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CHAPTER XIII—NUCLEAR WARFARE DEFENSE

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NUCLEAR WARFARE DEFENSE*

INTRODUCTION

On the morning of 6 August 1945, a lone U.S. Army aircraft suddenly appeared high in the sky over the city of Hiroshima, Japan. A single bomb was dropped. With the ensuing explosion, mankind was formally introduced to nuclear warfare and a new symbol of terror was born—the classical mushroom cloud. As a result of this one explosion, more than 4.5 square miles of the city was destroyed. In addition to this widespread destruction of property, 140,000 casualties were produced; of these, 70,000 were known to be killed or were missing and presumed dead.

Since that fateful day in 1945, our knowledge of the effects of nuclear weapons has continued to grow. Nuclear weapons have now been detonated at test sites in many parts of the world and by several nations of the world. Because nuclear weapons are now possessed by others and are an integral part of our armamentarium, it is essential that hospital corpsmen know as much as possible about the medical management of their effects.

PHYSICAL CONSIDERATIONS OF A NUCLEAR DETONATION

As pointed out in Chapter IX, the atom may be defined as the smallest possible or ultimate particle of an element which has the physical and chemical properties of that element. However, an atom is known to have an internal structure and can be split into subatomic particles. These subatomic particles, which are common to all atoms and are mostly electrical in nature, do not have the characteristic properties of the atom. In fact, the physicochemical characteristics of an atom are governed by the number of these subatomic particles contained in the atom. Thus C^{14}, a carbon atom with 6 protons and 8 neutrons, is chemically quite different from N^{15}, a nitrogen atom with 7 protons and 8 neutrons. And, although chemically identical, H^1, a hydrogen atom with 1 proton and 0 neutrons, is physically different from H^3, a hydrogen atom with 1 proton and 2 neutrons, since H^3 (tritium) is radioactive.

If a large atom is split (fission reaction) in such a way that a part of the mass is lost, a tremendous amount of energy is released. Similarly, if two smaller atoms are combined (fusion reaction) in such a way that a part of the mass is lost, energy will again be released. In either the fusion or the fission reaction, the loss of 1 atomic mass unit results in the release of 931 million electron volts. As applied to a nuclear weapon, this explosive power is measured in equivalent tons of TNT.

The nuclear bomb dropped on Nagasaki is calculated to have yielded approximately 20 kilotons which is equivalent to 20,000 tons of TNT. These types of nuclear weapons produce their effects by the fissioning of atomic material and are popularly called atomic, or A-bombs.

Bombs can now be produced which have yields in the megaton range—that is, they are equivalent to millions of tons of TNT. These higher yield weapons result from the discovery that explosive force increases with the addition of radioactive hydrogen (tritium) to the nuclear material in the bomb's warhead. That is, the increase in the explosive yield results from the fusion of radioactive hydrogen atoms to form helium atoms and the liberation of additional energy. These large-yield weapons are known as hydrogen or H-bombs.

MEDICAL CONSIDERATIONS OF A NUCLEAR DETONATION

Regardless of the yield of a nuclear weapon, the field tests at Yucca Flats, Nevada, and Bikini Atoll, Eniwetok, have shown that damage and casualty predictions can be made within reasonable limits. To reduce the complexity of these predictions, an arbitrary system defining four zones of destruction has been developed as shown in Table I. The actual area in each of these zones of destruction is dependent upon a large number

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of variables including: size or yield of the weapon used; height of burst (air, ground, subsurface, or underwater); types of structures involved; and to a lesser degree, geographic and meteorologic conditions.

TABLE 1.—*Zones of Destruction*

Zone	Blast (psi)*	Heat (cal/cm²)**	Deaths and injuries
			Percent
1	15–35	40–1, 000	90 killed, 10 injured
2	10–15	10–40	60 killed, 30 injured
3	5–15	8–10	35 killed, 50 injured
4	2–5	3–8	10 killed, 35 injured

*psi—pounds per square inch.
**cal/cm²—calories per square centimeter.

The first zone or the zone of complete destruction is that area in which there is an air blast or shock wave with overpressures of 15 to 35 or more psi, plus flash heat of 40 to 1,000 or more cal/cm². In this zone 90 percent of the population will be killed and 10 percent injured. For a 20-kiloton weapon similar to the one used against Nagasaki, this zone will have a radius of about ½ mile and cover an area of approximately ¾ of a square mile. If a 4-megaton H-bomb is used, this zone of complete destruction will have a radius of 1 mile or more and cover an area of approximately 4 square miles.

A second zone with 10 to 15 psi overpressures and 10 to 40 cal/cm² will show severe damage to all but heavily reinforced structures. In this zone 60 percent of the population will be killed, 30 percent will suffer from injuries and 10 percent will escape injury. For a 20-kiloton weapon, this zone will extend for a radial distance slightly in excess of 1 mile and, including the zone of complete destruction, will cover an area of 4 square miles. Similarly for the 4-megaton weapon, this zone will extend for a distance of approximately 4 miles from the target center and will include an area of approximately 48 square miles.

In the third zone there will be overpressures of 5 to 10 psi and 8 to 10 cal/cm² flash heat. Approximately 35 percent of the population in this zone will be killed, 50 percent will be injured, and 15 percent will be unharmed. If a 20-kiloton weapon is used, this zone will have a radius of about 1⅝ miles corresponding to an area of more than 8 square miles. This area will, of course, be proportionately larger for a 4-megaton weapon extending to a radius of approximately 6 miles and covering an area of more than 108 square miles.

The fourth zone is that zone which receives an air blast of 2 to 5 psi overpressures and 3 to 8 cal/cm² flash heat. This area will show collapse of frame buildings, but only partial damage to reinforced structures. However, this damage to reinforced structures will probably be great enough to require minor repairs before these structures are again habitable. It is estimated that 10 percent of the population will be killed, 30 percent will suffer varying degrees of injury and 60 percent will be uninjured in this zone. In the case of a 20-kiloton bomb, this will extend out to a radius of about 2 square miles and cover an area of over 12 square miles when added to the more severely damaged and destroyed zones. Whereas, a 4-megaton weapon will extend the area of destruction more than 8 miles from the center of the detonation, and increase the area of destruction and damage to approximately 200 square miles.

To gain some insight into the enormity of this destructive force, a hypothetical bombing of an American city is proposed utilizing some of the facts and figures known about such a city. These figures, which were obtained from the U.S. Census Reports, show that this city covers 69 square miles and has a total population of 802,000 people. If we assume that this city has the same ratio of medical support facilities as exists for the nation as a whole, then there will be approximately 1,070 doctors, 460 dentists, and 535 pharmacists. There will also be 73 hospitals and a total of 7,620 hospital beds.

Experience gained from the bomb tests at Nevada and Eniwetok indicates that the detonation of a 20-kiloton nuclear bomb over the center of this city will kill approximately 50,000 people and injure another 48,000. Of those killed, approximately 70 will be doctors, 30 dentists, and 35 pharmacists, and another 65 doctors, 25 dentists, and 30 pharmacists will be injured. In addition, it can be anticipated that 17 of the city's hospitals will be completely destroyed or rendered uninhabitable and that the remaining 56 hospitals will have less than 5,900 beds for the care of the injured.

If a 4-megaton weapon is used, the results will be even more appalling. Under the same set of circumstances, the 4-megaton bomb will produce more than 427,000 deaths and 285,000 injuries, and will destroy or render uninhabitable all hospital facilities within the city limits. It can also be predicted that less than 120 doctors and 100 dentists and pharmacists will escape injury and be available to treat casualties. Furthermore, it can be anticipated that there will be little or no medical assistance from the immediate surrounding vicinity since the zones of moderate to heavy damage resulting from this size bomb will involve more than 130 square miles of the surrounding suburbs. This power of a nuclear detonation to kill and injure is achieved by blast, heat, and ionizing radiation, either separately or in combination.

Blast Injuries

Injuries produced by blast may be divided into two categories:

1. Primary (or direct) blast injury; and
2. Secondary (or indirect) blast injury.

Primary blast injuries are produced by the direct action of the shock wave upon the human body as it spreads outward in all directions from the center of the explosion. Since the overpressures exerted by the shock wave persist for a very small fraction of a second as it passes, it requires approximately 100 psi to produce any significant injuries. The force of the shock wave is dissipated very rapidly as it spreads and overpressures of this magnitude are, therefore, found only within a very short distance from the center of a nuclear detonation. Since the range of lethal effects from exposure to the heat and radiation of a nuclear detonation is so much greater, the chance of significant primary blast injuries, by themselves, are extremely remote. Secondary (or indirect) blast effects constitute a very real hazard, however.

Rigid structures, unlike the human body, may be fragmented by the passing of the primary shock wave. The fragments thus produced may move with speeds in excess of 100 miles an hour and be as lethal a weapon as a rifle bullet or shell fragment. In addition, casualties may also be produced by structural collapse of buildings and other large rigid structures. Secondary blast effects may further produce injuries by hurling individuals against hard objects. In both Hiroshima and Nagasaki, the primary cause of death was the purely mechanical injury produced by indirect blast effects.

Thermal Injuries

The second way in which a nuclear bomb demonstrates its power is in the extremely high temperatures which it generates. In a nuclear detonation, the energy liberated per unit mass in the form of heat is much greater than it is in the case of an ordinary bomb. A nuclear weapon releases roughly one-third of its total dissipated energy in the form of heat or thermal radiation. In the case of a 20-kiloton A–bomb, the energy emitted as heat exceeds 6.7 trillion calories which is equivalent to about 8,000,000 kilowatt hours.

The temperatures for the detonations over Japan with the bomb exploding at an altitude of 2,000 feet have been estimated to be between 3,000° and 4,000° C. (5,400° to 7,200° F.) at ground zero. It is readily apparent with temperatures such as these that all combustible material will be immediately consumed at ground zero. Furthermore, the primary blast wave and the subsequent air currents following the detonation may produce a fire storm. A fire storm can be likened to a large forest fire. Heat from the fire already burning creates updrafts of air which are fed by gale-like winds along the ground. This phenomenon can devastate a city and produce huge death and injury rates.

As might be anticipated, severe burn is the second most important cause of death and injury from a nuclear detonation. It is convenient to divide all burns resulting from a nuclear explosion into two categories, namely, primary and secondary burns. Just as in the case of blast injuries, these categories refer to the manner in which the burns were sustained. *Primary burns* (usually referred to as flash burns) are the direct result of the *thermal radiation* emanating from a nuclear explosion, while *secondary burns* result indirectly from the *fires* caused by the explosion. Biologically, they are much the same and are treated in the same manner as any other burn of the same degree of severity.

Originally it was believed that the thermal emission (flash) lasted for approximately 3 seconds. From the repeated bomb tests, it has been found that the duration of the flash varies with the size of the weapon used and may be less than 1 second in some cases. In Japan, flash burns were responsible for between 20 and 30 percent of all the fatalities caused by the nuclear bombings. This type of burn was recorded at a distance of 1½ miles from ground zero at Hiroshima, and as far away as 2½ miles at Nagasaki. The incidence of these burns was inversely related to the distance from the center of the explosion.

Since all radiation travels in a straight line from its source, flash burns are sharply limited to those areas of the skin facing the center of the explosion. Furthermore, as shown in figure 1, clothing will protect the skin to some degree unless the individual is so close to the center of the explosion that the cloth is ignited spontaneously by the heat. When a burn occurs under clothing it tends to involve those areas where the clothes are tightly drawn over the skin as, for example, at elbows and shoulders. In addition, dark colored cloth will absorb more light and heat, whereas light colored cloth tends to reflect a greater proportion of the thermal radiation. This difference in heat absorption produced the unusual burn patterns on individuals who were wearing clothes with multicolored patterns at the time of the explosion. As shown in figure 2 the Japanese woman clad in a kimono at the time of the explosion had her back and arm badly burned in a pattern corresponding to the dark portions of the kimono while the skin under the light portions was unharmed.

Figure 1.—"Flash Burns" of Third Degree. Partia protection of lower extremities by cloth trousers, and complete protection of abdomen by multiple layers of a cummerbund. Burns of the back where there was no clothing are sharply outlined. Photo courtesy Armed Forces Institute of Pathology.

Figure 2.—Burn Pattern Beneath Multi-Colored Clothing. Photo courtesy Armed Forces Institute of Pathology.

Eye Burns.—In addition to injuries to the skin, the eyes may be affected by the flash of thermal radiation. If an individual is looking in the general direction of a nuclear detonation, he may be flash blinded. This blindness is not unlike that which an individual suffers when he has his picture taken with a flash camera, except that the blindness may persist for 20 to 30 minutes. In the Japanese bombings there is not a single case known in which flash blindness was permanent; recovery occurred in every case.

A second, and very serious type of eye injury may occur, however. If an individual is looking directly at the fireball of a nuclear detonation, he may receive a retinal flash burn similar to the flash burn which occurs on exposed skin. Unfortunately, when the burn heals, the destroyed retinal tissue is replaced by scar tissue which has no light perception capability and the individual has a scotoma (a blind or partially blind area in his visual field). If the involved area of the retina is sufficiently large, the net result may be total, permanent blindness in the involved eye.

Radiation Injuries

Ionizing radiation is the bonus of a nuclear bomb. The weapon was developed primarily to exploit its terrific ability to destroy by blast and heat. In this destructive package, then, radioactivity is the added bonus.

What is the source of the radioactivity from a nuclear weapon? Radioactivity is contained in a nuclear weapon. At the instant of detonation, much of this radioactive material is split (fissioned) into smaller particles which are also radioactive and are dispersed by the force of the blast. Radioactivity is further disseminated by the fireball, which contains many of the fission products. Most of these fission products are carried aloft and cause little or no immediate harm. Some of the products may remain on the ground entrapped in the fused soil, if the fireball touches the ground. Furthermore, the elements which make up the soil may become radioactive as the result of bombardment by the neutrons produced during the nuclear detonation (induced radioactivity). This residual radioactivity may be great enough to be hazardous to rescue teams entering the area for several days after the detonation.

The actual particles and rays involved in the production of radiation injuries are the alpha and beta particles, neutrons, and gamma rays. These particles and rays produce their effect by ionizing the chemical compounds which make up the living cell. If enough of these rays or particles disrupt a sufficient number of molecules within the cell, the cell will not be able to carry on its normal functions and will die. If a sufficient number of cells are killed or injured in such a way that they cannot carry out their functions, the entire organism, man, will die.

Alpha particles are, in reality, helium nuclei; that is, they are helium atoms which have lost their two orbital electrons. They have a mass, or weight, of approximately four atomic mass units and they have an electrical charge of +2. Because of this charge, alpha particles produce a high degree of ionization when passing through air or tissue. Also, due to their relatively large size and electrical attraction, they are rapidly stopped or absorbed by a few inches of air, a sheet of paper, or the superficial layers of skin. Thus, alpha particles do not constitute an external radiation hazard. However, because of their great ionization power, they constitute a very serious hazard when taken into the body through ingestion, inhalation, or through an open wound.

Beta particles are negative electrons. They have a mass of approximately 1/2,000 of a hydrogen atom and have an electrical charge of −1. Beta particles produce less ionization than alpha particles, but because of their smaller size and electrical charge, they have a much greater penetrating power. However, this penetrating ability is generally not great enough to extend through the intact skin. Therefore, beta particles, like alpha particles, constitute little or no external hazard but are quite definitely a serious internal hazard.

Neutrons are particles of approximately the same mass as hydrogen atoms and they carry no charge. Since they have no charge, they are not affected by the electrical field around an atom and are stopped only by collision with, and absorption into, the nucleus of an atom in their path. When they are absorbed (captured) by the nucleus of an atom, they frequently make this atom radioactive and it then becomes a point source of ionizing radiation until it returns to a stable state by radioactive decay. Although neutrons generated by a nuclear explosion are very important in producing induced radioactivity in most all materials near the center of the burst, direct neutron effects to the human body are very unlikely to produce additional casualties since the range of neutrons in air, although much greater than alpha or beta particles, is nevertheless much less than the lethal range of the blast or thermal effects resulting from a nuclear detonation.

Gamma rays are electromagnetic waves. They have no mass and no charge. Biologically, gamma rays are identical to X-rays of the same energy and frequency. Because they have neither mass nor charge, gamma rays have great penetrating power. Gamma rays produce their effects mainly by knocking orbital electrons out of their orbit thereby ionizing the atom so affected and, in addition, producing a beta particle. Gamma rays are an important medical consideration in a nuclear bombing since their range is great enough to produce biologic damage either alone or in conjunction with blast and thermal injuries.

DIAGNOSIS OF NUCLEAR CASUALTIES

Blast and thermal injuries resulting from a nuclear detonation are no different from mechanical injuries or burns produced by other means. Therefore, these injuries are identical to those described in Chapter III, First Aid and Emergency Procedures. However, the danger of additional injury resulting from exposure to ionizing radiation must always be considered and it is, therefore, important to remove the casualty from the radiation field and to decontaminate him before instituting definitive treatment. In general, only lifesaving procedures such as artificial respiration and hemorrhage control should be accomplished before moving a casualty.

The clinical features of radiation illness are dependent upon the total doses of ionizing radiation received by the individual and the rate at which he received that dose. Doses are expressed in rem (roentgen equivalent, man) of total body irradiation and relative uniformity of distribution of the radiation throughout the body is assumed. In this discussion of the effects of nuclear weapons we are concerned only with those types of radiation injuries which are produced by a relatively short exposure to a high dose of ionizing radiation and not with those chronic effects which may occur in workers who are occupationally exposed to low levels of ionizing radiation over a long period of time. Table II indicates the relative severity of injury which can be anticipated at various levels of short-duration exposure to ionizing radiation.

TABLE II.—*Effect of Short-Duration Exposure to Ionizing Radiation*

Dose	Severity
50 rem	Usually subclinical, not incapacitating.
100 rem	15 percent will have mild symptoms.
200–300 rem	Moderate to severe symptoms, incapacitating, a few may die.
400–600 rem	Severe symptoms, 50 percent will die.
800–1,000 rem	Death is probably inevitable in spite of treatment.

When an individual has sustained a radiation injury as the result of a nuclear detonation, it may be impossible to estimate the radiation dose from field measurements. However, the clinical course of acute radiation injury is roughly indicative of the dose received and can be estimated by observing the patient closely for the first 24 to 48 hours. As indicated in Table III the clinical course can be divided into four clinical stages or periods. Except for those individuals who have received a massive dose of ionizing radiation, most patients will follow this clinical course, although the symptoms, signs, and laboratory findings may vary in type, severity, and timing, depending upon dose and individual susceptibility.

TABLE III.—*Clinical Stages of Acute Radiation Injury*

Clinical stages	Approximate duration
1. Prodromal period	0 to 48 hours.
2. Latent period	2 to 3 weeks.
3. Period of illness	3 to 5 weeks.
4. Recovery period	8 to 15 weeks.

Prodromal Period

It may be difficult to assess this period since it can be influenced by psychologic factors in the involved individuals. The principal signs and symptoms include anorexia, nausea, vomiting, profuse sweating, malaise, and prostration. The time of onset and the severity of symptoms depend upon the dose of ionizing radiation received. In general, the earlier the onset, the higher the dose.

Symptoms appearing within 1 hour after exposure indicate either an overwhelming dose of radiation or a severe psychologic reaction. In 90 percent of those exposed to a significant amount of radiation, symptoms will occur within 1 to 4 hours after exposure. If no vomiting occurs by the end of the 4th hour, the patient probably has not received a significant dose of radiation. If, however, in addition to the early signs and symptoms, the patient rapidly develops diarrhea, ataxia (loss of muscular coordination), disorientation, coma, or cardiovascular collapse, he has received an overwhelming dose of ionizing radiation.

By the 6th to the 8th hour after exposure, the prodromal symptoms reach their maximum intensity. From the 24th to the 48th hour, symptoms subside in all but the overwhelmingly exposed group.

Latent Period

In the individuals who receive an overwhelming dose of ionizing radiation, the usual clinical course may be of continued illness with no latent period before onset of symptoms. In the less seriously exposed patients, the latent period may last for as long as 2 to 3 weeks during which time the patients remain symptom-free except for some mild weakness and fatigue.

Period of Illness

Those individuals who receive more than 800 rem rarely survive more than 24 hours. The illness terminates fatally following severe restlessness, incoherence, abdominal cramps and retching with the patient gradually subsiding into collapse, coma, and death.

Those individuals who receive more than 500 but less than 800 rem continue to be ill without an intervening latent period. Symptoms of nausea, vomiting, diarrhea, and abdominal cramps dominate the clinical picture and are accompanied by high fever and pancytopenia (deficiency of all cell elements of the blood). As the symptoms progress, blood appears in the stool and vomitus, and ultimately extreme prostration with episodes of shock develops. The patient becomes unresponsive to resuscitative measures and dies between 15 and 30 days after the initial exposure.

In those individuals who receive from 300 to 500 rem, symptoms reappear after a 12- to 14-day latent period. The symptoms begin with sore throat and fever, and marked pharyngitis with ulceration is found on physical examination. The condition rapidly develops with hyperemia (excess of blood in an area), bleeding of the gums, and loosening of the teeth. Epilation (falling of hair) begins, and purpura (subdermal hemorrhage) of the skin and mouth soon prevails. At this time occult blood shows in the stool. These signs persist until large ecchymotic (extravasated blood in tissue) areas develop. It is generally possible to demonstrate pancytopenia and acellularity (depletion of cells) of the bone marrow.

The patient becomes prostrate, lethargic, and intermittently disoriented. Oliguria and diarrhea begin and the diarrhea may be accompanied by massive hemorrhage, severe abdominal cramps, and occasionally obstruction of the intestines. Hematemesis (vomiting of blood), hematuria (blood in the urine) and, in females, vaginal bleeding occur. In spite of vigorous therapy with parenteral fluids, nutrients, blood transfusions, and other supportive measures, profound shock and coma generally develop, and death usually occurs between 25 and 40 days after the exposure to ionizing radiation.

Following a latent period of 2 to 3 weeks, those individuals who receive from 100 to 300 rem of ionizing radiation develop mild epilation and skin tenderness. At about the same time chills, fever, sore throat, headache, fatigue, and exertional dyspnea develop. The patient's condition degenerates rapidly and he requires bed rest. Mucous membranes redden and swell, and bleeding of the gums, blood in urine, and tarry, blood-stained stools generally follow. There is a gradual weight loss and an increase of susceptibility to secondary infections especially of the upper respiratory system. With adequate supportive treatment the clinical manifestations begin subsiding in 40 to 50 days. Although convalescence usually begins between 60 and 90 days after exposure, clinical recovery is usually not complete for 6 months.

MONITORING, DECONTAMINATING, AND SORTING NUCLEAR CASUALTIES

Measures for Self-Protection

Before proceeding to a discussion of monitoring, decontaminating and sorting, a brief word should be directed to those who will be assigned to rescuing and decontaminating duties. Teams entering areas of radioactivity for the purpose of removing casualties and those working in decontaminating stations need have no fear of alpha and beta particles penetrating the skin if ordinary precautions are taken to keep the skin adequately covered. The main concern is to prevent these radioactive particles from entering the body via inhalation or ingestion. This can be accomplished by wearing an appropriate face mask. If one is not available, the following improvisations are suggested to provide some protection:

1. Eight layers of thin cotton; for example, a man's folded handkerchief.

2. Three surgical masks.
3. A turkish towel.
4. Three layers of toilet tissue (caution: the tissue absorbs moisture from the breath and will tear easily).

Radioactive decay progresses rapidly in the early hours after a nuclear blast, and the hazards to rescue workers can be reduced considerably if operations can be delayed until natural decay has reduced the level of radioactivity. If teams trained in use of survey instruments are available, all guesswork can be removed for they will determine the intensity of radiation with their instruments and mark perimeters of danger zones.

Under most conditions, foul weather gear of standard stock issue will protect ordinary clothing and skin from direct contact with radioactive particles. A complete outfit includes the parka, trousers, rubber boots, and gloves and should be worn (together with the mask) for rescue work after zones have been established. Those who have only ordinary work clothing must consider themselves inadequately protected.

Monitoring

In a large-scale nuclear catastrophe there may be innumerable casualties suffering not only from mechanical injuries and thermal burns, but from radiation injuries and psychologic reactions as well. One of the first problems will be to organize an efficient system of sorting. The medical facility should consist of a personnel monitoring station, a clean and a contaminated emergency treatment station, a decontamination station, a sorting station and various treatment stations as shown in figure 3. It should be set up so that personnel must pass through a monitoring station prior to sorting for medical care. If there is a need for decontamination, the casualty should be routed through the decontamination station on his way to the sorting station. If possible the physical layout should be arranged so that no casualty can bypass the monitoring station and go directly to a treatment station. Also, casualties who are contaminated should be unable to enter clean areas without first passing through a decontamination station.

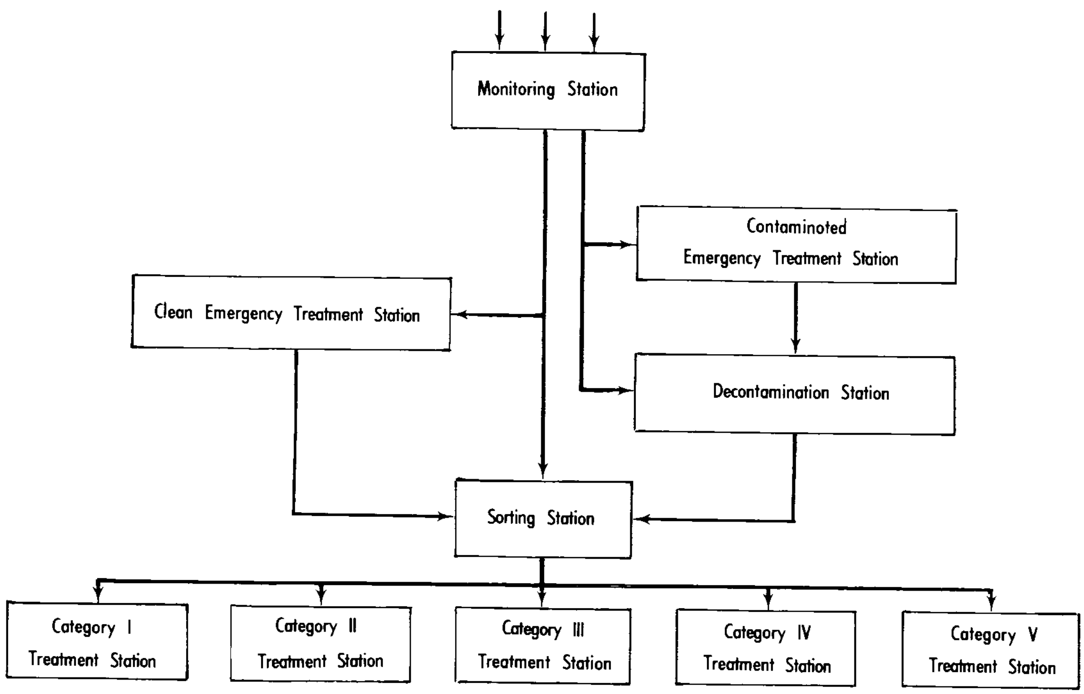

Figure 3.—Patient Flow Pattern and Medical Treatment Facility.

When patients are brought in by the rescue teams or arrive on their own, they should first proceed through the monitoring station to determine whether or not they are contaminated with radioactive material. No medical treatment should be instituted in the monitoring station.

Generally speaking, any personnel who have had training and are experienced as members of Radiologic Safety and Radiologic Decontamination teams, or as members of Damage Control parties should be sought and assigned to the monitoring station. However, it is advisable for those operating the monitoring station to have a basic knowledge of first aid, just as it is for rescue teams who are trained in first aid to have knowledge and experience with radiac instruments. In this way, individuals can be used in either capacity should the need arise.

After the patients are monitored, they are directed or taken down one of four avenues depending upon their physical condition. Those requiring immediate lifesaving measures are taken either to a clean or contaminated emergency treatment station whichever is appropriate. Both treatment stations are set up much the same and should have only those facilities which are necessary for immediate lifesaving forms of treatment. Personnel working in these stations should be better versed in emergency first aid care than those utilized for monitoring and for rescue teams, and they need not be trained in radiation monitoring.

After emergency lifesaving procedures have been attended to, casualties from the clean emergency treatment station should be taken directly to the sorting station and those from the contaminated treatment station should be taken to the decontamination station.

Those casualties who do not require immediate emergency treatment should be taken or sent from the monitoring station directly to the sorting station or to the decontamination station whichever is appropriate. The decontamination station should be set up to take, hold, and dispose of all contaminated clothing and to supply clean replacement clothing after the casualty has been decontaminated. It will also need monitoring equipment, showering and washing facilities, and some surgical capability for surgical decontamination when necessary. (For procedures of decontamination, see below.)

Of the personnel available to the treatment facility, several of those most experienced and knowledgeable in radiologic safety and radiation protection should be assigned supervisory jobs in the decontamination station. Also, it is highly desirable to have some personnel with operating room experience to decontaminate patients with traumatic injuries. It is not necessary for the other personnel working in the decontamination station to have any appreciable training or experience other than that given when the medical facility is put into operation.

Decontaminating

Early removal of radioactive "dirt" will reduce radiation burns, radiation dosage, and the chances of internal radiation. There are two rules to be remembered in the removal of radioactive contamination:

1. Removal of radioactive dirt is accomplished in the same way as good personal hygiene; i.e., soap and water, or, failing this combination, creams.

2. Contamination is easily spread and "spot" cleaning must be attended to before general decontamination procedures are started.

Cotton swabs or gauze may be used to decontaminate moist areas, gummed tapes to decontaminate dry areas. Any one of several skin cleansers may be used (see below). If after cleansing decontamination is inadequate, the process should be repeated 3 to 5 times; then, if contamination still persists, another preparation should be tried. The following preparations are suggested as decontaminants:

1. A mixture of 50 percent detergent and 50 percent cornmeal with enough water added to make a paste. This should be used with additional water as necessary and the radioactive area scrubbed for 5 minutes then rinsed.

2. A mixture of 30 percent detergent, 65 percent sodium hexametaphosphate, 5 percent carboxymethyl cellulose and 5 percent water. This should be used with additional water, the area scrubbed for 1 minute, then rinsed.

3. A cream made of 8 percent carboxymethyl cellulose, 3 percent detergent, 1 percent ethylenediaminetetraacetic acid (Versene), and 88 percent water. This cream should be rubbed into the

contaminated area vigorously for 1 minute, then wiped clean.

4. Abrasive soap used with water in a scrubbing action.

5. Mechanics' waterless hand cleansing cream. This cream should be rubbed into the area for 1 minute, then wiped or rinsed off.

After the hot spots have been removed, the second step is to shower with soap and water. Scrub the body, hair, and hands thoroughly. Clean the fingernails. After the shower, monitor again and if any contamination remains, again spot clean and shower. If the hair is contaminated, shampoo it several times.

If it becomes apparent that shampooing has not removed the radioactive material, clip the hair as close to the scalp as necessary to remove the radioactive material.

If areas become tender from excessive washing, it may be necessary to restore some of the skin oils. To do this, add a small amount of cornmeal to lanolin or ordinary hand or face cream and rub this mixture into the skin for 5 minutes and allow to remain on the skin for another 5 minutes, then remove. This will soothe the skin and prepare it for further decontamination if additional steps are necessary. Decontamination should be continued until the radioactivity has been reduced to the "safe" level set by the responsible Medical Department representative, or until he decides the surgical removal of the involved area is necessary in which event steps should be taken to bring the casualty to the care of a surgeon.

The steps outlined above all require large amounts of water. Facilities available may have only a limited supply of "clean" water. The following decontaminants attempt to take advantage of the chemical properties of the contaminant:

1. Apply ammonium citrate or citric acid to the "hot" areas and rub for at least 5 minutes. Then rinse the chemical off with plain water and dry the area.

2. Add 1 gram of a 1-to-1 mixture by weight of tartaric and citric acids to a basin of water and soak the hot area for several minutes. This is especially recommended for contaminated hands and feet.

Any uncontaminated cut, scratch, or wound should be protected with an impermeable tape or other suitable material while decontaminating the rest of the body. If a wound is already contaminated, the simplest and least drastic decontaminating method available should be tried first and always by trained medical personnel. First the wound should be carefully bathed or flushed with sterile water and a reasonable amount of bleeding should be encouraged.

Handling Contaminated Material

Radioactive material may be removed but not destroyed. Water then becomes a special problem. Water coming from an underground source usually is free from radioactive materials and is therefore usable, but water coming from a reservoir which has to depend upon a surface watershed for its source will not be usable. Fortunately, regular water-treatment processes which include coagulation, sedimentation, and filtration will remove most fallout material and, if the reservoir water can be properly treated, will be usable. *But* for safety's sake, water should never be drunk without testing. Distillation can be depended upon to free water of radioactive material and emergency drinking water can be provided by using this process.

Supplies and food can be protected from residual radiation by storage in dust-tight containers. Although the outside of the containers may become contaminated, most of this radioactive material may be removed by washing. The container can then be opened and the contents removed (with "clean" instruments or hands) and used without fear of causing significant contamination.

The outer wrappings on medical supplies and the peelings on fruit and vegetables also afford protection to their contents. After carefully removing the outer coverings and monitoring the contents, it may be found that these materials will be safe to use.

Contaminated clothing should be handled with care. It should never be casually placed on furniture, hung on walls, or dropped on floors. Clothing should be stored in garbage cans or disposable containers, and failing the availability of these, it should be placed on pieces of paper large enough to be rolled and secured. If grossly contaminated, this clothing should then be disposed of by burial at sea or in deep pits or trenches, whichever is appropriate.

Under certain circumstances clothing may be in short supply. In this event, lightly contaminated clothing can be salvaged to a large degree by special laundering techniques. An effective procedure is to have the clothing monitored and separated into different activity levels. Three washings in hot detergent should then follow for each level. After the initial three washings, the clothing should then be washed three times in a warm 1 percent Versene detergent, then thoroughly rinsed and dried. To be sure that this procedure has freed the clothing of radioactive material, each article should be monitored before it is released for reuse. Rubber and plastic materials are readily decontaminated in a warm detergent wash.

Sorting

All patients—those coming directly from the monitoring station, from the clean emergency treatment station, and from the decontamination station—must pass through the sorting station. The primary function of the sorting station is to determine into which of the five treatment stations each patient must go (see Table IV). To insure efficient operation of the entire medical facility and to return the greatest number of casualties to useful and necessary work while saving the maximum number of lives with the limited facilities available, it is essential to assign the doctor (or doctors) who has the best diagnostic ability to this station and to give him sufficient technical and nontechnical assistants to keep the flow of patients moving to the various treatment stations.

TABLE IV.—*Mass Casualty Treatment Categories*

Category I	Outpatient care only.
Category II	Moderate illnesses and injuries when chances of recovery are good following immediate definitive care.
Category III	Injuries and illnesses when chances of recovery are not jeopardized by delayed definitive treatment.
Category IV	Critical illnesses and injuries which require extensive, complicated, time-consuming and material-consuming procedures.
Category V	Illnesses and injuries which are beyond medical help.

Because of the critical shortage of medical supplies and medically trained personnel, as demonstrated in the example of the bombed American city given above, good judgment must be exercised in assigning personnel to the treatment of patients in the various injury and illness categories. The treatment station for Category I patients will require personnel who are capable of treating minor wounds, lacerations, simple fractures, burns and all the other injuries and illnesses similar to those usually seen and treated in outpatient facilities. Dentists, nurses, veterinarians, pharmacists, hospital corpsmen, Red Cross workers, scout leaders, athletic coaches, etc., should be assigned, thus freeing doctors for assignment to other categories. Patients in this category should be given the highest priority for treatment so that they may be sent to the appropriate military or civilian authorities as quickly as possible for utilization in rescue, salvage and repair, and reconstruction work.

By the nature of the illnesses and injuries involved, the largest number of medical and paramedical personnel with surgical skills will be required by Category II patients. It is highly possible that, under these difficult circumstances, it will be necessary to set up an operating room in such a way as to permit a surgeon to supervise 4 to 6 operating tables at one time while the definitive treatment is being performed by dentists, nurses, veterinarians, and operating room technicians. Practically all of the remaining medical and paramedical personnel will be required to take care of the postoperative treatment and nonsurgical casualties in this category.

If practicable, a few medical and paramedical personnel may be assigned to the patients in Category III and Category IV to provide comfort and prolong life until medical personnel and supplies become available. Otherwise, mature and understanding adults such as mothers and school teachers may be utilized to provide sympathetic support to these patients.

Additional mature and understanding adults, as well as all the available ministers, priests, and nuns who are not trained in nursing should be assigned to the care of the patients in Category V so that the patients may die in peace and comfort with dignity.

TREATMENT OF NUCLEAR CASUALTIES

The majority of injuries resulting from the detonation of an A– or H–bomb are likely to be mechanical wounds resulting from collapsing buildings and flying debris, and burns caused by the heat and light liberated at the time of detonation.

A burn is a burn regardless of whether it is caused by an A–bomb or napalm, and its management remains the same. This is also true of fractures, lacerations, mechanical injuries, and even shock. In none of these is the treatment dictated by the cause. For most of the conventional injuries, then, management as outlined in Chapter III, First Aid and Emergency Procedures, applies.

One word of caution regarding management of wounds and burns. Dressings for wounds and burns should follow a closed-dressing principle with application of adequate sterile dressing using aseptic techniques, if sufficient medical supplies are available. No attempt should be made at wound closing regardless of size, unless authorized by a physician.

There are a few variations in treatment which have been proposed by researchers in the field and one of these concerns the use of antibiotics. It has been recommended that antibiotics should not be given prophylactically, routinely, since this may cause the development of resistant bacteria within the host. If signs of infection develop, it is recommended that antibiotics should be given in large doses. When no physician is available to direct treatment, the corpsman should consult the section on Antibiotic Therapy in Chapter III, select an antibiotic on the basis of availability and appropriateness, and administer it in amounts three times that recommended. If the temperature is not controlled with the antibiotic employed, switch to another. If the fever recurs, switch to still another. Overwhelming infection can develop rapidly in the pancytopenic state.

It has been further recommended that whenever a broad-spectrum antibiotic is given, oral antifungal antibiotics should also be administered. Nystatin for oral suspension is on the supply table and the dosage is 1 ml. four times a day, continued for as long as the antibiotic is given.

To date, there is no specific therapy for the injuries produced by lethal or sublethal doses of ionizing radiation. This does not mean that all treatment is futile. Good nursing care and aseptic control of all procedures is a "must," and casualties should get plenty of rest, light sedation if they are restless or anxious, and a bland nonresidue diet. A meticulous history and physical examination with special reference to prior chronic infections should be done.

It is comforting to note that after even fairly high doses of radiation, therapy may not be necessary. Those exposed to high doses of beta and gamma radiation from fallout in the Marshall Islands, and others exposed to neutrons and gamma radiation in an accident at Oak Ridge had loss of hair and some bleeding. No treatment was indicated and none given, yet recovery was complete.

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