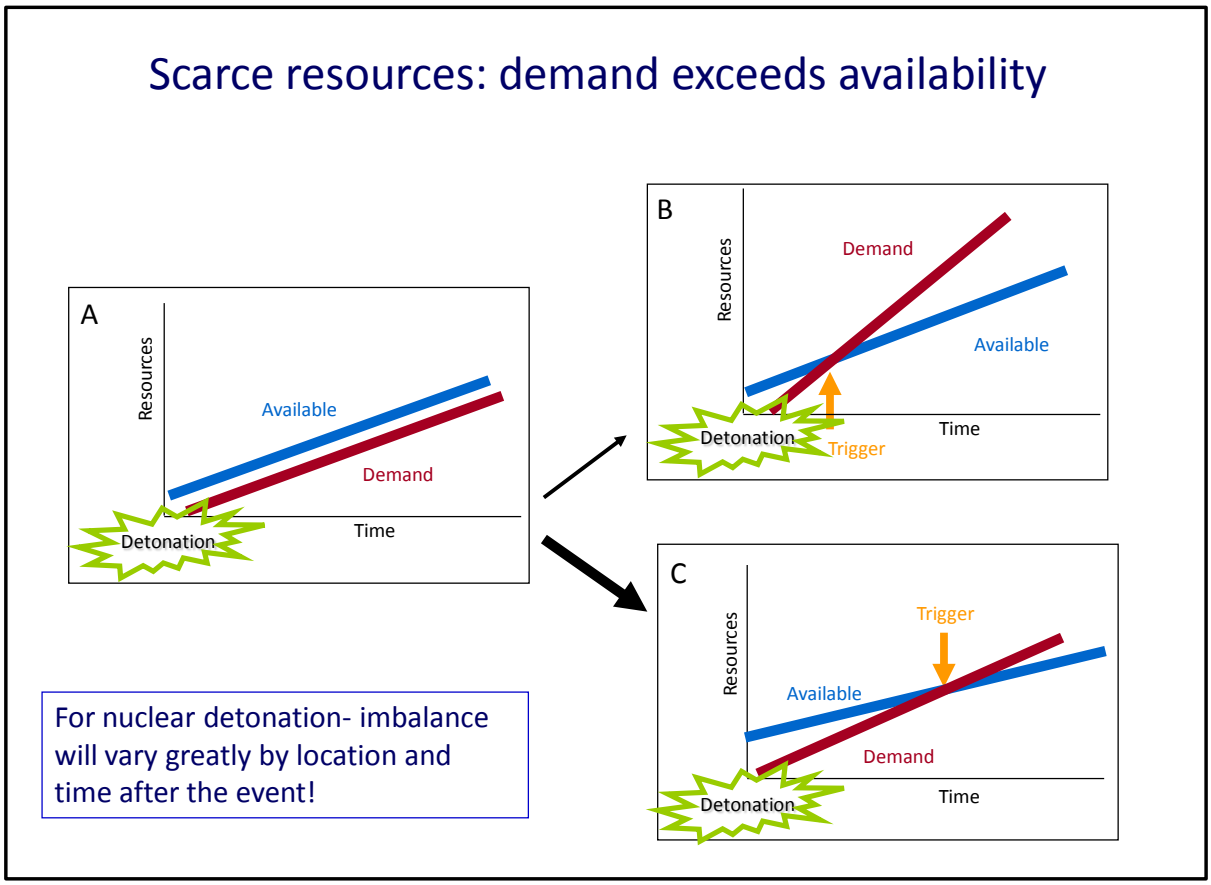
Overview

The immediate need for space, staff, medical countermeasures (MCMs) and supplies will likely be overwhelmed in a mass casualty incident, possibly creating a scarcity of resources. The extent of the scarcity will determine operational standards of care and the triage category in which medical providers place each individual. Given the extraordinary medical requirement for thousands of injured or sick people, it is not possible to preposition all necessary medical countermeasures and supplies. However, strategies for resource allocation under conditions of scarcity can help save lives, reduce morbidity, and improve the provision of compassionate care in a time of crisis. Current strategies in use or under development include state and regional stockpiles, User-Managed Inventory (UMI), Distributor-Managed Inventory (DMI) and the CDC's Strategic National Stockpile (SNS), which includes Vendor-Managed Inventory (VMI). Community and national preparedness should focus on the positioning and deployability of MCMs with routine medical uses (i.e., those with "dual utility"). For example, drugs that are in routine use for oncology and hematology may be effective MCMs for those with acute radiation syndrome (ARS) despite lack of licensure for this indication by the Food and Drug Administration (FDA). In order to allow for the use of MCMs for non-labeled indications under declaration of an emergency, the U.S. government has established a mechanism known as Emergency Use Authorization (EUA). Further policy refinement and integration of strategies for addressing the scarcity of resources during a mass casualty incident will be needed to optimize response coordination. These planning efforts could save lives and assist the immediate victims of a mass casualty incident.

Scarce Resources

The goal of planning and preparation is to have resources available to exceed the need, as in Figure 1A.[1] Following a nuclear detonation there will be an imbalance—a "trigger"—(Figure 1B) where need exceeds available resources at some locations,[2] (Note: the term "demand" is often used in medical parlance) (see Figure 2 in Coleman[3]). The goal of planning is to delay the trigger (Figure 1C) in order to minimize the time to resource replenishment in the "Poor" resource availability setting and in the "Crisis" standard of care condition.[3,4]

Figure 1A-C. Scarce Resources Occur As Need Exceeds Available Resources

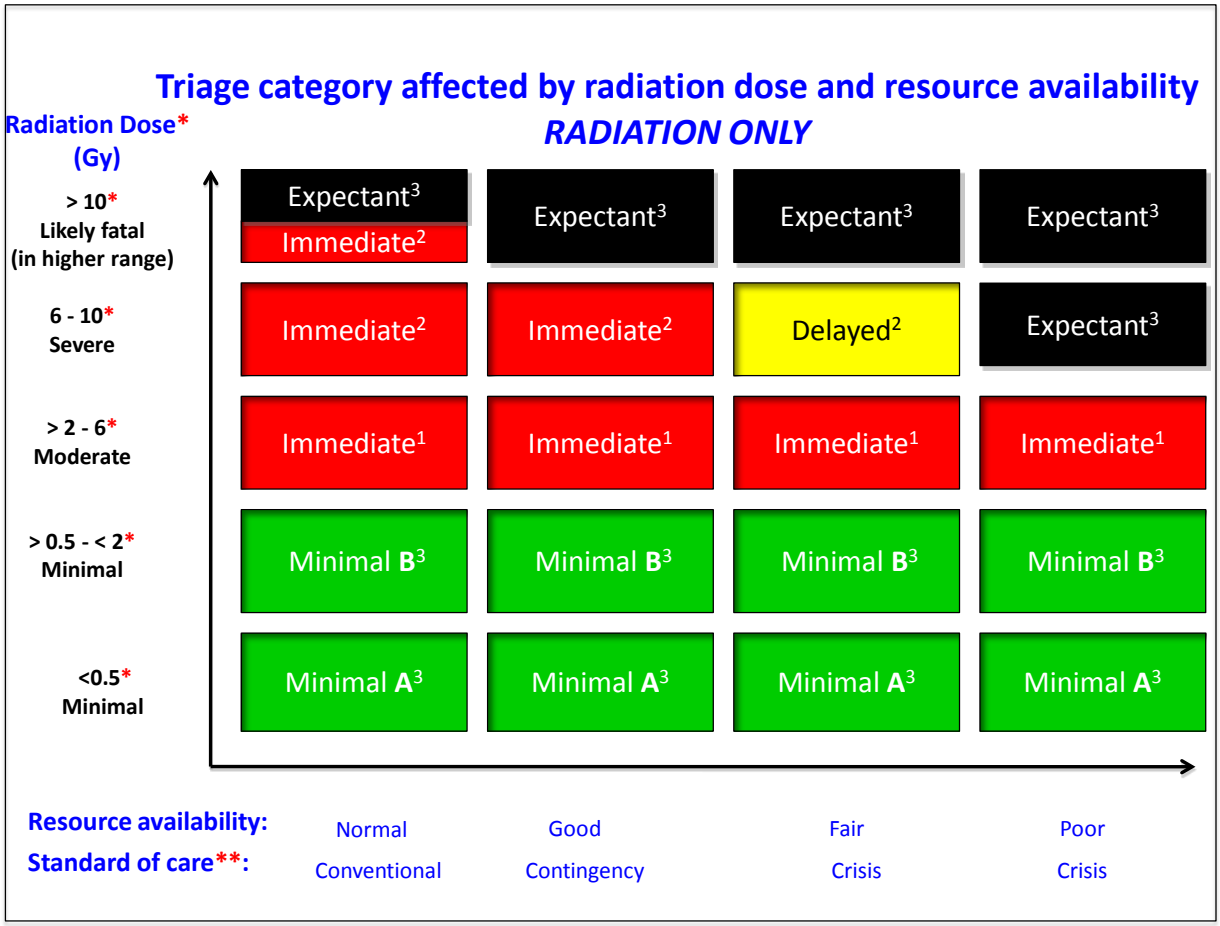


The impact of availability of resources on the medical care that can be administered is illustrated in Figure 2 using an example of victims with radiation sickness due to an improvised nuclear device detonation. This example includes people exposed to radiation only (i.e., no physical trauma), and provides a visual illustration of how the triage category would change as resource availability declines.[5] Details of triage for a nuclear detonation can be found in Coleman[5] and on the Radiation Emergency Medical Management (REMM).[6]

People needing immediate treatment priority (above "Minimal") are most likely to benefit ("Immediate"), followed by people who can wait, noted by the term "Delayed," and people judged to be "Expectant." As resource scarcity worsens, fewer people can be treated and the share of people benefiting from treatment declines as show on the x-axis of Figure 2. People who have received moderate radiation doses in the range of 2 - 6 Gy are most likely to benefit from medical intervention and would receive "Immediate" attention in all resource settings. On the other hand, the treatment priority of those who received severe radiation doses in the range of 6 - 10 Gy (and whose lives might be saved given sufficient resources to deliver a "Conventional" standard of care under "Normal" and "Good" resource availability) would be "Delayed" when there are crisis standards with "Fair" resources available, and "Expectant" when there is "Poor" resource availability.[5] Stated succinctly, the goal of planning and response is to avoid or delay "Fair" or "Poor" resource availability settings. Similarly, a key goal of

planning and response under conditions of limited resource availability is to resolve the shortages as rapidly as possible. Repeat triage is an essential component of the response so that a person initially triaged as "Delayed" or even "Expectant" could become "Immediate" as resources arrive.

Figure 2. Triage Category Depends On Both Severity Of Injury and Also On Resource Availability[5]



Bone marrow cytokines routinely used in the care of oncology and hematology patients are also critical MCMs for treating ARS in people who have received moderate or severe doses of radiation.[2] One such medical countermeasure is granulocyte-colony stimulating factor (G-CSF); however, there are others in this category. An example of how the need for bone marrow cytokines could be met for ARS is discussed below in Figure 3.

Figure 3. This legend for Figure 2 describes the definitions of resource availability below normal and provides a prioritization for the use of bone marrow cytokines.

Legend- Radiation Only

* Radiation dose received by the whole body or a significant portion of the whole body.
** Crisis standards of care IOM Letter Report 2009

Minimal B: Consider repeating both biodosimetry and clinical reassessments, especially at high end of this dose range
Minimal A. <0.5 Those with physical dose estimates based on location below 0.5 Gy need not report for medical evaluation. Joining a registry may be suggested after the incident.

The red/black split triage category for >10 Gy indicates that some victims may receive aggressive treatment at discretion of physician, especially if 10 Gy is received over prolonged time period.

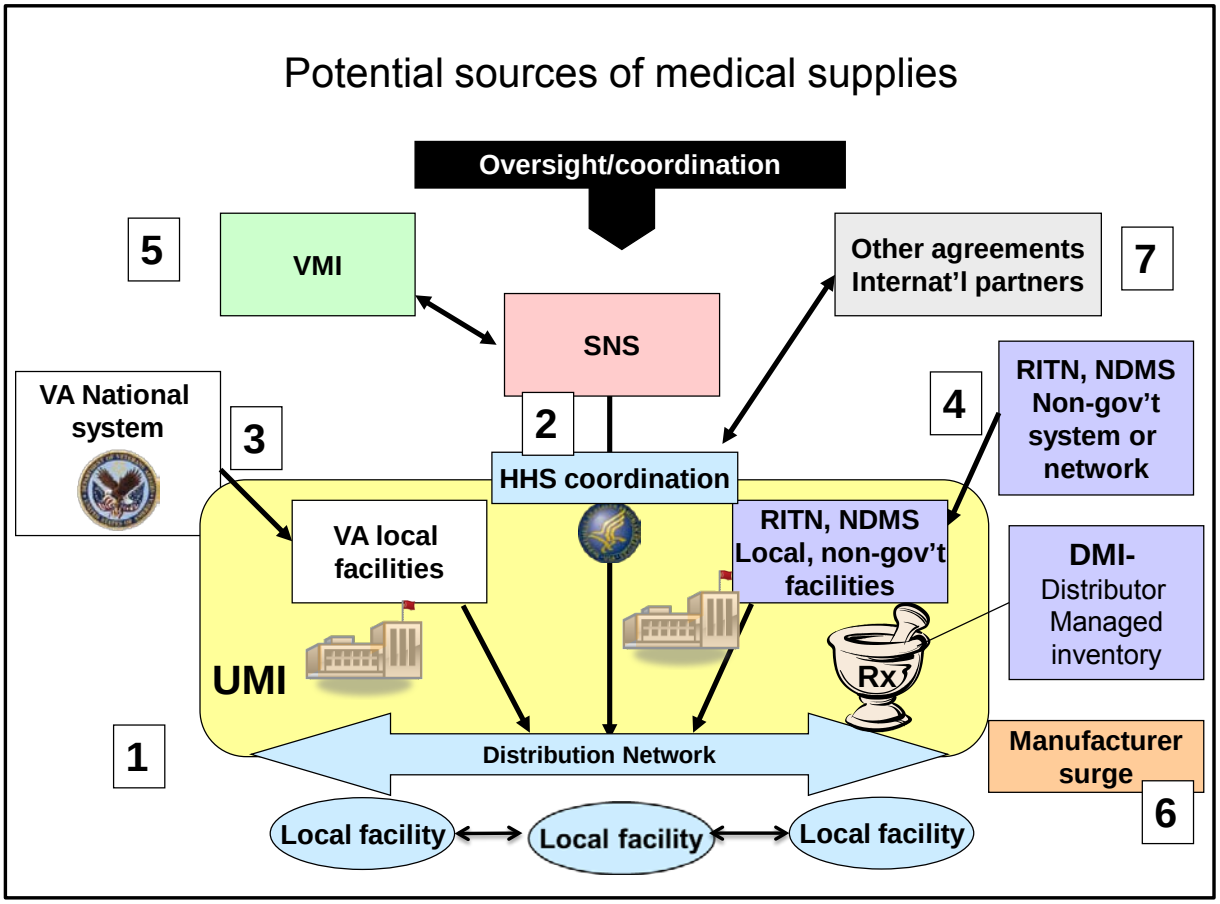
Resource availability below NORMAL:
GOOD conditions allow for maintenance of "functionally-equivalent" care through contingency operations
FAIR conditions require delaying care for severe injuries after moderate injuries
POOR conditions require classifying severe injuries as expectant

Myeloid cytokine category	G-CSF recommendation
1	G-CSF indicated.
2	G-CSF indicated, lower priority than Category 1.
3	G-CSF not indicated.

MCM Availability

Figure 4 illustrates potential sources of medical supplies and MCMs. The medical countermeasures used for the ARS example earlier are the bone marrow cytokines for the acute radiation hematological syndrome.[2] Current evidence indicates that cytokines administered *within 24 hours of exposure* mitigate the severity of the radiation injury, lowering infection rates, improving survival,[7] reducing the need for hospitalization, and decreasing the medical resources, staff, and space required to treat patients.

Figure 4. Potential Sources of Medical Supplies



The initial medical response will be undertaken by local responders in local facilities. In general, hospitals and medical facilities keep very low inventory and use "just-in-time" inventory management for obtaining and utilizing resources. Working from the local facility up, one could supplement supplies with the following:

- Local distribution networks by the user (i.e., UMI [#1]) or by the distributor (i.e., DMI), which could include a sufficient inventory or "bubble" to help meet immediate surge needs.[8] Since cytokines have a multi-year shelf life and are used routinely in cancer care, it may be possible to keep a 3-12 month supply on hand that could be used before it expires. This would provide many more "first doses" than otherwise possible with the just-in-time inventory approach. Potential participants in UMI include the Veteran's Administration [#3] and the Radiation Injury Treatment Network [#4].[9]
- The Strategic National Stockpile,[10] a national repository of pharmaceuticals, medical supplies, and equipment that can be deployed during a public health emergency for use by local/state/regional responders. Initial supplies can reach the affected area within 12-24 hours of the federal decision to deploy. The SNS also has agreements with

manufacturers to store some pharmaceuticals and supplies, called VMI, [#5] as part of their operational plan.

- Manufacturer surge capacity, which would likely occur either voluntarily in response to obvious need or by request of the local, state or federal government [#6]. This will likely take days to weeks.
- Medical supplies or drugs obtained from international partners in special circumstances [#7], although importing drugs is complicated and requires complex approval among governments as well as by the FDA.

Dual-Utility Concept of MCMs and Supplies

A favored approach to developing MCMs for terrorism and mass casualty response is to use drugs or supplies that have a routine use in medical care. This ensures familiarity of the MCMs within the medical community. Stockpiling can be problematic for drugs with short shelf lives, as frequent replacement is necessary unless the drug is eligible for the FDA's Shelf-life Extension Program. However, for drugs that may have a limited market, stockpiling may be an incentive to induce entry into the marketplace by drug manufacturers. Bone marrow cytokines fit the definition of "dual utility," as do antibiotics and other drugs.

EUA and "Off-Label" Use

Prescription drugs for use in medical care are approved by the FDA for treatment of a specific condition or disease and the prescribed use defined in the drug's labeling. While physicians routinely use prescription medications for "off-label" use in their daily practice, in a large scale emergency, there will be no or limited physician-patient relationship allowing this to occur. An Emergency Use Authorization[11] would be requested to use the drug for any purpose other than those detailed in the labeling.

The EUA authority granted by Congress in 2004 allows the FDA Commissioner to strengthen the public health protections against biological, chemical, radiological, and nuclear agents that may be used to attack the American people or the U.S. armed forces. Under section 564, the FDA Commissioner may allow MCMs to be used in an emergency to diagnose, treat, or prevent serious or life-threatening diseases or conditions caused by such agents, when there are no adequate, approved, and available alternatives.

At present, there are no drugs with a specific indication for treatment of ARS; however, there is vast experience in oncology, hematology, and bone marrow transplantation, all of which produce toxicity similar to radiation sickness. ARS treatment guidelines[6] are based on this prior medical experience and practice. A nuclear detonation will likely require treatment of ARS victims. As a result, drugs will need to be used "off label," as allowed by FDA regulation at the discretion of the physician in an established physician-patient relationship, or under an EUA granted by the FDA Commissioner for a large scale event.

Filling the Gap Before Outside Supplies Arrive

The pre-positioning of MCMs as close to an incident location as possible provides both time and logistical advantages for first responders. One innovation for increasing the availability of

MCMs as soon as possible after an incident is UMI which would be developed at the local, state and regional level, optimally in coordination with the federal planners. The benefits of UMI go beyond rapid deployment of MCMs by offering a more cost-effective approach for managing the inventory of MCMs compared to central stockpiling or VMI. The UMI concept is an emerging idea for enhancing distribution and stockpiling for MCMs.

The UMI concept is characterized by four key features:

(1) MCMs that are used for routine medical treatment and believed to be useful for treating mass casualty victims are considered "dual utility" drugs and may be appropriate for UMI consideration;
(2) The UMI model would require storage at multiple medical facilities across the nation; participating medical facilities would store a sufficient inventory or "bubble" to help meet immediate surge MCM needs;
(3) UMI-related MCMs would be managed to ensure the inventory would not expire before use; and
(4) The UMI "bubble" inventory would be used locally to treat casualties in an emergency, including evacuees from other localities.

The UMI "bubble" inventory could also be funneled locally to areas of greatest immediate need similar to central stockpiling and VMI. UMI implies a dynamic response system, linking the local, state, regional, and federal response while providing the potential for a more rapid response and more efficient management of limited resources; however, UMI would not eliminate the need for other stockpiling options and is not a good fit for all MCMs.

An additional advantage of UMI includes expanding widespread storage of MCMs—reducing the risk of mass MCM destruction at a single storage facility. The Veterans Administration medical care system is a natural fit for UMI, given its expanded role in civilian emergency response, its existing network of facilities/resources, and its well-developed pharmacy management system. With experience, data and further development, UMI could be considered for major medical centers, retail pharmacies, and distribution networks. UMI could potentially be more cost-effective than centrally stockpiling MCMs, by using first-in, first-out inventory management protocols that would eliminate wasteful expiration, replacement, and disposal of expensive dual-utility drugs.

Summary

The magnitude of the casualties and physical infrastructure following a nuclear detonation could produce a scarce resources situation, particularly close to the detonation site. This will likely require medical triage that differs from the usual "sickest first" standard.[5] Providing the necessary supplies will require preparation and innovative approaches beyond the "just-in-time" inventory used by medical facilities.

Authors

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The Increasing Role of Technology in Educating Responders and Planners about Mass Casualty Radiation Emergencies

Overview

The complex knowledge required for planning for and responding to medical aspects of a mass casualty radiation incident includes understanding at least the following: (1) the types of radiation emergencies that might occur, (2) how responses to "small" and "large" incidents differ, (3) the basics of radiation physics, (4) the difference between exposure and contamination, (5) how to diagnose and manage external and internal contamination, (6) how to diagnose and manage acute radiation syndrome, (7) principles, practices, and regulations of radiation safety including the proper use personal protective equipment, and (8) the basics of long-term effects of radiation exposure.

The actual depth of knowledge required will vary considerably, depending on the actual professional role during the incident, e.g., subject matter expert, emergency physician, trauma surgeon, health physicist, nurse, first responder in the field, regional response planner, staff at community reception centers and field medical stations. Even medical support personnel in hospitals who do not perform direct patient care will also need some training, as will workers in public safety, public health, public transport, and public utilities. This paper will focus only on those involved in planning for or delivering patient care.

A variety of types of radiation incidents require this specialized medical knowledge. A nuclear detonation is a complex, low-likelihood, high-consequence incident. Incidents with potentially large but less catastrophic consequences include industrial and transportation incidents, nuclear power plant incidents, large accidental medical exposures, and incidents related to terrorist-instigated radiological dispersal or exposure devices.

While customized pre-incident radiation education and training are available for the full range of health care responders and others, these resources have been significantly underutilized for a variety of reasons. In addition, there are sparse data about effectiveness of the training and how often it needs to be repeated for each type of responder. Currently there are major gaps in what responders do know and what they need to know. This paper addresses the nature of the gaps and a variety of potential approaches needed to narrow it.

Formulating the Problem: Information Gap

Complex, high-impact, low frequency incidents

Radiation emergencies are more complicated, potentially higher impact, and but much less likely to occur than many other kinds of mass casualty health emergencies that responders and planners routinely face. Recently, the term "black swan" has been applied to incidents of this nature.[1] "Black swan" incidents are not widely anticipated or planned for. Although high impact, mass casualty radiation emergencies are receiving increasing attention among the senior leaders of the medical planning and healthcare response communities[2], radiation-

specific training for the vast majority of planners and responders has lagged behind all-hazard training for other types of mass casualty emergencies.[3]

Lack of knowledge among healthcare workers charged with planning and responding
First responders, first receivers, and planners for radiation mass casualty emergencies need to acquire and maintain radiation-specific knowledge and skills over and above what they know from training for "all hazard" emergencies. At present, there is no universal agreement about the exact nature of the potential core radiation curriculum for the various types of responders. Moreover, few emergency or healthcare personnel have ever responded to or practiced for any type of radiation mass casualty emergency in formal drills or exercises.

Most health care responders with direct patient care responsibilities probably need to learn at least the basics about following:

- The types of radiation emergencies that might occur[4]
- How responses to "small" and "large" incidents differ
- Radiation physics[5]
- The difference between exposure and contamination[6]
- How to diagnose and manage external and internal contamination[7]
- How to diagnose and manage acute radiation syndrome[8]
- Principles, practices, and regulations of radiation safety including the proper use personal protective equipment[9]
- The basics of long-term effects of radiation exposure[10]

These knowledge gaps, along with worsening resource constraints, have complicated the development and implementation of detailed radiation emergency response plans. Furthermore, the statutes and regulations that govern federal, state, and local authorities and responsibilities during such incidents are complicated[11], making it difficult to create regulation-compliant, coordinated, realistic, detailed, and implementable plans for all entities that will be involved, including those in the private sector.

Reluctance to engage
Reluctance to train for and respond to radiation mass casualty emergencies has been reported, possibly resulting from one or more commonly held beliefs, including[12-15]

- Radiation medicine is too complicated for me to understand.
- If I learn this material I will forget it, especially if I don't use it.
- My personal risk during and after responding will be too high to participate in the response.
- Protecting and being with my family is my highest priority.
- Radiation response is the job of federal workers.
- Rescuing victims of radiation exposure is futile.
- We don't have the all the equipment and personnel necessary to do this correctly.

Approaching the Solution: Education and Training

Education and training[16-19] can address some of these gap issues, using both traditional and non-traditional (technological-based) means, as set forth in Table 1 below.

Table 1.

Traditional: Face-To-Face, Synchronous Classroom Learning
Advantages

• Classroom courses are currently available from many local, state, and federal agencies, [16-18] as well as professional societies, educational institutions, hospitals, and worker associations.
  • Resource materials for these courses are usually vetted by the offering agency/professional society/government agency.
  • Basic concepts are taught along with practical skills, including:
  o How to select, calibrate and use radiation survey equipment
  o Proper selection, donning, and doffing of personal protective equipment (PPE)
  o Selection, wear, and use of personal dosimeters appropriate for each response role
  o How to work in teams, especially within the Incident Command System (ICS) [20] and Hospital Incident Command System (HICS) [21]
  • Large government agencies medical credentialing entities can include questions about radiation emergencies in initial re-certification examinations.

Disadvantages

• Expense
  o Presenting courses in real time is expensive for agencies.
  o Face-to-face classroom training is expensive for students in terms of both money and time away from the job.
• There are relatively few subject matter experts in this field.
• Content must be updated regularly as administrative regulations/plans/procedures are updated and as medical practice advances.
• Official documents about radiation emergencies that underlie these training requirements are lengthy and beyond the expertise of most of trainees, even sophisticated medical responders.[11] Most responders and planners cannot be expected to read and understand them.
• Understanding and retention of complex, seldom-used content is poor.

Non-Traditional (Technology-Based) Educational Resources
Advantages
• Various electronic assets that provide radiation medical training and response already exist including websites and online courses,[16-19, 22-23] as well as content for mobile devices [24] Multimedia (photos, videos, animations) can enhance the efficiency and effectiveness of learning about complex radiation concepts and how to perform tasks.[25] • Novel teaching techniques can enhance interest in this topic and initiate learning in this topic, e.g., role-playing animated modules.[26] • Asynchronous learning is available 24/7, at the convenience of the student, and usually at a smaller cost than classroom training. • “What you need to know” can be provided to planners and responders “just-in-time” at the

time of the incident, when they are highly motivated learners. • Agencies leveraging technology assets (personnel and physical) can potentially save time and money, if the scale is large. • Content can be customized to the needs of the student, e.g. physician, nurse, EMT, etc. • Content updates can be disseminated more cost effectively than with print. • Mobile devices (smart phones) are ubiquitous, useful, and may be carried by many responders during the response[24]. Both interactive apps and content can be stored on smart phones. Tablet devices enhance the ability to carry content offline into the field. • Using continually updated, expert clinical management guidelines can assist clinicians working outside their usual scope of practice. This is familiar to clinicians, as algorithms are commonly used in medicine [6]. • Customizable templates for creating radiation emergency plans have been created that assist state and local medical agencies in developing their own response plans.[27-30] Final plans can then be published online in appropriately redacted or access-limited form.
Disadvantages

• Expense
  o There can be a major initial financial cost to create or purchase complete learning management enterprise platforms for large numbers of users.
  o Responders and planners enter training with widely differing needs, expertise, and sophistication. Customizing content for diverse audiences adds expense.
  o Building content for multiple mobile platforms is expensive.
• Pre-packaged, commercially generated course content may not match the procedures, plans, assets, and personnel of each venue.
• Downloaded content can become obsolete. Users need to be notified as content changes to update previously downloaded materials.
• Technology alone cannot totally replace face to face training for many things, including
  o Formal training in teams
  o Assessment of certain physical and cognitive skills like donning and doffing of personal protective equipment, the use of devices measuring radiation)

Technology can also assist with planning for and managing actual radiation incidents. A detailed description of all existing tools is beyond the scope of this chapter, but examples of such radiation incident management technology advances are available.[24] Some of the radiation-specific and all-hazard technological tools that are available include the following:

Radiation specific

- Hazard analysis with modeling and geographic information systems (GIS) helps managers make better decisions. These can include:
  - Maps with measured and estimated location-based radiation exposure levels (and other hazards) over time.
  - Maps with likely doses to the public and responders located in a specific area.
- Software to assist with clinical assessments of
  - Radiation dose (both external[30-32] and internal[30-31]) based on clinical and/or laboratory tests.

- Risk assessment of potential long-term adverse health effects like cancer[33]

It should be noted that few, if any of these software tools have been approved for clinical use by the FDA, and standard texts should also be consulted for estimating clinical dose from exposure and internal contamination.

All hazard

- Communication systems that:
  - Create and disseminate iteratively the accurate common operating picture among all responders
  - Enable faster, better, more secure command and control
  - Share operating plans, situation reports, task assignment details
  - Manage incident intelligence
- Social media assists information sharing [34-37]
  - Incident managers can acquire and process information rapidly from the public and disseminate accurate information back to the public.
  - Public and private enterprises can enhance rapid communication within organizations
- Electronic rostering of victims and responders for current and future management
- Methods of finding and reuniting separated family members
- Electronic health records that are easily transferred when victims move
- Detailed reference materials accessible to everyone

So What Is The Solution?

No single approach will fill all radiation training and education needs for each of the health care workers responding to mass casualty radiation emergencies. Each group of planners and responders and each venue will have to customize what they do to be "ready," given their unique set of risks, responsibilities, and assets. Subject matter experts and educators need to create useful, understandable, well-vetted, and up- to-date radiation medicine curricula that can supplement standard all-hazard training.

Trainers should be aware that technology could provide efficiencies for teaching, learning, credentialing, and responding, especially with "just-in-time" information available on mobile platforms. Nonetheless, it is crucial for students to access authoritative, vetted information, since misinformation is common on the Internet, especially regarding radiation emergencies and their management. One recent example includes the erroneous recommendations about the need for and benefits of potassium iodide in the United States during the 2011 Fukushima power plant incident in Japan.

Even after personal training is completed and repeated at appropriate intervals, healthcare planners and responders need to test and practice their skills and knowledge by participating in realistic, formal drills and exercises with the teams they will actually work with during the emergency.[38] Future enhancements in technology hardware, software, and networking will likely continue to improve managers' effectiveness and efficiency in complex incidents.

The U.S. Department of Health and Human Services has developed several websites, listed below which help fill radiation emergency information and training gaps.

- **Radiation Emergency Medical Management (REMM)** www.remm.nlm.gov provides just-in-time information, and vetted background material. There are also clinical tools for responders. Training opportunities from a variety of sources are also aggregated. www.remm.nlm.gov/training.htm
- **Centers for Disease Control and Prevention** focuses on radiation-related public health issues. Training opportunities are also provided. emergency.cdc.gov/radiation/
- **Office of the Assistant Secretary for Preparedness and Response,** focuses on integrating radiation issues into all-hazard preparedness and response. www.phe.gov/emergency/pages/default.aspx

Excellent radiation emergency training is also available on site and off site from

- Armed Forces Radiobiology Research Institute at the Uniformed Services University of the Health Sciences, Bethesda, MD. www.afrri.usuhs.mil/
- Radiation Emergency Assistance Center and Training Site (REAC/TS) at the Oak Ridge Institute for Science and Education (ORISE), Oak Ridge, TN. orise.orau.gov/reacts/

Conclusion

Although the response to radiation emergency mass casualty incidents is complex, there are new and more efficient ways to assist the responder and planning communities to prepare and respond to these "Black Swan" incidents.[1]

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International Agencies, Networks, and Radiation Safety Guidance

Overview

Any atmospheric release of radiation can become an international issue due to the presence of sensitive radiation detectors worldwide that monitor for potential nuclear testing and are able to detect very low levels of radiation. This paper includes the response capabilities of the major international agencies with whom the U.S. would interact and the response resources the U.S. would provide to other countries. The lowest levels that can be detected are well below the amount that requires any protective actions; however, given the fear of radiation, when radiation is detected it often requires investigation, explanation, and public education. The World Health Organization (WHO) and International Atomic Energy Agency (IAEA), both under the United Nations (UN), develop recommendations for planning and preparedness and assist with networks that have expertise and laboratory capability for biodosimetry (REMPAN) and medical response (RANET). Individual countries set their own protective action guidelines (projected doses used to limit exposure to workers and the public) based on expertise from professional societies such as the National Council for Radiation Protection (NCRP) and the International Commission on Radiological Protection (ICRP).

While all the guidelines are scientifically based, minor differences in dose and in radiation units used can produce some confusion. For international response, the U.S. has the United States Agency for International Development (USAID) Disaster Assistance Response Team (DART) and the Radiation Emergency Assistance Center/Training Site (REAC/TS) from the Department of Energy (DOE) as well as experts from the other federal agencies including Health and Human Services (HHS), Department of Defense, Nuclear Regulatory Commission, and others. Ideally, data sharing among the various groups will facilitate a coordinated response; however, the initial uncertainties from limited data and the minor differences in protective action guidelines among nations may serve to produce speculation and some confusion, which the communications and nuclear experts will need to address.

International Atomic Energy Agency (IAEA), United Nations[1]

The prime objectives of the IAEA's Response System are to facilitate:

1. Exchange of official real-time information among Member States/relevant international organizations;
2. Provision of assistance/advice to States/relevant international organizations upon request; and
3. Provision of relevant, timely, truthful, consistent and appropriate public information.

The **Emergency Notification and Assistance Technical Operations Manual (ENATOM)** defines the roles and responsibilities of the IAEA, the State Parties, and the IAEA Member States for being prepared and for responding to nuclear accidents and radiological emergencies. The IAEA maintains an Incident and Emergency Centre (IEC) that fulfills the functions that are placed on the IAEA by the Conventions and by relevant safety standards and decisions of the policy-making bodies.

Response and Assistance Network (RANET)[2]
RANET's major objectives:

1. Strengthen the IAEA's capability to provide assistance and advice, and/or to coordinate the provision of assistance as specified within the framework of the Assistance Convention, and
2. Promote emergency preparedness and response capabilities for nuclear or radiological emergencies/incidents among IAEA Member States.

In the U.S., REAC/TS is currently the only deployable response team that supports RANET.

World Health Organization (WHO), United Nations[1]
WHO works closely with the IAEA to prepare for and respond to nuclear accidents and radiological emergencies—principally to provide, consult, and coordinate medical assistance to victims of such events where severe radiation exposure has occurred. Advice can also be provided to national authorities on how to prepare and respond to such radiation accidents, or what kind of public health actions may be needed.

Emergency medical support for radiation exposed individuals is provided through the WHO's **Radiation Emergency Medical Preparedness and Assistance Network (REMPAN).**[3] REMPAN is activated following notification of a radiation accident with casualties from the IAEA or directly to WHO (even in the case of a single victim with severe overexposure).[4,5]

REMPAN's objectives:

1. To promote medical preparedness for radiation emergencies in WHO Member States;
2. To provide medical and public health advice, assistance, and coordination of medical management at international and regional levels in nuclear or radiological emergencies; and
3. To assist in follow-up studies and rehabilitation.

Assistance provided by Collaborating Centers and Liaison Institutes in radiation emergencies may include:

- Human Resources Specialists: Specialists in radiation medicine, health physics, radiology, hematology, and other appropriate specialties (e.g., burn departments), as well as skilled nurses and technicians.
- Equipment: Most centers are well-equipped to provide special medical assistance to overexposed persons. They have portable equipment for radiation monitoring.
- Medical Services: Assistance can be provided for the diagnosis, prognosis, medical treatment, and medical follow-up of persons affected by radiation.
- Scientific Services: Expertise can be provided to assess radiation doses to exposed persons (most of the REMPAN institutions have biodosimetry laboratories).
- Transportation: Advice can be provided on the transportation of affected persons.

- Specialized Teams: WHO can organize multinational teams to render medical assistance onsite.

WHO BioDoseNet[6,7]
WHO's BioDoseNet is a global network of biodosimetry laboratories whose role is to support management and decision-making in cases of large radiation emergency events where the capability of an individual laboratory is likely to be overwhelmed. In preparedness for such events, the BioDoseNet focuses on harmonization of methodology, quality assurance, knowledge-sharing, and intercomparision exercises.

Radiation Emergency Assistance Center/Training Site (REAC/TS)[8]
The Radiation Emergency Assistance Center/Training Site (REAC/TS), established in 1976 and operated by Oak Ridge Institute for Science and Education (ORISE), provides 24-hour direct or consultative assistance regarding medical and health physics problems associated with radiation in local, national, and international incidents.

REAC/TS is recognized as the established leader in the management of medical accidents involving radiation, both nationally and internationally. A team of leading experts in emergency management and radiation incident response, REAC/TS provides training and consultation to its clients, such as the U.S. Department of Energy (DOE) and the Centers for Disease Control and Prevention (CDC).

Some of the REAC/TS resources include:

On-call 24 hours
A radiological emergency response team consisting of physicians, nurses, health physicists, coordination and necessary support personnel, is on 24-hour call to provide first-line responders with consultative or direct medical and radiological assistance at the REAC/TS facility or at the accident site. Specifically, the team has expertise in, and is equipped to conduct:

1. Medical and radiological triage;
2. Decontamination procedures and therapies for external contamination and internally deposited radionuclides;
3. Diagnostic and prognostic assessments of radiation-induced injuries including DTPA and chelation therapy; and
4. Radiation dose estimates by methods that include cytogenic analysis, bioassay, and *in vivo* counting.

Training
The REAC/TS facility serves not only as a treatment facility, but also a central training and demonstration unit where U.S. and foreign medical, nursing, paramedical, and health physics personnel receive intense training in medical management for radiation accidents. Regularly-schedule courses for occupational health and emergency medicine professionals, as well as health/medical physicists, include:

- Pre-Hospital Radiation Emergency Preparedness (PREP);
- Radiation Emergency Medicine (REM);
- Health Physics in Radiation Emergencies (HPREM); and
- Advanced Radiation Medicine (ARM).

International Response

REAC/TS participates with the international community via its designation as a WHO Collaborating Center of the REMPAN and the IAEA RANET. In addition, REAC/TS has provided continuing medical education and accident response to over 40 countries.

As a WHO Collaborating Center, REAC/TS can:

- Serve as a focal point for advice and possible medical care in cases of human radiation injuries;
- Facilitate the progressive establishment of a network of equipment and specialized staff in human radiopathology;
- Assist in the establishment of medical emergency plans for large-scale radiation accidents;
- Develop and carry out coordinated studies on human radiopathology and epidemiological studies that may be appropriate;
- Assist in the preparation of relevant documents and guidelines; and
- In the case of actual radiation accident, provide direct or consultative services to foreign governments at the request of WHO or IAEA.

U.S. Agency for International Assistance (USAID), Office of the United States Foreign Disaster Assistance (OFDA), Disaster Assistance Response Team (DART)[9] The Office of United States Foreign Disaster Assistance (OFDA) is the office within United States Agency for International Development (USAID) responsible for facilitating and coordinating U.S. Government emergency assistance overseas. OFDA provides humanitarian assistance to save lives, alleviate human suffering, and reduce the social and economic impact of humanitarian emergencies worldwide.

OFDA deploys Disaster Assistance Response Teams (DART) in response to all types of natural disasters and other catastrophes where lives or livelihoods are threatened. These teams are assembled on an as-needed basis and include a range of experts from across the federal, state and local levels of government as well as the private sector. For example, in response to the nuclear accident in Japan, OFDA deployed a DART team consisting of urban search and rescue teams and technical experts in nuclear issues from across the U.S. Government.

Global Health Security Initiative (GHSI)[10]

The Global Health Security Initiative (GHSI) is an informal, international partnership among like-minded countries to strengthen health preparedness and response globally to threats of biological, chemical, radiological, and nuclear (CBRN) terrorism and pandemic influenza. This Initiative was launched in November 2001 by Canada, the European Union, France, Germany, Italy, Japan, Mexico, the United Kingdom, and the United States. The WHO serves as an expert

advisor to the GHSI. Technical and policy subject matter experts participate in working groups around specific areas of expertise:

- Risk Management and Communications Working Group
- Pandemic Influenza Working Group
- Chemical Events Working Group
- Radio-nuclear Threats Working Group
- Communicators Network
- Laboratory Network

Members of the Radio-nuclear Threats Working Group (RNWG) meet regularly in-person or via teleconference to share information on public health preparedness for radio-nuclear threats in their countries or organization.

Department of Health and Human Services (HHS)

The federal response structure is described in Larson.[11] Expertise on radiological and nuclear response is available from the Office of the Assistant Secretary for Preparedness and Response (ASPR)[12] and the CDC.[13] These experts will assist international incidents by providing advice and deployment, if requested.

Office of the Assistant Secretary for Preparedness and Response (ASPR)[12]

HHS leads and coordinates the overall federal health and medical response to an emergency, including supplemental assistance to state, local, tribal, and jurisdictional governments in identifying and meeting the public health and medical needs of victims of major disasters. It is coordinated by the HHS Secretary principally through ASPR and the Secretary's Operation Center (SOC). The SOC operates 24 hours a day, 7 days a week, 365 days a year and serves as a focal point for synthesis of critical public health and medical information on behalf of the U.S. Government. Its responsibilities include:

- Response Coordination;
- Public Health and Medical Deployment;
- Situational Awareness.

Center for Disease Control and Prevention, Radiation Emergencies[13]

The CDC Radiation Studies branch and collaborating groups within CDC provides technical expertise, educational fact sheets, tool kits for health professionals and responders, information on population monitoring and more.[14] The Agency for Toxic Substances and Disease Registry (ASTDR)[15] provides information and expertise on risk communication.

Protective Action Guidelines (PAG)[16]

The response to a nuclear incident involves three phases:[16]

- The **Early** phase (or emergency phase) is the period at the beginning of the incident when immediate decisions for effective protective actions are required, and when actual field-measurement data generally are not available.

- The **Intermediate** phase of the response may follow the early phase response in as little as a few hours. The intermediate phase of the response usually begins after the incident source and release have been brought under control and protective action decisions can be made based on measurement of the exposure and radioactive materials deposited.
- The **Late** phase is the period when recovery and cleanup actions designed to reduce radiation levels in the environment to acceptable levels are commenced. This phase ends when all the remediation actions have been completed. With additional time and increased understanding of the situation, there will be opportunities to involve key stakeholders in providing sound, cost-effective cleanup recommendations that are protective of human health and the environment.

PAGs are established by a wide range of experts. Background to the basics of radiation exposure and dose are described by Simon.[17] Protective action guidelines relate to the risk of developing a radiation-inducible cancer and are not related to the mitigation and medical countermeasures required for the acute radiation syndrome, described by Chao.[18] If the exposures are reached, there are protective action recommendations that are recommended. Tables 1 and 2 are U.S. guidance.[16] The National Council on Radiation Protection and Measurements (NCRP) assembles expert panels to address radiation issues.[19]

Table 1. PAGs for Radiological Dispersal Device (RDD) and Improvised Nuclear Device (IND) Incidents

TABLE 1.—PROTECTIVE ACTION GUIDES FOR RDD OR IND INCIDENTS

Phase	Protective action	Protective action guide	Reference
Early	Limit Emergency Worker Exposure.	5 rem (or greater under exceptional circumstances[1].	EPA PAG Manual.
	Sheltering of Public	1 to 5 rems projected dose[2]	EPA PAG Manual.
	Evacuation of Public	1 to 5 rems projected dose[3]	EPA PAG Manual.
	Administration of Prophylactic Drugs.	For potassium iodide, FDA Guidance dose values[4 5].	FDA Guidance[6].
Intermediate	Limit Worker Exposure	5 rem/yr	See Appendix 1.
	Relocation of General Public	2 rems, projected dose first year Subsequent years: 500 mrem/yr projected dose.	EPA PAG Manual.
	Food Interdiction	500 mrem/yr projected dose	FDA Guidance[7].
	Drinking Water Interdiction	500 mrem/yr dose	EPA guidance in development.
Late	Final Cleanup Actions	Late phase PAG based on optimization.	

[1] In cases when radiation control options are not available or, due to the magnitude of the incident, are not sufficient, doses above 5 rems may be unavoidable. For further discussion see Appendix 1.
[2] Should normally begin at 1 rem; however, sheltering may begin at lower levels if advantageous.
[3] Should normally begin at 1 rem.
[4] Provides protection from radioactive iodine only.
[5] For other information on medical prophylactics and treatment please refer to *http://www.fda.gov/cder/drugprepare/default.htm* or *http://www.bt.cdc.gov/radiation/index/asp* or *http://www.orau.gov/reacts*.
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Table 2. Guidelines for Emergency Workers

TABLE 2—EMERGENCY WORKER GUIDELINES IN THE EARLY PHASE[2]

Total effective dose equivalent (TEDE)[a] guideline	Activity	Condition
5*rem* (0.05 *Sv*)	All occupational exposures	All reasonably achievable actions have been taken to minimize dose.
10 *rem* (0.1 *Sv*)	Protecting valuable property necessary for public welfare (*e.g.*, a power plant).	• All appropriate actions and controls have been implemented; however, exceeding 5 *rem* (0.05 *Sv*) is unavoidable. • Responders have been fully informed of the risks of exposures they may experience. • Dose >5 *rem* (0.05 *Sv*) is on a voluntary basis. • Appropriate respiratory protection and other personal protection is provided and used. • Monitoring available to project or measure dose.
25 *rem* (0.25 *Sv*)[b]	Lifesaving or protection of large populations. It is highly unlikely that doses would reach this level in an RDD incident; however, worker doses higher than 25 *rem* (0.25 *Sv*) are conceivable in a catastrophic incident such as an IND incident.	• All appropriate actions and controls have been implemented; however, exceeding 5 *rem* (0.05 *Sv*) is unavoidable. • Responders have been fully informed of the risks of exposures they may experience. • Dose >5 *rem* (0.05 *Sv*) is on a voluntarily basis. • Appropriate respiratory protection and other personal protection is provided and used. • Monitoring available to project or measure dose.

[a] The projected sum of the effective dose equivalent from external radiation exposure and committed effective dose equivalent from internal radiation exposure.

[b] EPA's 1992 PAG Manual states that "Situations may also rarely occur in which a dose in excess of 25 *rem* for emergency exposure would be unavoidable in order to carry out a lifesaving operation or avoid extensive exposure of large populations." Similarly, the NCRP and ICRP raise the possibility that emergency responders might receive an equivalent dose that approaches or exceeds 50 *rem* (0.5 *Sv*) to a large portion of the body in a short time (Limitation of Exposure to Ionizing Radiation, National Council on Radiation Protection and Measures, NCRP Report 116 (1993a). If lifesaving emergency responder doses approach or exceed 50 *rem* (0.5 *Sv*) emergency responders must be made fully aware of both the acute and the chronic (cancer) risks of such exposure.

A key concept for managing radiation exposure is ALARA (As Low As Reasonably Achievable). Although it is debated, radiation risk models assume that any radiation can increase the lifetime risk of developing cancer,[20,21] with a single dose of 100 mSv increasing the overall lifetime risk of developing cancer by approximately 0.8%.[20]

The International Commission on Radiological Protection (ICRP)[22] provides guidance that differs from the U.S. guidance (Table 3). The issues of risk determination are discussed in more detail in Simon.[17]

Table 3: International Commission on Radiological Protection (ICRP) Guidance for Occupational Exposure[23]

Dose Guidance Value	Type of Emergency Operation

Normal occupational dose limits apply; i.e.,:
• A limit on effective dose of 20 mSv/year, averaged over 5 years (i.e., a limit of 100 mSv in 5 years) with the further provision that in any single year:
  o The effective dose should not exceed 50 mSv, and
  o The equivalent dose should not exceed
  ▪ 150 mSv for the lens of the eye,
  ▪ 500 mSv for the skin (average dose over 1 cm^2 of the most highly irradiated area of the skin) and
	Recovery and Restoration

▪ 500 mSv for the hands and feet	
• In principle, no dose restrictions are recommended if, and ONLY IF, the benefit to others clearly outweighs the rescuer's own risk. Otherwise, every effort should be made to avoid deterministic effects on health (i.e., effective doses below 1000 mSv should avoid serious deterministic health effects, and below ten times the maximium single year dose limit as given above should avoid other deterministic health effects). • All reasonable efforts should be made to keep doses below twice the maximum single year limits (see above).	Rescue operations:[1] • Saving life • Preventing serious injury • Actions to prevent the development of catastrophic conditions. Other immediate and urgent actions to prevent injuries or large doses to many people.

[1] Under conditions that may lead to doses above normal occupational exposure limits, workers should be volunteers and should be instructed in dealing with radiation hazards to allow them to make informed decisions. Female workers who may be pregnant or nursing should not participate in these operations. Adapted from International Commission on Radiological Protection.[23]

Summary

With the detectability of low levels of radiation, any significant atmospheric release from a nuclear detonation or nuclear power plant incident would become an international issue. The United Nations' IAEA and WHO will be involved in the assessment and medical response based on international reporting regulations and medical response networks. The U.S. international emergency assistance is coordinated through USAID with reach-back expertise to federal agencies. Health and medical expertise is available through HHS and REAC/TS (supported by DOE). Protective Action Guidelines provide total annual doses for various activities at which protective action recommendations are suggested. These are not fixed numbers and the ALARA (As Low As Reasonably Achievable) concept is important since the risk assumed may vary depending on the benefit derived.

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