The "RTR" Medical Response System for Nuclear and Radiological Mass-Casualty Incidents: A Functional TRiage-TReatment-TRansport Medical Response Model

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Abbreviations:
Gy = Gray (unit of radiation exposure)
HHS = [US] Department of Health and Human Services
IND = improvised nuclear device
PAG = Protective Action Guidelines
RDD = radiological dispersal device
REMM = Radiation Event Medical Management system
RTR = Radiation Triage, Treatment, and Transport medical response system

Abstract

Developing a mass-casualty medical response to the detonation of an improvised nuclear device (IND) or large radiological dispersal device (RDD) requires unique advanced planning due to the potential magnitude of the event, lack of warning, and radiation hazards. In order for medical care and resources to be collocated and matched to the requirements, a [US] Federal interagency medical response-planning group has developed a conceptual approach for responding to such nuclear and radiological incidents. The "RTR" system (comprising Radiation-specific **TR**iage, **TR**eatment, **TR**ansport sites) is designed to support medical care following a nuclear incident. Its purpose is to characterize, organize, and efficiently deploy appropriate materiel and personnel assets as close as physically possible to various categories of victims while preserving the safety of responders. The RTR system is not a medical triage system for individual patients. After an incident is characterized and safe perimeters are established, RTR sites should be determined in real-time that are based on the extent of destruction, environmental factors, residual radiation, available infrastructure, and transportation routes. Such RTR sites are divided into three types depending on their physical/situational relationship to the incident. The RTR1 sites are near the epicenter with residual radiation and include victims with blast injuries and other major traumatic injuries including radiation exposure; RTR2 sites are situated in relationship to the plume with varying amounts of residual radiation present, with most victims being ambulatory; and RTR3 sites are collection and transport sites with minimal or no radiation present or exposure risk and a victim population with a potential variety of injuries or radiation exposures. Medical Care sites are predetermined sites at which definitive medical care is given to those in immediate need of care. They include local/regional hospitals, medical centers, other sites such as nursing homes and outpatient clinics, nationwide expert medical centers (such as cancer or burn centers), and possible alternate care facilities such as Federal Medical Stations. Assembly Centers for displaced or evacuating persons are predetermined and spontaneous sites safely outside of the perimeter of the incident, for use by those who need no immediate medical attention or only minor assistance. Decontamination requirements are important considerations for all RTR, Medical Care, and Assembly Center sites and transport vehicles. The US Department of Health and Human Services is working on a long-term project to generate a database for potential medical care sites and assembly centers so that information is immediately available should an incident occur.

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Background

Preparation for a mass-casualty radiological or nuclear incident in the US requires unprecedented planning, organization, and cooperation among Federal agencies, and state, local, tribal, territorial, regional, and private sector responders. The Office of the Assistant Secretary for Preparedness and Response of the Department of Health and Human Services (HHS) is responsible for all-hazards preparedness. The RTR model is designed specifically for radiation-related mass-casualty events due to the:

1. Threat of potential radiation hazards for responders and victims;
2. Abruptness and potential enormity of a nuclear incident;
3. Need for medical care and resources to be collocated and matched to the requirements;
4. Need to predetermine as much of the detail of the response as possible; and
5. Need for responders to rapidly communicate conditions on the ground.

The "RTR" model was developed for radiation mass-casualty responses. It is in place for both an Improvised Nuclear Device and a Radiological Dispersal Device (RDD). The National Planning Scenarios have been used to conduct detailed planning for a 10-kiloton IND detonation in an urban setting (IND, Scenario #1) and a cesium-137 (Cs^{137}), (cesium chloride) improvised explosive RDD detonation (RDD, Scenario #11).[1] The RTR model and plan are consistent with the designated responsibilities of HHS by the Homeland Security Presidential Directives #18 and #21[2,3] and the National Response Framework.[4]

In order to estimate the requirements generated by a domestic IND or RDD detonation, there must be modeling and a planning process that describes both concepts of operations and more detailed, multi-jurisdictional (or joint) response plans. Accurate estimates of the required resources depend upon understanding the predicted consequences that can be obtained by modeling, and the basic response strategies that can and will be employed.

In developing the basic concepts supporting radiation (radiological and/or nuclear) response plans for the US Federal Emergency Support Function #8 (*Public Health and Medical Services*) of the National Response Framework,[4,5] it is understood that the initial response to any incident is the jurisdiction of the local and state emergency responders. Due to the magnitude and nature of an IND or RDD incident, a local/state public health emergency likely will be declared followed by a Stafford Act Presidential declaration of emergency or major disaster,[4,6] thereby involving Federal response. To be effective, all tiers from institutions and local responses, through state and Federal responses, must have cohesive plans based on a common nomenclature and shared priorities. The US National Incident Management System and resource typing glossaries[7] help to facilitate seamless, multi-tiered response to major incidents much like a common nomenclature.[8] The Federal radiological response involves assets from multiple agencies and groups including the HHS, the Department of Homeland Security, the Department of Energy, the Department of Defense, the Department of Veterans Affairs, the Department of Transportation, the Defense Threat Reduction Agency, and others.

Planning the medical response to the detonation of an IND or RDD requires coordination with subject matter experts in nuclear and radiological emergencies who traditionally have not held central roles in emergency management. Specific expertise will be needed to coordinate monitoring and quantification of environmental contamination, to assist in the management of radiation injuries,[9,10] to establish laboratory capabilities for the measurement of radionuclides (radiobioassay) and assessment of individual exposures (biodosimetry), and to provide flexible protocols for optimal use of resources that are in high demand, but have limited local availability.[11]

To assist in developing concepts for integrated medical response to a mass-casualty IND incident that incorporates these additional considerations, a model system was developed. In this system, three types of RTR sites for out-of-hospital management (**TR**iage, **TR**eatment, and **Tr**ansport) are designated based on their proximity to the blast location, the ongoing presence of radioactive *groundshine* (radiation emitted from the ground that had been made radioactive by the nuclear explosion) and *fallout* (radioactive material falling following the explosion), their accessibility to transportation,[12] and the types of victims near these sites. It was named the RTR System as the location of usable sites depends on the potential exposure to radiation ("R") and the site-specific activities and requirements for TRiage, TReatment, and TRansport ("TR") of the associated victim populations. In addition to the three types of RTR sites, the model incorporates definitive medical care sites that include hospitals, medical centers, and other healthcare facilities such as nursing homes and medical clinics, alternate care facilities such as Federal Medical Stations, and distant, even nationwide medical facilities such as cancer centers, burn centers, and trauma centers, that can provide specialty care of patients with burns, bone marrow depletion, or other complications from trauma and radiation. Finally, the model also includes human services sites (Assembly Centers). These sites are established in major facilities (stadiums, schools, convention centers, shopping centers, etc.) along evacuation routes well outside of the areas affected by the blast or plume. Many of the potential Assembly Center sites can be designated in advance of potential incidents. At Assembly Center sites, registries of displaced persons, their initial locations during the event, and planned destinations can be initiated and linked virtually. Those requiring medical attention or biodosimetry studies based on their injuries or location during the event, but who are asymptomatic, will be referred to appropriate sites for follow-up. Assistance with sheltering, transportation, and other human services are facilitated through these sites as well.

The spectrum of the *acute* medical consequences of an IND or RDD attack include both temporary and permanent blindness (IND), blast injuries, including hearing loss from ear drum perforation, burns injuries, trauma from debris or structure collapse, and the sequelae of radiation exposure. Combined injuries that include radiation and physical injuries from trauma have a higher fatality rate than the sum of the individual injuries. It is important to note that traumatic injuries from the blast can occur in the absence of radiation, and likewise, radiation exposure can occur without other injuries. Psychological stress[13,14] and the need to care for extant medical conditions during the loss of the normal medical care infrastructure will add to the demands of the emergency response.

Effects of Radiation Exposure

The presence of radiation and the clinical effects it produces will influence triage, treatment, and transport strategies as a result of their impact on the exposed victims as well as the constraints they impose on emergency responders. Medical injury from radiation falls into three broad categories:[15–18]

1. *Acute Radiation Syndrome* is due to whole or substantial partial body exposure to a dose of radiation above 1 Gy (Gray; 1 Gy = 100 rem) that likely will cause some mild clinical effects such as nausea and vomiting; doses >2 Gy likely will require immediate treatment for potential organ toxicity and other clinical effects. The acute radiation syndrome includes, by increasing dose: hematopoietic syndrome, cutaneous syndrome, gastrointestinal syndrome, and central nervous system effects. The risk and severity of these effects/syndromes increase with increased radiation exposure (often called the "deterministic" effect);
2. *Chronic effects of radiation* include tissue fibrosis and organ dysfunctions that occur months to years after exposure.[16] The major organ at-risk is the lung, which requires a dose in excess of 8 Gy to cause radiation fibrosis. For other tissues, substantially higher doses are required to cause chronic effects such that the higher dose is lethal and the victim would not likely survive the initial radiation injury; and
3. *Radiation-induced cancer* and other tissue effects may occur years to decades following exposure.[19–23] The cancer risk (likelihood of developing a cancer) increases with increasing exposure to radiation; however, the severity of the cancer is unrelated to dose (often called "stochastic" effect). Whether the risk increases linearly with increasing dose at the low end of the dose range (<10 cGy or 10 rem), or that these lower doses are less of a risk is a subject of debate.[24–27] Nonetheless, the linear relationship usually is assumed for radiation protection purposes. Protective Action Guidelines established for industrial or occupational exposures suggest that annual radiation exposure be limited to <5 rem per year, although higher exposures may be considered for persons engaged in life-saving measures/rescue operations.[28,29]

Medical Responses and Management

During most mass-casualty incidents, local emergency medical services providers provide the initial triage, treatment, and transport. It is recognized that during larger events, people likely will self-transport or use non-emergency medical services mechanisms to go to the nearest hospital, so it will take some time before a secure perimeter and casualty collection and triage points are established. Triage determines the order in which patients are treated and transported to the nearest or most appropriate hospital. Prehospital treatment typically occurs at a field station or in an ambulance en route to the hospital. For mass-casualty incidents, medical triage determines victim care requirements: immediate care, delayed care, palliative care, or no treatment, and establishes victim priority for transport to definitive care locations.[30,31] Due to the large number of patients involved, on-scene treatment areas or casualty collection points (RTRs) will be established to maximize the effective management of a large number of patients awaiting transport to definitive care by the limited field personnel. Concentrating patients at discrete locations in the field also increases the efficiency of the transportation function.

Medical triage following radiation incidents is more complex than in other mass-casualty incidents. Indeed, Cone and Koenig[31] have noted "Field trauma triage systems currently used by emergency responders at mass-casualty incidents and disasters do not adequately account for the possibility of contamination of patients with chemical, biological, radiological, or nuclear material". They reviewed a number of medical triage systems,[31–35] including T1–4 and color coded (green, yellow, red, black) designations.[34,35] Other radiation-specific triage systems have been proposed as well,[36–39] but they are better suited for incidents involving a limited number of casualties. Response and triage strategies differ between military[40] and civilian settings, but both consider how to best use limited resources through establishment of plans and guidelines in advance of an event.[11] The complexity of a radiation event including multiple types of injuries and the limited outcome data available suggest that a consensus approach to developing a triage approach would be valuable.[41] This is under consideration by HHS.

Field management and treatment of victims of a nuclear incident also present greater challenges than during other mass-casualty incidents because of the potential scope of a nuclear detonation and the complicated radiation environment that may result. There will be requirements for the initial care of trauma and burn injuries, but there also will be issues related to operations in the radiologically contaminated environment as well as the management of patients with acute radiation sickness and combined injuries requiring treatment or palliative care.

Many victims also will need to undergo decontamination between initial contact and transport to definitive medical care. Gross field decontamination decreases the continued exposure of externally contaminated patients and minimizes the amount of radiological material transferred to the transportation assets and the downstream medical community (subsequent contamination). Removal of outer clothing and washing with water and mild soap removes most of the contamination. Following an IND detonation, self-decontamination is an important part of limiting the dose.[42,43]

The magnitude of a nuclear incident also will impact transportation plans compared to other mass-casualty incidents. Disruption of normal transportation activities/routes by physical destruction, the influx of response assets along said routes, the inability for response assets to reach the site and set up, and the affected population attempting to self-evacuate will impede victim transport operations and subsequently, the effective delivery of victims to definitive care. Following a mass-casualty incident, it typically is necessary to distribute victims to definitive care sites across a broader region because the local trauma centers quickly are overwhelmed. A mass-casualty incident involving radiation will require a wider distribution of patients to find available beds for all of the victims, and obtain the medical specialty services for management of radiation-related injuries. A networked system for locating these assets and transporting patients to the most appropriate definitive care sites must be included in a medical response model to a nuclear incident.

Finally, a robust capability for identifying, tracking, and providing a wide range of human services for those displaced by the detonation and/or plume also will be required. This human services component will involve a small but essential medical element comprising documentation of potential radiation exposures, recommendations or referrals for appropriate follow-up care for those who may have been exposed, and establishment of a registry/tracking system of the displaced persons.

One of the greatest challenges of a radiological incident for the emergency response community will be determining where responders can deploy safely, and the length of time that they can work under ambient conditions. To help address what is an "acceptable" level of radiation exposure for emergency responders, a number of experts in health physics and emergency response fields have developed Protective Action Guidelines (PAGs) through evidence-based development and interagency consensus.[28] The controversy in estimating the risk of radiation-induced cancer has been noted above.[24–27] These PAGs propose time limits for working in various conditions of radioactivity.[28,44,45] The acceptable levels of exposure for personnel should be a command decision, and should follow pre-established PAGs.

This paper outlines a radiation incident-specific Triage, Treatment, and Transport model for effective management of a mass-casualty incident. Rather than a single type of prehospital treatment or casualty collection site, the unique characteristics of the nuclear scenario require three distinct types of field sites to accommodate the victim population types and the environmental conditions in which the responders are working. These are called Radiation TRiage, TReatment, and TRansport (RTR) sites. In addition, the model includes nationally networked sites for definitive medical care, and assembly centers to address the registration and human services functions.

The Model

In the process of developing the RTR model, current civilian and military medical response plans were inventoried and characterized by interagency working groups. Potential casualty numbers and categories of injury were provided by the Interagency Modeling and Atmospheric Assessment Center under the [US] Department of Homeland Security, the National Atmospheric Release Advisory Center,[46] and the Defense Threat Reduction Agency.[47]

The RTR model was designed to be scalable[48] and enhance the opportunity for efficient collaboration among all tiers of the emergency medical response. Resources can be pre-positioned appropriately, or, if possible, deployed soon after an IND event.

The RTR medical response system in an IND event is diagrammed in Figure 1. The concentric circles denote the IND detonation epicenter as well as the zones with likely lethal prompt radiation, blast overpressure (shockwave), and thermal damage, as well as the radiological plume and fallout. The size and location of these zones relative to one another depend on the size of the IND detonation[41] and meteorological conditions. Near the epicenter, multiple/combined injuries will be common, and immediate fatalities are expected, potentially numbering in the many tens of thousands. Planning models to estimate numbers and locations of individuals with different types of injury can be used for any given city, time of day, and meteorological conditions.

The prevailing upper-level atmospheric wind (jet stream) is illustrated with the arrow and label on the left. For an IND, the radiation plume will reach upper-level atmospheric winds within a minute and will begin returning to earth within minutes to hours as fallout.[49] Immediately after an event, the direction and speed of the wind that will carry the plume will be available from the Interagency Modeling and Atmospheric Assessment Center.[46] Surface winds will be influenced greatly by the blast and urban canyon effects; however the atmospheric winds can be tracked and downwind deposition sites will be predicted. Of course, the ability of models to predict detailed exposure rates is limited, and weather conditions change. Actual environmental measurements will determine ambient dose rates, including local hot spots where debris settles. These dynamic considerations serve to emphasize the importance of continuous, on-scene radiation monitoring for environmental conditions and personnel exposure.

Inner and **Outer Perimeter** lines representing ambient radiation exposure levels per unit time will be established by the incident commander and/or safety officer with advice from health and medical physicists using computer models, area radiation-sampling by on-site response teams, and detailed victim dose information that may be available. Local responders likely will request assistance from the Federal Radiological Monitoring and Assessment Center[50] and other Federal response teams. The estimated dose rates (in rem or Gy per hour) will determine allowable work time for responders in each zone, as indicated by the marked field perimeter lines. They also will be used to estimate potential radiation exposure and the subsequent likelihood of a victim developing acute radiation syndrome. Ambient radiation levels will change rapidly over time as the radioactive plume rises and travels through the upper atmosphere, fallout is deposited, and radioactive decay occurs. Therefore, frequent modeling, measurement, and documentation will be necessary so the safety perimeters/zones can be adjusted accordingly.

RTR Sites

The incident commander will designate the RTR Sites with input from emergency responders. There will be multiple venues for each RTR-site type. Many of these venues will be defined spontaneously in real time as victims collect or are brought to specific areas/sites. These may be areas that are perceived by victims as providing shelter[51] and/or sites of opportunity established by responders. The major functions at RTR sites are identification, triage, medical stabilization (or provision of palliative care), and transport of victims, when possible. Gross decontamination[42,43] also

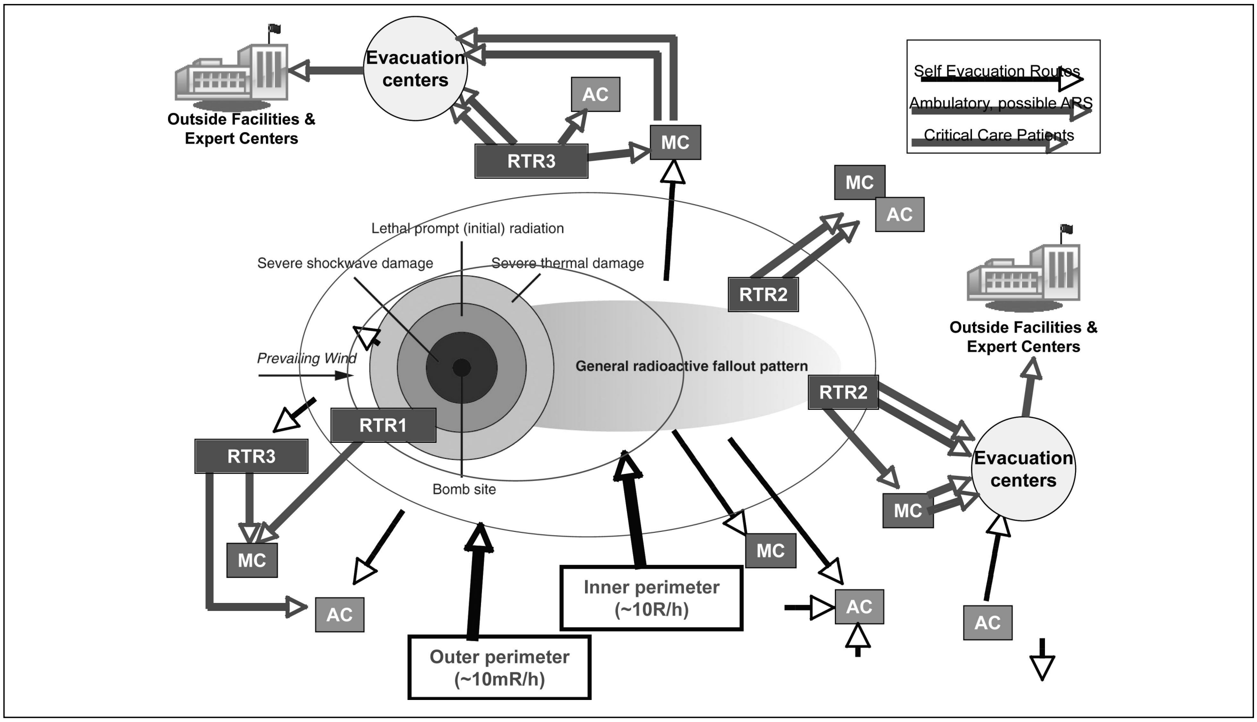

Figure 1—Diagram of the Radiation Triage, Transport, and Treatment (RTR) medical response system for an improvised nuclear device event. (RTR1, near the blast; RTR2, near the plume; and RTR3, not limited by radiation, where casualties may have physical trauma from blast or thermal, but will likely be unexposed to radiation; AC = Assembly Center; MC = Medical Care site)

may be performed at these sites as permitted, though stabilizing serious injuries takes precedent over decontamination.

There are three different types of RTR sites based on physical relationship to the epicenter and fallout. The radiation and infrastructure considerations will impact the types of patients encountered in the respective areas as well as the availability of responders, length of time responders can serve in the area, and transportation constraints. The latter will bear on the ability to evacuate patients from the RTR sites and the options for transporting supplies and personnel to the sites. Victim flow will be the result of the destruction of infrastructure, spontaneous aggregation of victims, self-evacuation, ability to communicate information to victims, and ability to provide services or care. The multiple RTR sites will self-assemble. The goal is to get the victims to Medical Care sites and Assembly Centers.

The location of the RTR1 sites will be near the epicenter of the incident, and will be associated with the highest levels of ambient radiation. At the RTR1 sites:

1. Many or most victims are non-ambulatory, or soon will be; victims will have physical trauma, burns, acute radiation syndrome, and combination injuries;
2. Based on both their proximity to the blast and time to onset of symptoms, it will be clear that many of the victims have been lethally irradiated and primarily will require comfort care;
3. Because of ambient radiation levels, emergency medical responders will have limited periods of time to work safely in this environment;
4. Transportation will be delayed after such a large incident and response assets likely will have difficulty reaching these sites, possibly for a few days, due to infrastructure loss and persistent radiation; and
5. The combination of the proximity to the epicenter, paucity of resources, and transportation limitations will render the RTR1 sites the most austere of all of the RTR sites, and will pose the greatest challenges for providing care to victims.

The locations of the RTR2 sites will be in or near the path of the radiation plume/fallout, which will start at the epicenter and could extend for long distances. Similar to RTR1 sites, these sites either may be spontaneous gathering points for victims or aid stations established by emergency medical responders. While identification, triage, treatment, and transport all are the ultimate goals of these sites, patients at RTR2 will be treated for survivability rather than palliation, contingent on the availability of supplies and responders' time constraints. The sites will have more supplies and responders than will the RTR1 sites. At the RTR2 sites:

1. Most victims will be ambulatory, and fewer victims will have combined injuries. Many victims may have significant radiation exposure from fallout;
2. The time constraints for responders must be monitored carefully due to ambient radiation, but likely will be longer than at the RTR1 sites;
3. If response caches have been mobilized to the appropriate areas, it may be possible to initiate some treat-

ment for mitigation of acute radiation syndrome (e.g., cytokines) and provide symptomatic treatment. Strategies and detailed concepts of operations for forward deployment of medical countermeasures are being developed by HHS and interagency, state, and local partners that might ultimately improve response capabilities at these sites; and

4. Transportation still may be delayed in reaching these sites, and even when transportation routes are intact, they may be choked by evacuees and/or responders.

The locations of RTR3 sites will be away from the immediate blast zone (ambient radiation) and plume. (There may be glass and blast damage miles from the epicenter that is not complicated by radiation, so structural damage to buildings does not necessarily mean radiation is present). At the RTR3 sites:

1. Almost all victims will be ambulatory, and many people may have minor to no injuries and no significant radiation exposure;
2. The time constraints for responders at these sites will reflect regular disaster shift schedules and is not limited by ambient radiation. Local physical dose monitors and radiation safety officers will alert the incident commander and/or safety officer if a RTR3 site becomes contaminated. Should a RTR3 site become contaminated, this may result in movement of the RTR3 site to a clean location, or conversion of the site to RTR2 operations, using the dose-rate information to help determine work/rest cycles;
3. Symptomatic treatment can be administered if appropriate, prior to transportation;
4. Following triage and initiation of minor treatments, available transportation assets will evacuate victims to medical care or assembly center sites as appropriate, some of which may be at a far distance;
5. Radiation monitoring devices and people who know how to calibrate and use them, and decontamination capabilities should be available at the RTR3 sites. Transportation will be available here, and it is important to minimize contamination of health and shelter facilities and transport vehicles.
6. The RTR3-related infrastructure will be relatively intact, so roads and logistics should not impose serious limitations to the capabilities at these sites. Control of the evacuation and transport routes will be vital, and will be facilitated greatly by civilians abiding with public messages.

The RTR model can be used as an information network for the incident commander during the early stages of an event to rapidly convey the local situation and allow the implementation of the response in a way that optimizes distribution of resources while accounting for the limits imposed by radiation. A typical report from a RTR2 site would identify the location and indicate that "there are 78 victims and four responders present with a measured dose rate of 0.5 rem/hr". The profiles of the triage category distribution likely will be characteristic of the RTR-site types. For example, a RTR1 site may have a majority of black tags (expectant category) and virtually no green designations ("walking wounded" category),[35] while the opposite would be true in the RTR3 site.

As part of the transportation plan, the destination of all victims leaving an organized RTR site, including RTRs 1–3, Medical Care, and Assembly Center sites, will be communicated to a central location for tracking and facilitation of victim distribution to Medical Care sites and regional/national facilities and expert centers with capacity. Once organized, the locations of the sites can be provided by public service announcements and other methods of emergency communication to assist those who are self-evacuating to register and obtain needed aid. The same announcements will provide area-specific advice as to whether to evacuate or shelter-in-place.

Medical Care Sites

Medical Care sites are venues where sophisticated medical care will be administered. These include hospitals, clinics, and medical centers. They are the focal points for the delivery of expert medical personnel and materiel. Some of the facilities nearest to the blast will not be operational due to a loss of infrastructure, and others may not be usable due to their location within the fallout area. Regarding Medical Care sites:

1. Medical Care sites should be identified as thoroughly as possible before an incident. Their Geographic Information System coordinates, addresses, and details on capabilities and capacities such as trauma level and bed counts should be included. A bed-count would be done at the time of an incident and at regular intervals, consistent with National Surge Capability plans. The National Hospital Available Beds for Emergencies and Disasters System (HAvBED) currently provides this capability to some degree,[52] and this system integrates medical facilities with state and Federal governments. Currently, HHS utilizes HAvBED with integrated reporting from multiple jurisdictions;
2. During a large event, some medical care facilities will be unusable due to their location, while other sites such as outpatient clinics and nursing homes not normally used as major medical facilities may become incident-specific hospitals to maintain the local medical care capacity;
3. Disaster Medical Assistance Teams will be deployed immediately to support triage and provide medical care at the austere disaster site, or they can be set-up to augment the emergency departments of receiving Medical Care sites;[53]
4. Alternate care facilities, such as Federal Medical Stations[54] will be set up as rapidly as possible, usually within 24–72 hours, to care for less severely ill medical needs populations;
5. Victims with immediate medical needs will be transported or directed from RTR1, 2, and 3 sites to Medical Care sites. Additionally, people with medical needs, displacement, and socio-behavioral needs to the best of their ability, will likely self-evacuate to the Medical Care sites. Some will require special assistance and guidance to evacuate. Those who do not need immediate medical care will be directed to Assembly Centers or to their homes as appropriate;

6. Many of those in need of medical care may require decontamination. For those who self-evacuate following radioactive contamination, it will be necessary for the Medical Care sites to provide this service;
7. Medical history, including the victim's location during the incident, as well as portal monitoring to detect the presence of radiation contamination, will be important in the medical evaluation process. Information gathered from history or monitoring, if possible, should be captured during triage intake and should stay with the patient;
8. To provide necessary space for severely injured victims, Medical Care facilities nearest the epicenter will discharge or transfer patients to home care, if possible, or other facilities outside of the region.
9. Some Medical Care sites may be long distances from the site of the event and even beyond state boundaries. Transportation of victims to these facilities may require activation of national networks such as National Disaster Medical System[55] and the Radiation Injury Treatment Network[56] with coordination by state and Federal authorities. The Radiation Injury Treatment Network provides coordinated and integrated medical care capability for victims with radiation injury, and currently includes a number of National Marrow Donor Program Centers and National Cancer Institute Comprehensive Cancer Centers[57,58] with future expansion planned;
10. Victim tracking in Medical Care facilities will rely largely on patient records established during the event. They will be integrated with the data collected at the RTR sites and/or patient transport tracking systems, the development of which remains a work in progress;[59] and
11. Anticipating that most physicians will not have had experience managing radiation injuries, and will have little time to review, a just-in-time, algorithm-based set of medical guidelines and a comprehensive tool called the Radiation Event Medical Management[9,10] system (REMM) has been developed in collaboration with the National Library of Medicine and is available at http://remm.nlm.gov.

Assembly Centers will be evacuee receiving and registry centers as well as temporary shelters where people may receive food and shelter and/or can check in with authorities so that they can be accounted for after the event. These sites are for those with no or minimal requirements for medical care. Some may arrive directly or may have been directed from RTR and Medical Care sites. Regarding Assembly Center sites:

1. They will be predetermined as much as possible, including major public facilities, highway rest stops, schools, auditoria, sports facilities, shopping centers, etc. Some will form spontaneously, especially along evacuation routes. Some predetermined sites likely will be unusable due to the plume;
2. Very limited or no medical care will be available or needed at these sites, although some medical history and blood testing may be done for radiation screening of victims. Many or most people will not have been in the blast or plume;
3. Information as to where persons were at the onset of the event and thereafter should be captured at Assembly Center sites, if possible;
4. Some non-victims may be in close proximity to Medical Care sites, but should be sent to Assembly Center sites or home rather than use Medical Care resources;
5. Some victims who are possibly at risk for acute radiation syndrome but who have few symptoms may enter the response/tracking system at Assembly Center sites because they moved away from the blast and may not encounter assistance until this point. They would need further evaluation and medical care at Medical Care sites at some point in time;
6. Nearly all people will be ambulatory;
7. Preparedness education and public messaging will provide guidance to evacuation and/or sheltering in-place;
8. Staffing may include non-medical personnel or those with limited medical expertise. The focus at Assembly Center sites is providing minimal medical care, housing, and human services, as detailed in Emergency Support Function #6 of the National Response Framework,[4] which is coordinated by the Federal Emergency Management Agency; and
9. Complete victim and evacuee tracking will be done but may not be fully accomplished given the large number of victims.

Evacuation Centers and Drop Zones

Evacuation centers and drop zones should not be confused with Assembly Center sites, as the former are hubs for major victim and evacuee transport by land, rail, air, and/or water. Some hubs may be designated for incoming supplies and personnel and others for outgoing, while others may transport persons or goods both in and out.

1. Transportation is a major challenge covered by the Emergency Support Function #1 of the National Response Framework.[4] This will be accomplished by local/regional assets through ambulance contracts, volunteer allocations, and vehicles. The Department of Transportation will assist "Federal, state, tribal and local governmental entities, voluntary organizations, nongovernmental organizations and the private sector in the management of transportation systems and infrastructure during domestic threats or in response to incidents".[6] Extensive self-evacuation likely will occur. Transport capacity will be severely limited in the early hours after an IND, and control of the evacuation and transport routes will be critical.
2. Medical supplies, including those from the Strategic National Stockpile,[62] will be sent to Points of Distribution from which they will be transported to Medical Care sites and, to a lesser extent, Assembly Center sites; again recognizing the challenge due to limited infrastructure.
3. New solutions, including pre-positioning and forward deployment of time-sensitive or anticipated medical countermeasures are being developed by Emergency Support Function #8, and state and local planners, and are a work in progress.

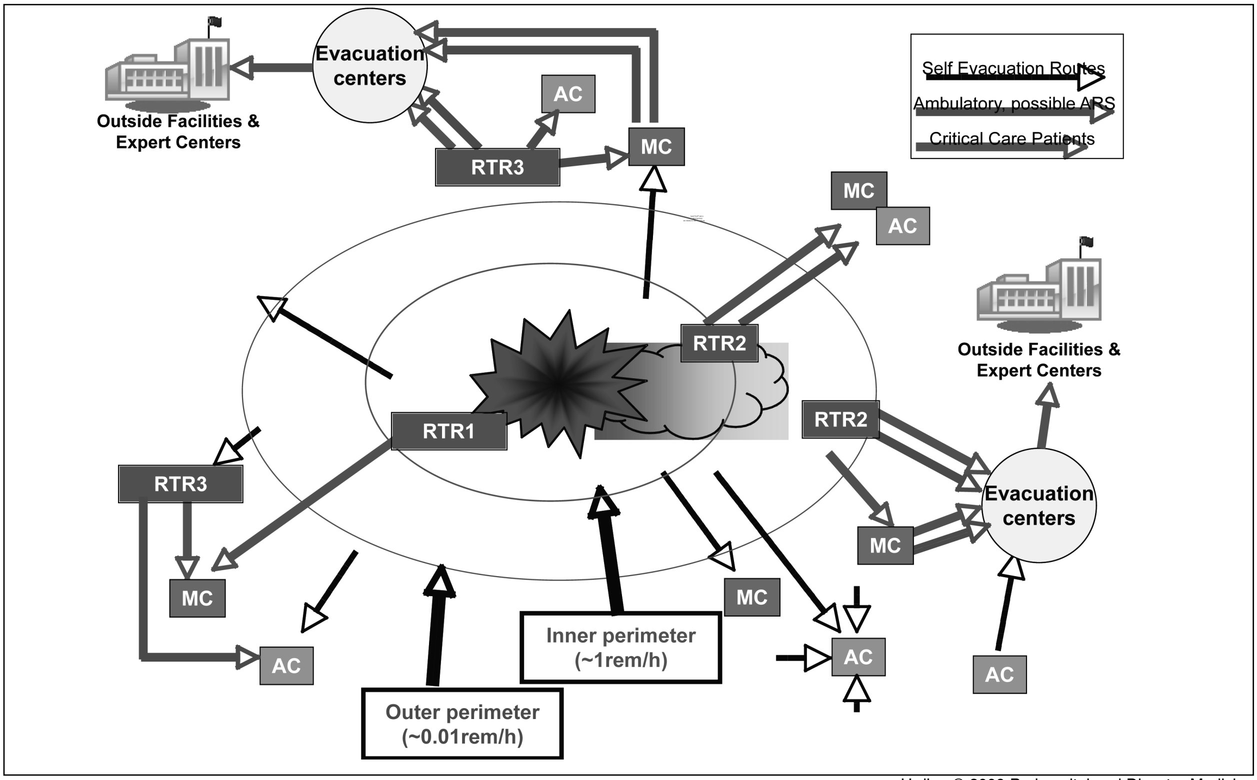

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Figure 2—Diagram of the RTR medical response system for an radiological dispersal device (RDD) incident. (RTR1 = near the blast; RTR2 = near the plume; and RTR3 = not limited by radiation, where casualties may have physical trauma from blast or thermal, but will likely be unexposed to radiation; AC = Assembly Center; MC = Medical Care site)

Victim Movement—Arrows in Figure 1 indicate the three general categories of victim movement: (1) self-evacuation; (2) ambulatory requiring medical care; and (3) non-ambulatory. Many of the non-ambulatory will require definitive care, although some, such as at-risk populations,[4] only may require transport to Assembly Center sites. In general, victims/people will flow away from the incident epicenter and into the surrounding area, with some lateral movement of individuals who do not evacuate the region (e.g., to relatives' homes or Medical Care sites) and some sheltering-in-place. Despite the size of an IND incident, those not near the epicenter or within the plume may safely remain where they are or may return as infrastructure is restored.

1. Medical transport from the RTR1 sites will be severely limited, especially during the first hours and days.
2. Self-evacuation will likely be a major source of victim movement. Victims likely will go to Medical Care and Assembly Center sites based on knowledge from local preparedness plans and/or directions from responders and the media. Those who do not need immediate medical care will be directed to Assembly Center sites and told specifically to avoid Medical Care sites.
3. Some of those at risk for acute radiation syndrome from fallout may self-evacuate to Medical Care and Assembly Center sites. Depending on medical history and initial evaluation, some may need to be directed to appropriate facilities for further evaluation (e.g., blood tests and/or biodosimetry or bioassay studies),[12] and some may need transport to expert care centers to be monitored and treated as outpatients for the development of acute radiation syndrome.
4. Identification of contaminated victims and the provision of effective decontamination, including self-decontamination, is critical to medical management in radiation events. In addition to decontaminating victims and first responders, protection and decontamination of materiel, facilities, shelters, and transport vehicles is important. A nuclear incident is large, and assistance from all tiers of government and the private sector will be needed for adequate decontamination capacity in the response.

The RTR medical response system for an explosive RDD, which is a much smaller incident than is an IND detonation is in Figure 2. Unlike an IND, in which a large amount of radiation is discharged by the detonation (and immediately dissipates with the blast), and is broadly deposited in the fallout, an RDD is a much smaller device that disperses radioactive material as with a dirty bomb or aerosolization device. (Non-explosive dispersal of radioactive material also is a form of RDD.) Radiation exposure depends on the duration of the proximity to radioactive material. Most of the radiological exposure from a RDD is from external contamination, but some victims may have internalized radiological material from inhalation, ingestion, contaminated shrapnel, or wound contamination.[12,63] While a large incident is possible,[63] most RDD incidents

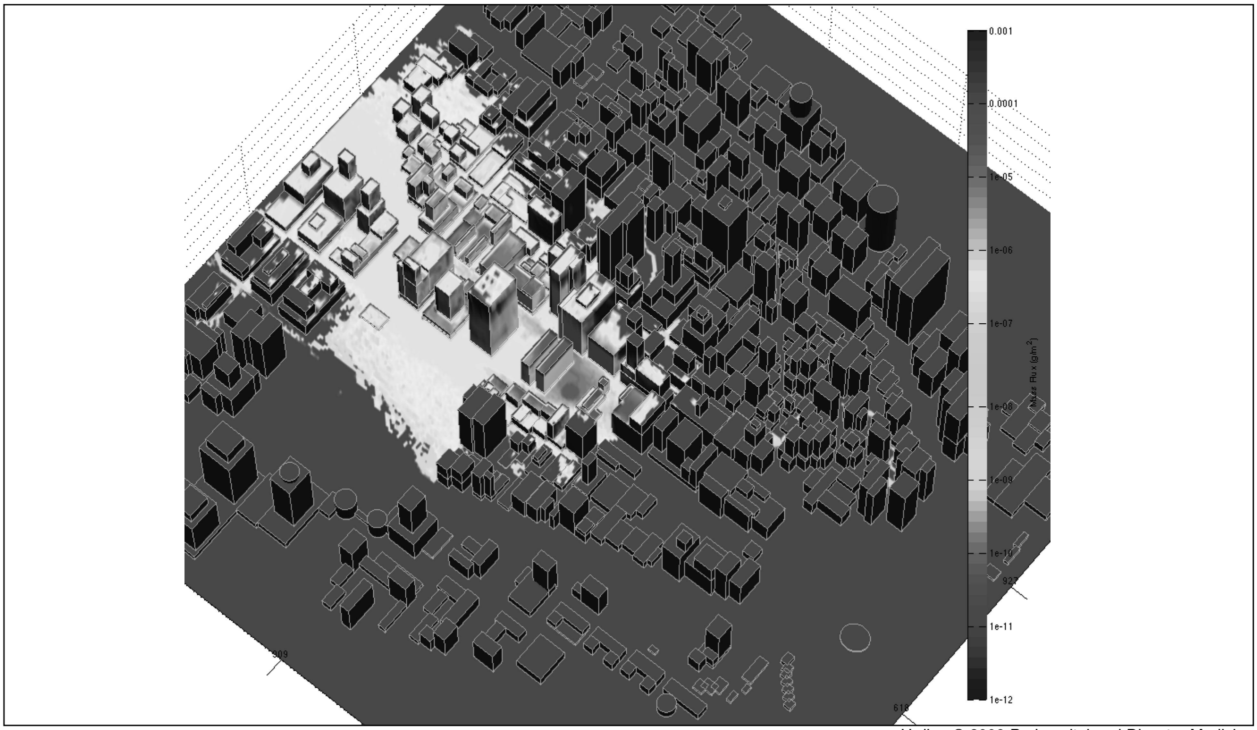

Figure 3—Illustration of simulated deposition of radiological contaminant in a city, by the Quick Urban & Industrial Complex (QUIC) modeling system. The QUIC modeling system illustrates the deposition of radiological contaminant from an radiological dispersal device (RDD) in an urban setting in which the color gradient from red to blue indicates greatest to least deposition respectively. This image is provided by courtesy of Michael Brown, Los Alamos National Laboratory.

involve a limited section of a city, will likely have a radius of a few hundred meters, and involve fewer victims than from an IND. The RDD plume is short lived, settling or diffusing within minutes to a half-hour, and is confined largely to surface and urban winds. Distribution of radioactivity would be determined by an urban canyon effect and depending on prevailing winds and city layout, can be limited or broadly contaminating (Figures 3).[64] While some resuspension and spread of radioactive material may occur during response operations and ground movements, the ambient radiation zone is largely determined by the footprint of where the material initially landed.

Thus, for a RDD event, the high-level winds displayed by Interagency Modeling and Atmospheric Assessment Center modeling maps will show the direction and distance that only very small amounts of buoyant radiological particles (likely not enough for health effects) will be carried. While long-range deposition of RDD fallout is worth noting for possible interdiction of food supply and eventual clean-up, radiological material carried beyond the local site is unlikely to cause acute radiation syndrome because it is too limited in quantity.

The functions of RTR1–3, Medical Care, and Assembly Center sites are the same for a RDD as for an IND. The inner and outer perimeters and the blast zone will be nearer to the epicenter and used by the responders and local incident commander to determine the RTR1–3 sites as well as determining if any medical care and assembly center sites are non-functional due to their location or infrastructure damage.

Figure 4 illustrates how the radiation dose rate (rem or Gy per hour) will be used to determine protective action guidance for first responders occupying areas in proximity to the RDD detonation (exclusion zones) and also the risk to victims for developing acute radiation syndrome. While radiation distribution models are vital to shaping the initial response, on-the-ground measurements are critical for determining where responders can or cannot spend time and whether or not a victim is at risk for developing acute radiation syndrome. Figure 4 illustrates that the time permitted within a zone depends on the dose rate. The time limitation for responder occupancy of a zone is based on the risk to a person/responder for developing a radiation-induced-cancer (<0.5% per 5 rem), which characteristically does not occur until years or decades later.[12,16,19,20]

Mapping the Doses: Plume versus Footprint

Experience from recent exercises suggests that information on Interagency Modeling and Atmospheric Assessment Center plume/dispersal plots could be confusing to incident commanders and responders. Interagency partners are working on improved nomenclature and data display. When looking at plume and footprint maps, one must distinguish: (1) acute dose rate for the risk for developing acute radiation syndrome; (2) acute dose rate for implementing protective action guidelines for responders and

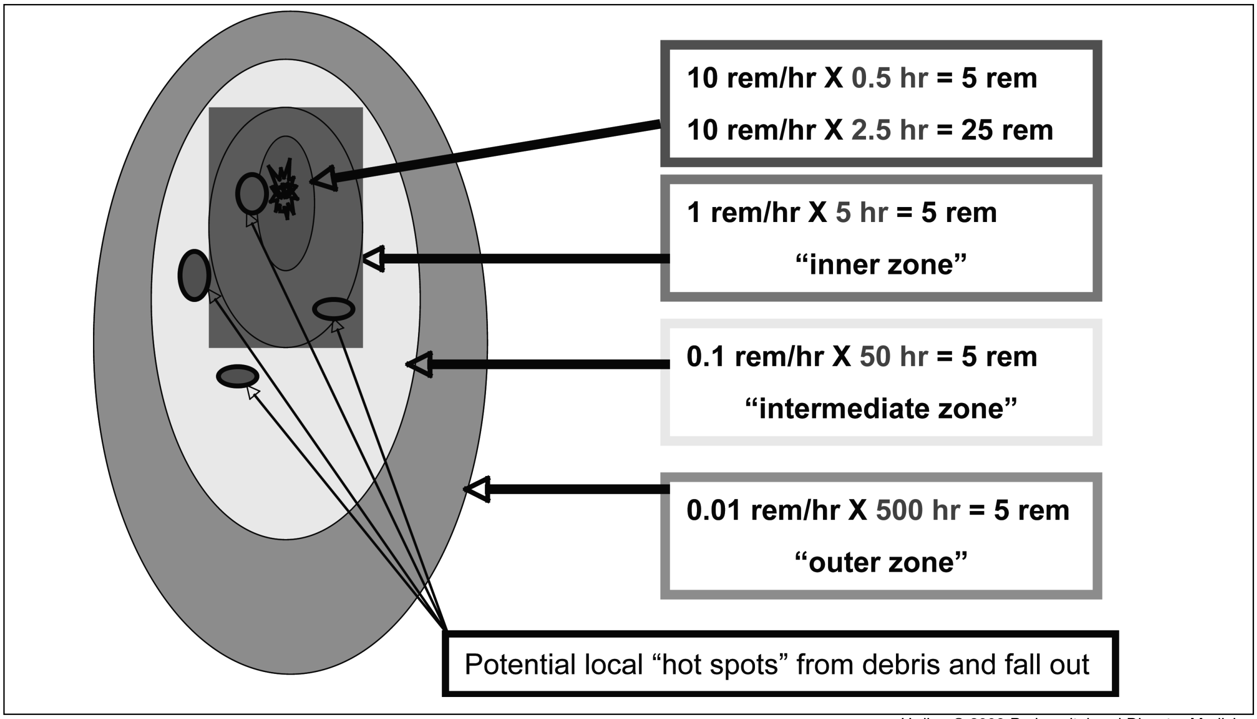

Figure 4—Radiation zones

victims (in rem per hour or per day); and (3) the much lower dose rate for interdiction of food and water and site mitigation (rem per day or month or year). The latter, while important, is part of the long-term recovery process, and thus, there is time to sort this out once the initial incident management is under control.

Creating Maps and a National Database for Medical Care and Assembly Center Locations

Data regarding locations of medical facilities, public facilities that might serve as Medical Care and Assembly Center sites, and facilities that would serve as transportation and distribution centers exist. The Office of the Assistant Secretary for Preparedness and Response is embarking on a project called the MedMap Project to enhance this data set in a geospatial system and to coordinate this data/display with non-Federal responders.

Medical Personnel for Surge Capacity

The amount of medical supplies and number of personnel needed for an event as large as an IND will produce initial shortfalls based on the absolute quantity needed and potential reluctance of responders to participate in an event involving radiation.[65–67] Kaji *et al* noted that increasing patient care capacity is the key focus.[68] Experience also has demonstrated a strong interest of civilian volunteers wanting to contribute their efforts.[48] To support these personnel, there is the Medical Reserve Corps in the Office of Surgeon General[69] which is "Dedicated to establishing teams of local volunteer medical and public health professionals to contribute their skills and expertise throughout the year as well as during times of community need" and the Emergency System for Advance Registration of Volunteer Health Professionals within HHS—"This system of State based systems will, when complete, form a National system that will allow efficient utilization of health professional volunteers in emergencies by providing verifiable, up-to-date information regarding the volunteer's identity and credentials to hospitals or other medical facilities in need of the volunteer's services."[70] Specific medical expertise for managing radiation events will come from the Radiation Injury Treatment Network[56] and volunteer help from professional medical societies.

Discussion

Readiness for a nuclear or radiological mass-casualty incident requires extensive preparation and planning due to the potential magnitude and consequences.[1,12,31,63] Concern for acute radiation injury and delayed effects of acute radiation exposure (especially radiation-induced cancer[12,19,20,28]) makes responses to an event even more complicated because of the additional pressures to leave the area and reluctance by responders to enter a radiation zone.

The HHS is responsible for coordinating the Federal public health and medical responses to Presidentially-declared disasters and public health emergencies.[2,3,5,6] An effective response plan will require collocating medical personnel and supplies with the victims in need, transporting victims to appropriate aid locations, and protecting responders and victims from radiation exposure as best as possible.

The RTR model has been developed to facilitate planning to meet these needs. The model outlines the major components of a response and configures them in a way upon which a medical and logistics management system can be overlaid for planning purposes. The RTR sites (RTR1—near the blast with persistent radiation, RTR2—

near the plume with some persistent radiation, and RTR3—collection points with minimal to no radiation risk) will be determined in real time while Medical Care and Assembly Center sites will be largely pre-determined with data on these sites available on a detailed map usable by Federal and non-Federal planners and incident commanders. There is an ongoing effort within HHS (MedMap project) to map and store information on Medical Care sites and also on possible Assembly Center sites so that as much information as possible is immediately available in the face of an event.

Nuclear incident response requires extensive medical support so that Medical Center sites well beyond the region will be engaged and include national and international capabilities. Medical care systems include the National Disaster Medical System,[55] the growing Radiation Injury Treatment Network,[56–58] and other medical centers. Personnel shortages will be filled by volunteers including those in the Medical Reserve Corps and Emergency System for Advance Registration of Volunteer Health Professionals[69,70] and just-in-time medical management guidelines are available on REMM.[8,9]

For all RTR sites, including the RTR1–3, Medical Care, and Assembly Center sites, full victim tracking is required, and developing systems that can perform this function is a high priority.[59] For those potentially at risk for internal contamination and the development of acute radiation syndrome based on history and symptoms,[8] laboratory determinations for exposure and internal contamination are needed. There also are plans for establishing a radiation laboratory network.[12] Transportation will be an enormous challenge and evacuation and supply routes must be controlled with attention to contamination and worker safety issues. Sheltering-in-place, including preparedness education and public messaging will reduce the pressure on the medical response system.

Conclusions

The RTR Medical Response system provides a model for the conduct of triage, transportation, and on-site treatment taking into account the limitation imposed on responders by radiation. Dialogue and planning between Federal and non-Federal partners is needed. The Office of the Assistant Secretary for Preparedness and Response and other HHS and Federal and non-Federal partners are working on the various components of the response to radiation incidents,[12] as well as on all-hazards preparedness and responses for the vision of "a Nation Prepared".[71]

The RTR system is an integral part of the zonal response approach included in the "Planning Guidance for Response to a Nuclear Detonation", prepared by a subcommittee of the Homeland Security Council, January 2009.

References

1. National Response Plan: Planning Scenarios (Scenarios #1 and #11 related to radiological/nuclear incidents). Available at http://www.globalsecurity.org/security/library/report/2004/hsc-planning-scenarios-jul04.htm (scenarios). Accessed 05 July 2008.
2. Homeland Security Presidential Directive (HSPD) #18: Medical Countermeasures Against Weapons of Mass Destruction. Available at http://www.whitehouse.gov/news/releases/2007/02/20070207-2.html. Accessed 05 July 2008.
3. HSPD #21: Public Health and Medical Preparedness. Available at http://www.whitehouse.gov/news/releases/2007/10/20071018-10.html. Accessed 05 July 2008.
4. Description of National Response Framework. Available at http://www.fema.gov/emergency/nrf. Accessed 05 July 2008.
5. Emergency Support Function #8, Public Health and Medical Services. Available at http://www.nmfi.org/natlresp/files/ESF8.pdf. Accessed 05 July2008.
6. National Response Plan, Nuclear/Radiological Incident Annex. Available at http://hps.org/documents/NRPNuclearAnnex.pdf. Accessed 05 July 2008.
7. National Incident Management System (NIMS). Available at http://www.fema.gov/emergency/nims/index.shtm. Accessed 05 July 2008.
8. Koeing KL, Dinerman N, Kuehl AE: Disaster nomenclature—A functional impact approach: The PICE system. *Acad Emerg Med* 1996;3:723–727.
9. Radiation Event Medical Management (REMM). Available at http://www.remm.nlm.gov/. Accessed 05 July 2008.
10. Bader JL, Nemhauser J, Chang F, *et al*: Radiation Incident Medical Management (REMM): Web site guidance for health care providers. *Prehosp Emerg Care* 2008;12:1–11.
11. Roberts M, Hodge JG, Gabriel E, *et al*: Mass medical care with scarce resources: A community guide. Available at http://www.ahrq.gov/research/mce/mceguide.pdf. Accessed 05 July 2008.
12. Coleman CN, Hrdina, C, Bader JL, *et al*: Medical response to a radiological/nuclear event: Integrated plan from the Office of the Assistant Secretary for Preparedness and Response, Department of Health and Human Services. *Ann Emerg Med* 2008 (in press).
13. Rubin GJ, Brewin CR, Greenberg N, Simpson J, Wessely S: Psychological and behavioural reactions to the bombings in London on 7 July 2005: Cross sectional survey of a representative sample of Londoners. *BMJ* 2005;17;331(7517):606.
14. Chen H, Chung H, Chen T, Fang L, Chen JP: The emotional distress in a community after the terrorist attack on the World Trade Center community. *Ment Health J* 2003 39(2):157–165.
15. Waselenko JK, MacVittie TJ, Blakely WF, *et al*: Medical management of the acute radiation syndrome: recommendations of the Strategic National Stockpile Radiation Working Group. *Ann Intern Med* 2004;140:1037–1051.
16. Coleman CN, Blakely WF, Fike JR, *et al*: Molecular and cellular biology of moderate-dose (1-10 Gy) radiation and potential mechanisms of radiation protection: Report of a workshop at Bethesda, Maryland, December 17–18, 2001. *Radiat Res* 2003;159:812–834. Review.
17. Koenig KL, Goans RE, Hatchett RJ, *et al*: Medical treatment of radiological casualties: Current concepts. *Ann Emerg Med* 2005;45(6):643–652.
18. Weisdorf D, Chao N, Waselenko JK, *et al*: Acute radiation injury: Contingency planning for triage, supportive care, and transplantation. *Biol Blood Marrow Transplant* 2006;12:672–682. Review.
19. Preston DL, Pierce DA, Shimizu Y, *et al*: Dose response and temporal patterns of radiation-associated solid cancer risks. *Health Phys* 2003;85:43–46. Review.
20. Preston DL, Shimizu Y, Pierce DA, *et al*: Studies of mortality of atomic bomb survivors. Report 13. Solid cancer and noncancer disease mortality: 1950–1997. *Radiat Res* 2003;160:381–407.
21. Prysyazhnyuk A, Gristchenko V, Fedorenko Z, *et al*: Twenty years after the Chernobyl accident: Solid cancer incidence in various groups of the Ukrainian population. *Radiat Environ Biophys* 2007,46:43–51.
22. Ivanov V, Ilyin L, Gorski A, *et al*: Radiation and epidemiological analysis for solid cancer incidence among nuclear workers who participated in recovery operations following the accident at the Chernobyl NPP. *J Radiat Res (Tokyo)* 2004;45:41–44.
23. Committee to Assess Health Risks from Exposure to Low Levels of Ionizing Radiation, National Research Council: *Health Risks from Exposure to Low levels of Ionizing Radiation. BIER VII. Phase 2*. Washington, DC: National Academies Press, 2006.
24. Brenner DJ, Doll R, Goodhead DT, *et al*: Cancer risks attributable to low doses of ionizing radiation: assessing what we really know. *Proc Natl Acad Sci USA* 2003;25(100):13761–13766.
25. Brenner DJ, Sach RK: Estimating radiation-induced cancer risks at very low doses: Rationale for using a linear no-threshold approach. *Radiat Environ Biophys* 2006;44:253–256

26. Tubiana M, Aurengo A, Averbeck D, Masse R: The debate on the use of linear no threshold for assessing the effects of low doses. *J Radiol Prot* 2006;26:317–324.
27. Scott BR: Low-dose radiation risk extrapolation fallacy associated with the linear-no-threshold model. *Hum Exp Toxicol* 2008;27:163–168.
28. Protective Action Guidelines (PAGS). Available at http://www.epa.gov/radiation/rert/pags.htm. Accessed 05 July 2008.
29. National Council on Radiation Protection and Measurements: NCRP Report No. 138, Management of Terrorist Incidents Involving Radioactive Material. Available at http://www.ncrponline.org/Publications/138press.html. Accessed 05 July 2008.
30. Dons RJ, Cervency TJ: Triage and Treatment of Radiation-Injured Mass Casualties, In: Zajtchuk R (ed): *Textbook of Military Medicine. Medical Consequences of Nuclear Warfare*. Falls Church: TMM Publications, 1989, pp 37–55.
31. Cone DC, Koenig KL: Mass casualty triage in the chemical, biological, radiological, or nuclear environment. *Europ J Emerg Med* 2005;12:287–302.
32. Cone DC, MacMillan DS: Mass-casualty triage systems: A hint of science. *Acad Emerg Med* 2005;12:739–741.
33. Sacco WJ, Navin DM, Fiedler KE, Waddell RK, Long W, Buckman RF: Precise formulation and evidence-based application of resource-constrained triage. *Acad Emerg Med* 2005;12:759–770.
34. Sacco WJ, Navin M, Waddell RK, *et al*: A new resource-constrained triage method applied to victims of penetrating injury. *J Trauma* 2007;63:316–325.
35. START triage system, including flow chart and triage tag color-system. Available at http://www.citmt.org/start/default.htm. Accessed 05 July 2008.
36. Fliedner TM, Friesecke I, Beyer K, (eds): Medical Management of Radiation Accidents. *Manual on the Acute Radiation Syndrome*. Oxford: British Institute of Radiology, 2001.
37. Armed Forces Radiobiology Research Institute: Biodosimetry Assessment Tool. Available at http://www.afrri.usuhs.mil/. Accessed 05 July 2008.
38. Kuniak M, Azizova T, Day R, *et al*: The Radiation Injury Severity Classification (RISC) system: An early injury assessment tool for the frontline health-care provide. *B J Rad* 2008;81(963):232–243.
39. Berger, ME, Christensen, FM, Lowry PC, *et al*: Medical management of radiation injuries: Current approaches. *Occup Med* 2006; 56(3):162–172.
40. Armed Forces Radiobiology Research Institute: Military medical resources/radiation-casualty management. Available at http://www.afrri.usuhs.mil/www/outreach/mmoresources.htm. Accessed 05 July 2008.
41. Devereaux A, Christian MD, Dichter JR, *et al*: Summary of suggestions from the task force for mass critical care summit, January 26-27, 2007. *Chest* 2008;133:s1–s7.
42. Miller K, Groff L, Erdman M, King S: Lessons learned in preparing to receive large numbers of contaminated individuals. *Health Phys* 2005;98(Suppl 2):s42–s47
43. Centers for Disease Control and Prevention: Radioactive contamination and radiation exposure. Available at http://www.bt.cdc.gov/radiation/contamination.asp. Accessed 29 June 2008.
44. Conference of Radiation Control Program Directors, Inc: "Radiological Dispersal Device (RDD) [Dirty Bomb] First Responder's Guide—The First 12 Hours". Available at http://www.crcpd.org/RDD.htm. Accessed 05 July 2008.
45. International Commission on Radiation Protection: ICRP Publication 96: Protecting People Against Radiation Exposure in the Incident of a Radiological Attack. Available at http://www.elsevier.com/wps/find/bookdescription.cws_home/707248/description#description. Accessed 05 July 2008.
46. Interagency Modeling and Atmospheric Assessment Center (IMAAC) of National Atmospheric Release and Advisory Center (NARAC), Department of Energy. Available at https://narac.llnl.gov. Accessed 05 July 2008, and https://naracweb.llnl.gov/NaracWeb/jsp/imaacsession.jsp. Accessed 05 July 2008.
47. Defense Threat Reduction Agency. Available at http://www.dtra.mil/. Acccessed 05 July 2008.
48. Auf der Heide E: Disaster planning, Part II. Disaster problems, issues and challenges identified in research literature. *Emerg Clin North Am* 1996;14:453–480.
49. Glasstone S, Dolan P: *The Effects of Nuclear Weapons*, 3rd ed. Washington, DC: US Department of Defense, 1977.
50. Federal Radiological Monitoring and Assessment Center (FRMAC), Department of Energy. Available at http://www.nv.doe.gov/nationalsecurity/homelandsecurity/frmac/default.htm. Accessed 05 July 2008.
51. Auf der Heide E: Convergence behavior in disasters. *Ann Emerg Med* 2003;41:463–466.
52. National Hospital Available Beds for Emergencies and Disasters (HAVBED). Available at http://www.ahrq.gov/prep/havbed/. Accessed 05 July 2008.
53. Disaster Medical Assistance Teams (DMAT). Available at http://www.hhs.gov/aspr/opeo/ndms/teams/dmat.html. Accessed 05 July 2008.
54. Federal Medical Stations. Available at http://www.hhs.gov/disasters/discussion/planners/medicalassistance.html Accessed 05 July 2008.
55. Description of the National Disaster Medical System (NDMS). Available at http://www.ndms.hhs.gov/. Accessed 05 July 2008.
56. Radiation Injury Treatment Network (RITN). Available at http://www.nmdp.org/RITN/. Accessed 05 July 2008.
57. National Marrow Donor Program. Available at http://www.marrow.org/. Accessed 05 July 2008.
58. National Cancer Institute Cancer Centers Program. Available at http://www.cancer.gov/cancertopics/factsheet/NCI/cancer-centers. Accessed 05 July 2008.
59. National Mass Patient and Evacuee Movement, Regulating, and Tracking System Patient tracking. Available at http://www.ndms.chepinc.org/presentations/2008/main_training_summit/course_24_-_national_patient_movement_initiative_-_biddinger_paul.pdf. Accessed 05 July 2008.
60. Emergency Support Function #6, Mass Care, Housing and Human Service Annex. Available at http://www.fema.gov/pdf/emergency/nrf/nrf-esf-06.pdf. Accessed 05 July 2008.
62. Strategic National Stockpile (SNS). Available at http://www.bt.cdc.gov/stockpile/. Accessed 05 July 2008.
63. Harper FT, Musolino SV, Wente WB: Realistic radiological dispersal device hazard boundaries and ramifications for early consequence management decisions. *Health Phys* 2007;93(1):1–16.
64. Radiological dispersal device simulation by Quick Urban and Industrial Complex (QUIC) modeling systems calculates radiological particle deposition in a city. Image provided courtesy of Michael Brown, Los Alamos National Laboratory. Further reading available at http://www.lanl.gov/orgs/d/d4/atmosphere/docs/LA_UR_02_2559.pdf; and http://ams.confex.com/ams/pdfpapers/80330.pdf. Accessed 03 April 2008.
65. Mackler N, Wilkerson W, Cinti S: Will first-responders show up for work during a pandemic? Lessons from a smallpox vaccination survey of paramedics. *Disast Manag Response* 2007;5:45–48.
66. Becker SM: Addressing the psychological and communication challenges posed by radiological/nuclear terrorism: Key developments since NCRP Report No. 138. *Health Phys* 2005;89:521–530.
67. Center for Study of Traumatic Stress: Psychological and behavioral issues healthcare providers need to know when treating patients following a radiation event. Available at http://www.centerforthestudyoftraumaticstress.org/downloads/CSTS_issues_radiation%20event.pdf. Accessed 05 July 2008.
68. Kaji A, Koenig K, Bey T: Surge capacity for healthcare systems: A conceptual framework. *Acad Emerg Med* 2006,13:1157–1159.
69. Medical Reserve Corps. Available at http://www.medicalreservecorps.gov/HomePage. Accessed 05 July 2008.
70. Emergency System for Advance Registration of Volunteer Health Professionals. Available at http://www.hrsa.gov/esarvhp/. Accessed 05 July 2008.
71. Vision and mission statements for the Office of the Assistant Secretary for Planning and Response, ASPR/HHS. Available at http://www.astho.org/pubs/VANDERWAGEN-SF.pdf Additional details of ASPR available at http://www.hhs.gov/aspr/index.html. Accessed 05 July 2008.