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Atomic bomb : medical aspects

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MEDICAL ASPECTS OF THE ATOMIC BOMB WITH EMPHASIS ON THE RADIATION EFFECTS.

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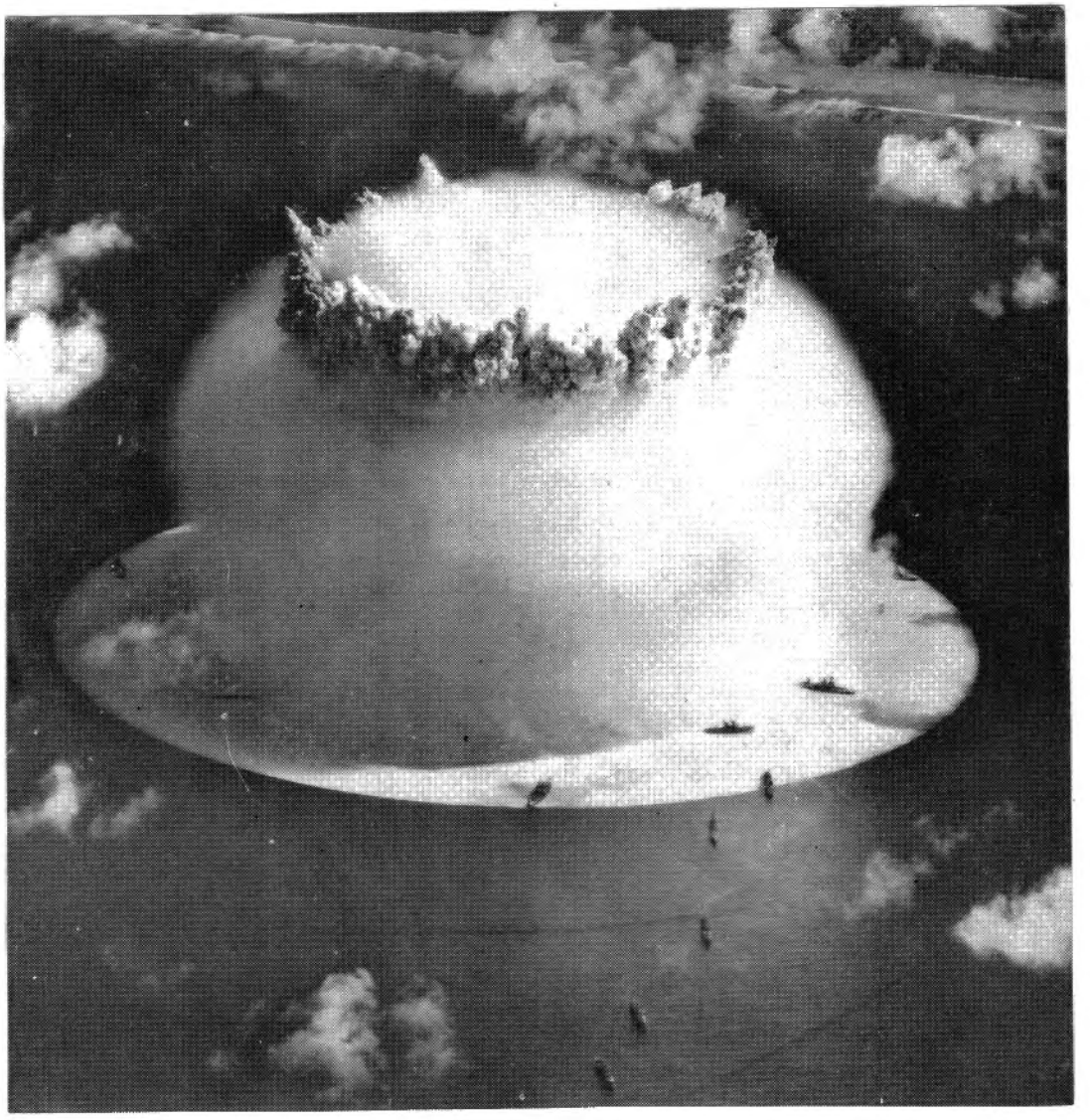
TABLE OF CONTENTS.



MEDICAL ASPECTS OF THE ATOMIC BOMB

WITH EMPHASIS ON THE RADIATION EFFECTS.

1. INTRODUCTION

The discovery of x-ray by Roentgen in 1895 opened to the world the field of ionizing radiation. Soon after the discovery Becquerel noted the first indication of its being a biologic hazard when he discovered a burn on the skin underlying his vest pocket containing a vial of radium. A half century later a hundred thousand people were to die from this same biologic hazard released by atom bombs dropped on their cities.

During the present hour of international unrest when no community in the world is apparently safe from an atomic bombing, the medical profession should be aware of the potential dangers of the bomb and how best to handle the large number of casualties in event of a local emergency.

Additional problems related to this biologic hazard which might arise as a result of the release of radiant energy during use of fissionable or radio-active material are cited by Warren (1). The fast or slow burning of a uranium pile being used in research or power production might inflict damage on humans in contact with it; or the use of radioactive isotopes in research, medical therapy, and in manufacturing processes might expose large numbers of people to its toxic effects and resultant case problems confronting the physician would be numerous and complex.

Should an atomic bombing occur, local medical facilities could not possibly handle all victims presented to them in the critical period immediately following the explosion. On the first day of the bombing of Hiroshima, for example, approximately 85,000 persons required care. (2) There is no doubt that many died who might have been saved by modern, competent therapy.

Should such a catastrophy occur in the future, among the casualties would be found many who had received such high doses of ionizing radiation that death in a few hours or days would be inevitable in spite of all known therapeutic measures, and on whom time and materials spent would be useless. On the other hand, many of the less seriously exposed could be saved and would recover permanently if they were to receive adequate therapy. It is on this latter group that medical facilities should logically be concentrated insofar as humanely possible.

It is the purpose of this paper to discuss the medical effects of the atom bomb in general; but more specifically, to cover its radiation effects in an effort to provide a background for evaluation of those casualties which would benefit most by the limited medical care available immediately following an atomic explosion.

In order to appreciate conditions at the time of an atomic bomb blast it would be well to reconstruct the scene in Hiroshima as determined by various governmental investigative groups in talking with survivors; (3)

"The morning of 6 August 1945 began bright and clear. At about 0700 there was an air-raid alarm and a few planes appeared over the city. Many people within the city went to prepared air-raid shelters, but since alarms were heard almost every day the general population did not seem to have been greatly concerned. About 0800 an all-clear was sounded after the planes had disappeared. At this hour of the morning many people were preparing breakfast. This fact is probably important since there were fires in charcoal braziers in many of the homes at this time. Some of the laboring class were at work but most of the downtown business people had not gone to work. Consequently, a large percentage of the population was in their homes and relatively few were in the more strongly constructed business buildings.

"After the all-clear sounded persons began emerging from air-raid shelters and within the next few minutes the city began to resume its usual mode of life for that time of day. It is related by some survivors that they had watched planes fly over the city. At about 0815 there was a blinding flash. Some described it as brighter than the sun, others likened it to a magnesium flash. Following the flash there was a blast of heat and wind. The large majority of people within 3,000 feet of ground zero were killed immediately. Within a radius of about 7,000 feet almost every Japanese house collapsed. Beyond this range and up to 15,000-20,000 feet many of them collapsed and others received serious structural damage. Persons in the open were burned on exposed surfaces, and within 3,000-5,000 feet many were burned to death while others received severe burns through their clothes. In many instances clothing bust into spontaneous flame and had to be beaten out. Thousands of people were pinned beneath collapsed buildings or injured by flying debris. Flying glass particularly produced many non-lethal injuries at greater distances from the center of the blast. - - -.

"Shortly after the blast, fires began to spring up over the city. Those who were able made a mass exodus from the city into the outlying hills. There was no organized activity. The people appeared stunned by the catastrophe and rushed about as jungle animals suddenly released from a cage. Some few apparently attempted to help others from the wreckage, particularly members of their family or friends. Others assisted those who were unable to walk alone. However, many of the injured were left trapped beneath collapsed buildings as people fled by them in the streets. Pandemonium reigned as the uninjured and slightly injured fled the city in fearful panic. Teams which had been previously organized to render first aid failed to form and function. Those closer to ground zero were largely demobilized due to injuries and death. However, there were physically intact teams on the outskirts of the city which did not function. Panic drove these people from

the city just as it did the injured who could walk or be helped along. Much of the city's fire-fighting equipment was damaged beyond use so that soon the conflagrations were beyond control.

"In Nagasake a similar but slightly less catastrophic picture occurred. The blast was not centered over the main business section of the city but was up the valley about two miles. There were large industrial plants, hospitals, the medical school and partially built-up residential areas near the ground zero. The terrain in this area was uneven with large hills which shielded certain areas. Due to the shielding factor and the distance of the explosion from the center of the city, Nagasaki was less completely destroyed than Hiroshima and the panic was apparently less."

Details relative to the nature of the injuries and the distances at which they occurred are discussed later, but the foregoing presentation was necessary for one to appreciate the state of the population immediately after the bomb exploded.

II. NATURE OF ATOMIC BOMB CASUALTIES.

A. Introduction. Generally speaking, the casualties produced by an atomic bomb can be divided into three large groups;-

1. Blast injuries.

2. Burns.

3. Radiation sickness.

In order to appreciate how these are produced one must first consider the conditions resulting at the instant of detonation of the bomb. At this time, there is generated an incredible amount of energy of four main types;- mechanical, heat, light and ionizing radiation (alpha, beta, gamma rays and neutrons). The energy released is formed by the phenomenon of nuclear fission during which atoms of uranium 235 and plutonium 238 are bombarded by neutrons. When a neutron hits such a fissionable nucleus the

atom is split and two or three new neutrons are released. These new neutrons are available to produce fission of other atoms of the same material and the "chain reaction" resulting in an atomic explosion is instantly propagated.

The type of injury the victims sustain depends on a number of factors;- (1) distance from center of explosion; (2) amount and type of shielding between the victim and the various forces acting on him; (3) method in which the force acts on him - for example, (a) burns can be of the primary flash burn type caused by the initial heat of the explosion or can be secondary in nature if the person is trapped in a burning building, (b) blast effects can be primarily due to the direct compression wave of the initial explosion causing rupture of the ear drums, viscera, etc., or secondarily due to falling and flying debris, (c) radiation effects vary with the type of radiation (alpha, beta, and gamma rays, or neutrons) and the mode in which it reaches the body - - externally through air and penetrating the skin into deeper tissues or internally in the form of contaminated products ingested, inhaled, or by gaining entrance to the body through breaks in the skin.

All the above factors will be discussed under appropriate headings, but for now mention of the distance-from-center-of-explosion relationship, magnitude of casualties produced, and relative importance of the various types of injuries seen following the blast may serve to give a general picture of the medical problems at hand.

The degree and type of injury produced as related to the distance from the center of the blast or "ground zero" has been summarized as follows;-

1. Within one-half mile of zero point of the air-burst detonation, personnel in the open would die almost instantaneously or within a few hours from the blast, heat, and radiation effects.

2. Within a radius of one-half mile and one mile from zero point, some persons would die instantly, while a majority would receive varying degrees of injury. Ordinary houses and structures would suffer complete destruction or extensive damage and fires would be widespread.

3. Outside a radius of one mile and within a radius of two miles from zero point, personnel would suffer injuries from flash burns and indirect blast effects.

4. Outside a radius of two miles and within a radius of four miles, personnel would be injured by flying fragments and suffer superficial wounds. Structures would be half or partially destroyed within this radius.

An idea of the magnitude of the atomic bomb casualties presented to medical personnel in Hiroshima and Nagasaki is indicated by the following estimates of LeRoy (1) in his review of studies made by Army and Navy medical missions to Japan:-

ATOM BOMB CASUALTIES.

	HIROSHIMA	NAGASAKI
Population	300,000	200,000
Dead	80,000	40,000
Injured	40,000	25,000
Patients in need of immediate care	85,000	50,000

Not all these casualties were in need of immediate medical care for in each city approximately one-sixth the total number of casualties were killed instantly or died under circumstances in which no help was possible. They were burned to death by the direct heat

of the bomb, were crushed under demolished buildings or trapped in burning debris. About one-seventh of the total escaped both mechanical injuries and burns but received a dose of gamma rays sufficient to make them sick one to five weeks later. On the basis of these estimates approximately 85,000 persons in Hiroshima, and 50,000 in Nagasaki required care on the day of the bombing.

An analysis of 381 cases at Nagasaki relative to the type of injuries at various distances from ground zero reveals the following: (3)

DISTANCE (feet)	TOTAL CASES	PERCENT OF PATIENTS SHOWING				
		radiation epilation	radiation sickness	flash burns	flame burns	secondary injuries
0 - 3,281		116	28	39	9	62
3,281 - 6,562		215	36	41	9	50
6,562 - 9,643		50	12	16	18	26

In regard to an air burst explosion it has been estimated that 70 per cent of those exposed would suffer from trauma, 65 per cent from burns, and over 35 per cent from radiation (3). Traumatic wounds and burn casualties would demand immediate care, but attention to control of pathologic conditions sure to develop later on in radiation casualties would have to be anticipated and appropriate measures taken as will be discussed later.

B. Blast Effects.

The blast effects may be further subdivided into direct and indirect types and differ in no essential respect from those produced by the conventional type high explosive bomb. (3)

The direct blast effects are caused by the compression wave which travels outward from the focus of detonation enveloping the individual and compressing him, causing tissue disruption such as rupture of ear drums, lungs or viscera at tissue-gas interfaces. These primary effects were not great in the atomic bombing of Hiroshima and Nagasaki because of the height above the city at which the bombs were exploded. On the basis of available information the British have estimated that the maximum pressure did not exceed two atmospheres, and in accordance with most observors felt that true blast effects alone were rare and probably accounted for only a small percentage of the total casualties. (3,4).

Secondary blast effect, i.e. injuries produced by falling and flying debris were large in number. The collapse of buildings was sudden and thousands of people were pinned beneath the debris. Injuries by flying glass became more prominent at increasing distances from ground zero. People indoors, especially near windows were hit by showers of glass fragments which penetrated deep into muscles. Usually the fragments were small, very numerous and produced great trauma although death from this cause was rare and the wounds healed up within six weeks. (3)

General available information indicates that secondary injuries occurred up to 15,000 feet from ground zero. (3) Japanese houses collapsed within a radius of about 7,000 feet at both Hiroshima and Nagasaki, but serious damage resulted in a much wider range. It appears that secondary injuries, particularly those of lethal nature, began to fall off rapidly at distances beyond 7,000 feet, but that many

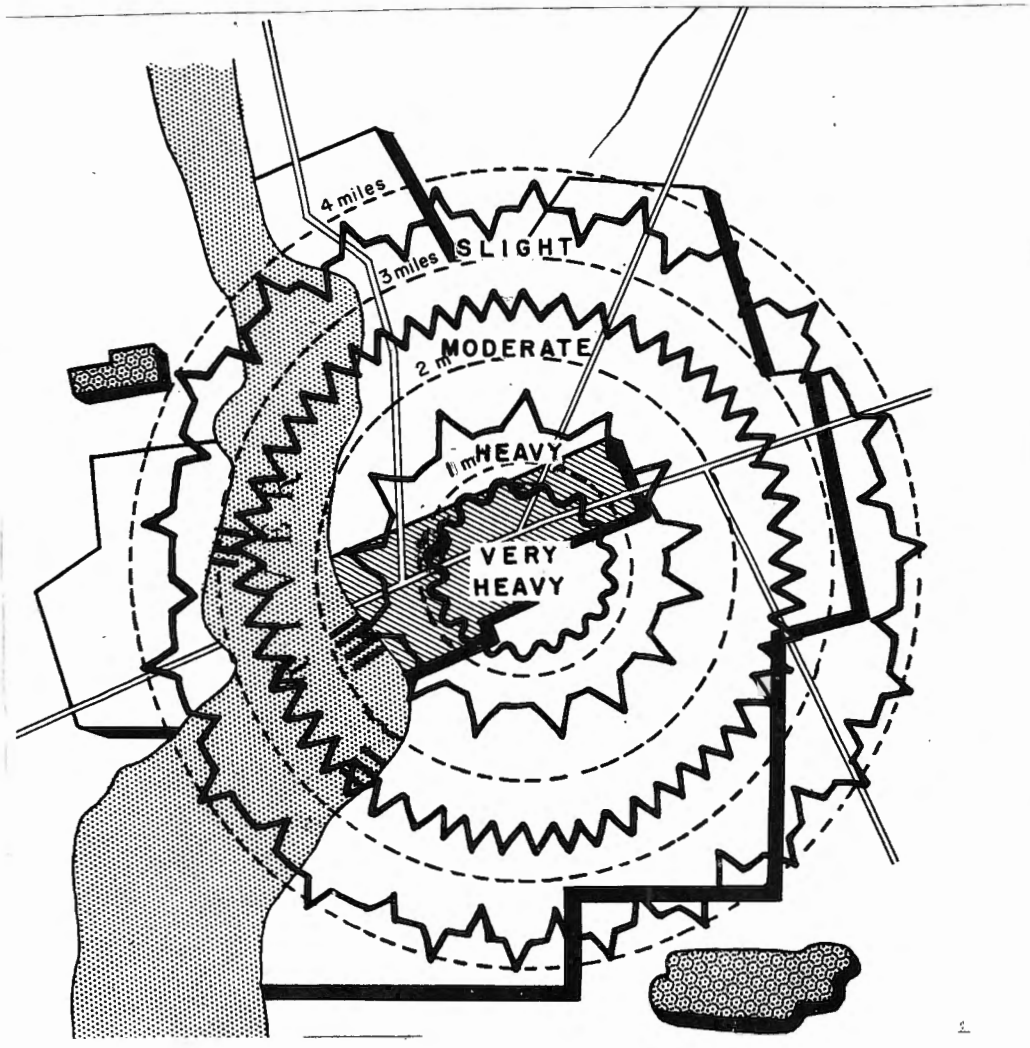


Fig. 1 Atom Bomb Blast Damage

of minor nature did occur up to 15,000 feet. (See Fig. 1.)

Data obtained from one large military hospital provided an approximate breakdown of the major types of these wounds. (2)

NINOSHIMA HOSPITAL, HIROSHIMA	
Fractures	11%
Lacerations mainly due to fragments of glass	37%
Contusions	52%

These injuries resembled those that would be seen after hurricanes, earthquakes and to some extent after ordinary air raids. There were few blast injuries of the sort caused by high explosive bombs. By far the greatest source of air-blast injury was: (1) displacement of the victim himself against the ground or other fixed object, or objects hurled against him; (2) collapse of buildings crushing victims instantly or pinning them down to await death by secondary fires. However, since the blast effects were combined with other effects such as primary and secondary burns, radiation effects and injuries produced by falling debris the exact degree to which it influenced the number of deaths cannot be accurately stated. (2)

C. Burns.

The burns produced at Hiroshima and Nagasaki may also be subdivided into two categories;

1. Flash burns caused by the flash of tremendous heat given off as the bomb burst.

2. Flame burns or "secondary" burns caused by secondary fires.

(Large numbers of people were burned to death because they were seriously injured, or trapped in debris when uncontrolled fires swept both cities within an hour after the bombing).

In an atomic explosion two types of radiation are released. One consists of light and heat rays which range on the spectrum from the vicinity of ultra-violet to that of infra red and cause an outrush of superheated air and gases leading to the thermal effects. The other is the invisible ionizing type which causes radiation sickness.

No reasonable estimate of the actual temperature of the reaction has been released officially, but it was almost unbelievably great judging by the effects. During the fraction of a second that it lasted, inflammable objects were scorched or set afire as far from the source as 11,000 feet. (1) Practically every person in a line of sight relation to the flaming airburst sustained burns of the exposed parts of the body that faced the blast. People received flash burns serious enough to warrant treatment as far as two and one-half miles from the center of explosion of the bomb. (2,3). (See Figure 2.)

Victims reported seeing the flash of the explosion. Some even had time to throw an arm up across the chest or face. It was not until several seconds after the flash that they realized that they had been injured. No heat was felt, and it was only when they looked down that they realized they had been burned. (6)

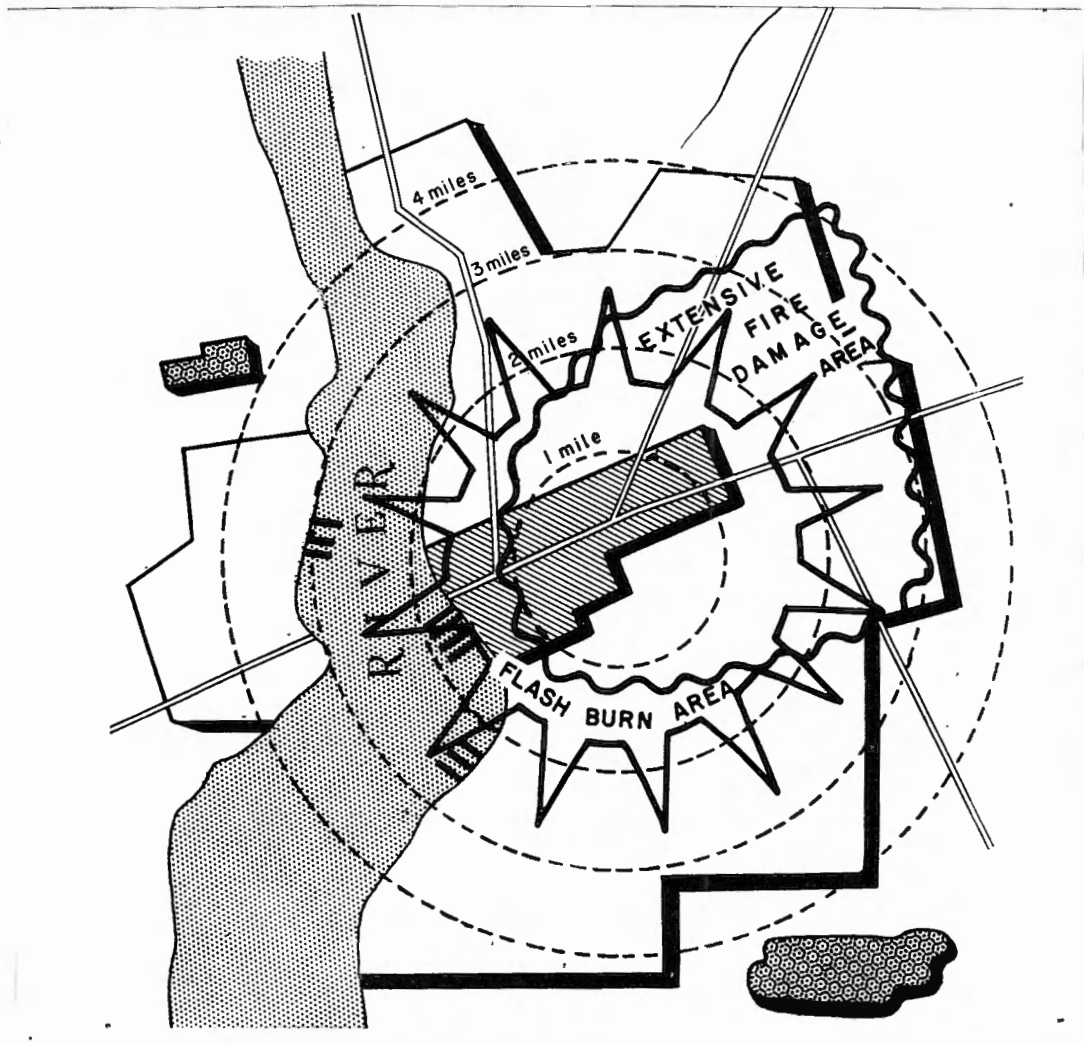
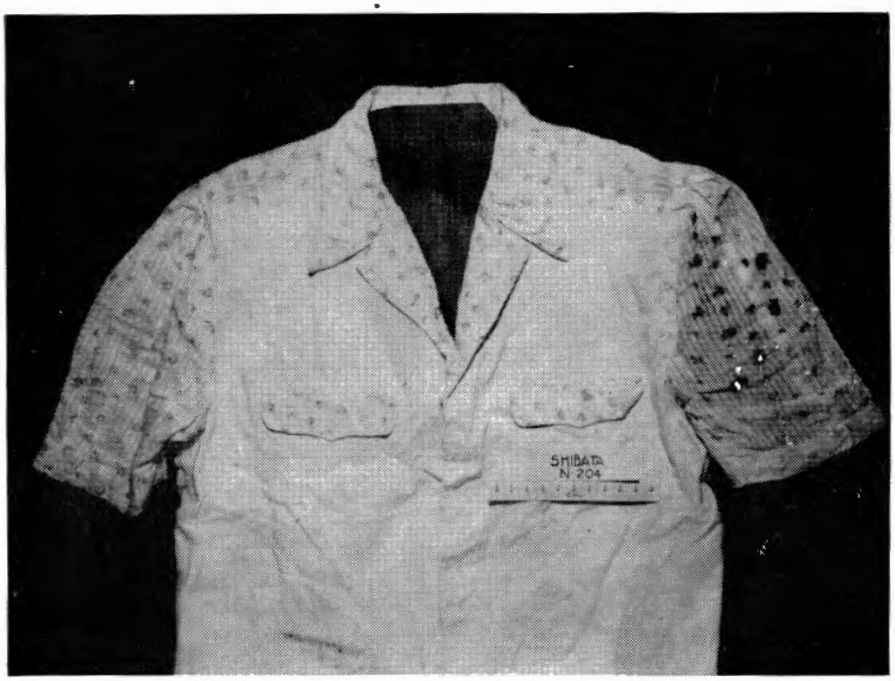


Fig. 2 Atom Bomb Thermal Effect

The burn was of the flash type, so that almost any object or material that happened to be located between the source of heat and the victim, protected the parts which were under cover or in the shadow. Close to the center, however, the heat was so intense that burns occurred under clothing. An interesting relation to the color of such clothing was seen in that the skin under dark material was burned more severely than that under white cloth. Bizarre designs were produced on the skin of patients whose clothing was patterned material. The darker shades absorbed more heat, consequently the burns produced were worse. Tissues under tight-fitting clothing were more seriously burned, so it seemed that the air between the body and loose clothing afforded certain protection. Thicker clothing helped prevent burns also as evidenced by lack of skin burns under seams where there was an extra layer of cloth. (3,7,8)

Many of the flash burns were of second or third degree. (8) They healed promptly and did not show any unusual clinical features. The tendency to keloid formation was no greater from these burns than from other thermal burns. It was explained that the large degree of secondary infection which followed in most cases and resulted in delayed healing may have been responsible for the excess scar tissue formation which was rather frequently seen. (3) Serious contractures which developed in survivors could have been prevented by adequate therapy at time of injury.

Secondary burns accounted for a considerable number of deaths in both Hiroshima and Nagasaki. Most of these victims were injured otherwise or pinned beneath the debris and therefore unable



Jacket (burn marks on left sleeve) showing action of infrared rays. Less effect on white background

Keloid following burn. (Photograph taken 18 months after injury.)

Keloids, contractures, and ulcers

Atom Bomb Flash Burn Effect

to escape from the fires. Some of the secondary burns in survivors apparently resulted from their efforts to extract members of their families or others from the collapsed and burning buildings. A few secondary burns resulted from clothing set fire by the primary heat of the bomb.

The bright light that accompanied the explosion has been described as many times more intense than that of the sun. It may be thought of as comparable to sunlight concentrated by a "burning glass", and in this sense it increased the amount of heat which caused the flash burns. Ultraviolet rays formed as part of the emission caused typical conjunctivitis in some of the victims. (2)

D. Radiation Injury.

The most unique feature of an atomic explosion is the release of radiation which causes ionization of living tissue. It has been calculated that the radio activity which results from such an atomic detonation is equivalent to more than one million tons of radium (9).

In the production of radiation casualties three general types of radiation must be considered; (3,5)

1. Prompt radiation liberated at the time of detonation and lasting for only a short period.

2. Residual radiation from primary fission products deposited on the ground.

3. Induced radiation caused by neutron capture of certain elements such as steel, silver, phosphorous, etc.

The several dangerous rays and substances produced by the chain reaction breakdown of heavy unstable uranium 235 and plutonium 238 include alpha and beta particles, gamma rays, neutrons, fission products, and a portion of the mother substances undergoing fission themselves. (10)

Alpha particles consist of rapidly moving helium nuclei and are liberated by that fraction of the bomb which does not detonate, but is scattered over a wide area and mixes with the fission products. They have a very short range in air (few cm.) and very low penetrating power (can be shielded out by a thin sheet of paper) but are 10,000 times as dangerous as gamma rays if they gain entrance to the body by ingestion, inhalation, through a break in the skin, or by other means. (10) They constitute the "internal" type radiation hazard mentioned earlier in this paper.

Beta particles consist of ordinary electrons emitted from nuclei and are emitted by fission products and at the time of initial burst. Their range in air is limited (6-10 cm.) and can be absorbed by a thin sheet of aluminum. They can produce skin burns but their main hazard comes if they gain entrance to the body, so they are also classed as an "internal" hazard. (10)

Gamma rays consist of photons emitted from nuclei and differ from x-ray only in that they are higher energy photons. They are released at the initial explosion, also by the fission products. They have an extremely long range in air and are very penetrating. (It takes about five feet of concrete to stop them.) They constitute

an "external hazard" in that they cause radiation sickness by penetrating the skin, and probably were the ones responsible for most of the radiation casualties at Hiroshima and Nagasaki. (10)

Neutrons consist of uncharged nuclear particles. They are liberated only at the time of fission and are not liberated by fission products. They are also penetrating (depending on their energies), and their power of ionization is about five or six times as effective as gamma rays, which places this particle among the serious external hazards. Also they cause "induced" radio-activity in other substances which they bombard and give rise to a secondary dangerous radiation source. They can be stopped by about two feet of water or earth. (10)

By "fission products" is meant the other elements in the radioactive series formed during the breakdown of the mother substance. These products are dangerous because they emit beta particles and gamma rays. (10)

Only about one tenth the original bomb substance is actually fissioned during the explosion. The rest is scattered into the atomsphere (water, or whatever the case may be) as unfissioned radioactive elements emitting alpha particles, therefore, they are one source of serious internal radiation hazard. (10)

From the preceding, it is seen that important consideration in evaluating the amount and type of radiation a victim might receive would be; (a) distance from the blast, (b) amount of shielding, (c) external or internal type of radiation. The two explosions in Japan

and the air explosion at Bikini were detonated at a height where blast effects would be the main result and the irradiation effects minimized. As mentioned above most of the radiation effects in such an air burst were due to the release of penetrating gamma rays.

Some residual radiation from primary fission products did exist, for in an air burst, the radioactive cloud would float downwind, and as it moved gradually filter out its radioactive material (called "the fall out") to contaminate areas downwind. At Hiroshima and Nagasaki there was measurable evidence of the residual radioactivity from known fission products such as the barium, strontium and lanthanum fractions. This contamination was not serious, however, for there were recorded examples of people who entered the bombed areas shortly after the explosion and stayed there prolonged periods without experiencing radiation sickness. (3,4,10,11) If the bomb were detonated closer to the earth's surface, however, the hazard from this type contamination might create a more serious problem and help render large areas uninhabitable for long periods. (11)

Residual radiation due to induced radiation was not a serious problem in the air bursts either. No recorded examples of neutron-induced radiation are listed. Again, however, if the bomb were detonated closer to the earth's surface it is felt that induced radiation might be a much more serious and dangerous problem.

In an underwater explosion such as the one conducted at the Bikini experiment, residual radiation would be a serious problem. (11,12). Neutron bombardment of the sodium ions in sea water gives

rise to induced gamma radiation. This is carried up in the base surge and floats downwind as a cloud of radioactive mist which coats ships and other objects with a lethal film of radioactive material. From Bikini results it is calculated that the effects would have been lethal to personnel on ships two miles downwind.

From results at Hiroshima and Nagasaki and from experimental tests at Bikini, it appears that nearly every living thing fully exposed to gamma rays from a high air burst up to about 3,000 feet was killed. (3) Actually, those who died from radiation sickness per se within this distance had been adequately protected against blast, flame and flash burn death by some strong structure which failed to protect them from radiation. This was conclusively shown at Bikini test Baker at which time animals down in the steel holds of ships survived blast, flame and heat but subsequently died of radiation effects. (12)

The following table and figure 3 give some idea of the distance relation to radiation effects as actually seen at Hiroshima: (3)

DISTANCE (feet)	TOTAL CASES	CASES SHOWING DEFINITE RADIATION EFFECTS		CASES SHOWING NO RADIATION EFFECTS	
		No. cases	percent	No. cases	percent
0 - 1,640	73	69	94	4	6
1,640 - 3,281	339	323	95	16	5
3,281 - 4,921	262	128	49	134	51
4,921 - 6,562	278	68	24	210	76
6,562 - 8,202	97	26	27	71	73
8,202 - 9,732	31	12	39	19	61

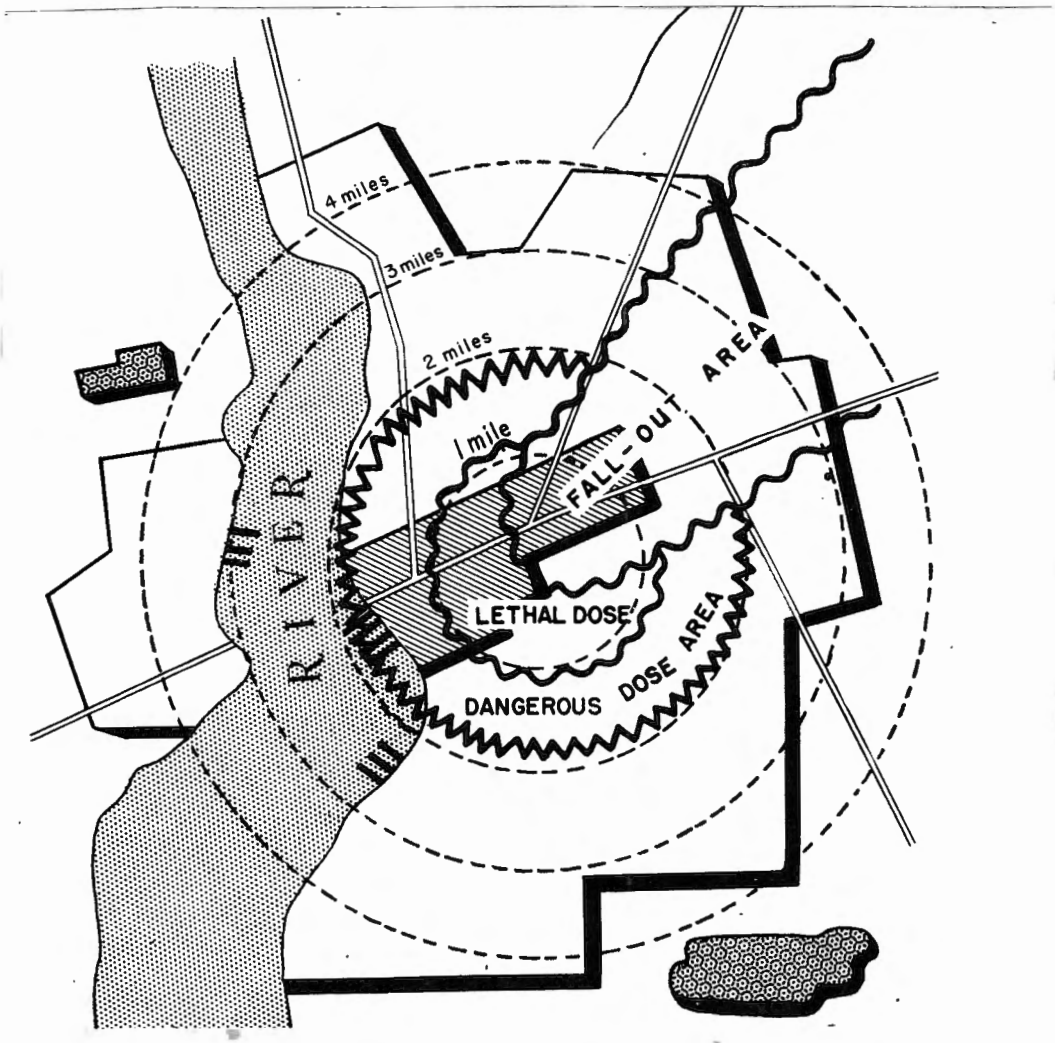


Fig. 3 Atom Bomb Lethal Dose Area

There is reason to believe that if the effects of the blast and fire had been entirely absent from the bombing, the number of deaths among people within a half mile radius would have been almost as great and that those within a one mile radius would have survived for a few days to three or four weeks, only to die of radiation disease. (3) In event of a future atomic disaster among this latter group of survivors would be found the casualties who could be saved by prompt and energetic therapy, but who would die if they be deprived of it. They are the ones who would have to be identified and given first priority in treatment if the number of deaths from radiation effects of the bomb is to be significantly lowered.

Clinical Picture:- "Atombombendisease" was the term used by the Japanese to cover the clinical syndrome, exclusive of traumatic injury and burns, that developed in victims following an atomic bombing. (13) In general the time of appearance of symptoms and the clinical course depended on the total amount of radiation received by the victims. Clinically the radiation sickness victims were divided into three groups:

1. Those most severely exposed. Death occurred within ten days after the bombing. These people experienced nausea and vomiting within an hour or so of the explosion.

2. Those receiving moderately severe exposure. Death came from ten days to six weeks later. Nausea and vomiting occurred later during the day of the bombing or during the following day and was associated with malaise.

3. Those less severely exposed and who died after six weeks as a result of some other condition like pneumonia, lung abscess or tuberculosis in relation to their general debility.

The following table gives some idea of the time relationship and severity of the symptoms and signs as they developed following the explosion. (2)

ONSET OF SYMPTOMS OF RADIATION INJURY

	Most Severe	Severe	Moderately Severe
Vomiting	1st day	1st day	1st day
Diarrhea	2-7 days	4-21 days	14-35 days
Fever	2-7 days	14-28 days	
Leukopenia	2-7 days	7-28 days	7-28 days
Purpura	4-7 days	14-48 days	
Epilation		7-28 days	14-35 days
Mucous membrane ulceration		14-28 days	14-28 days
Anemia		7-28 days	10-35 days
Death	4-10 days	10-42 days	30-90 days

Unfortunately, the disorganization of the Japanese was so great that no adequate material exists to determine the exact nature of the immediate effects. Warren (14,15) assumes, however, that they parallel experimentally induced changes in animals and represent the syndrome of radiation sickness carried to an extreme degree. He assumes that there is little morphologic evidence other than leukopenia and loss of adrenal lipoid.

The most severely injured persons complained of nausea and vomiting on the first day of the bombing followed by anorexia, malaise, severe diarrhea, thirst and fever. Death (probably from toxic autolysis of tissues) in delerium quickly followed. Some died within two or three days after onset of symptoms, and most of them within a week. (4) Temperature records in all these patients were remarkably similar. Usually between the fifth and seventh days and sometimes as early as the third, there was a step-like rise in temperature, usually continuing to the day of death. (3) The earlier the fever, the more severe the symptoms and the poorer the prognosis. The bloody diarrhea resembled that of bacillary dysentery. Examination of the blood showed a pronounced reduction or total lack of leukocytes and blood platelets. Upper respiratory and gastric mucous membranes showed acute inflammation. There were no skin lesions which could be attributed to gamma rays. One group of autopsies in this early stage showed subarachnoid hemorrhage in 60% of the patients. (3) Sections of spleen and bone marrow showed the disappearance of normal lymphocytes and marrow cells so that only the stroma and framework of the organs remain. The general patterns of the observations in these cases resembles closely that described by Shouse, Warren and Whipple (16) in dogs receiving large single doses of roentgen rays.

The larger portion of radiation cases which had been at greater distances did not show severe symptoms until one to four weeks after the explosion. In a typically severe case, the first evidence of the disease was nausea and vomiting on the day of the bombing,

followed by a feeling of malaise. The patient then began to improve and felt fairly well until about the beginning of the second week when epilation began. Within 12 to 48 hours he again experienced malaise and anorexia and a step-like fever developed which went up to 104-105° to become sustained to fatal termination. In some of these patients the temperature would go only about to 102°, remain for a few days then subside and the patient would soon regain their feeling of good health and go on to recovery. From this it is apparent that the degree of fever apparently had a direct relation to the severity of exposure to radiation.

Other manifestations which were commonly seen in these patients were leukopenia and anemia, inflammation and necrosis of the gums, stomatitis, pharyngitis, petechiae and intractable bloody diarrhea. (3,8)

In some of the less severely irradiated individuals the bone marrow failed to regenerate. The symptoms described in the second group continued and the patients died of extreme emaciation and aplastic anemia.

In others, concomitant with partial or complete recovery of the marrow, most of the striking manifestations classed as anemia disappeared but they succumbed to such complications as lung abscesses, septic bronchopneumonia and tuberculosis. (8)

Deaths from radiation reached a peak in three to four weeks and had practically ceased after seven to eight weeks.

Pathologic Physiology and Anatomy:- The purely destructive effects of radiation on tissue has been emphasized in a recent report by Bloom. (17) The fundamental biologic effect is the production of ionization within the cell when an alpha or beta particle, neutron, or gamma ray hits it and breaks off a negatively charged electron resulting in a positively charged atom. This changed atom with the negative electron, is known as an "ion pair". The different radiations alpha, beta, etc., act differently to produce these ion pairs but the end result is the same in any case and in the reports on atomic bomb victims no effort to differentiate them has been made.' (3)

Theories as to how ionization affects the cell are numerous and inconclusive. Some of the more popular ones include; (5)

1. Some chemical exchange that interferes with the normal interchange between the nucleus and the rest of the cell.
2. Changes in permeability of the cell membrane.
3. Production of a toxic substance within the cell.
4. Changes in intercellular environment.

Microscopically, any one or all of the number of cellular changes may be observed, such as:- (1) changes in staining characteristics; (2) increased granularity; (3) vacuolation; (4) swelling of cellular components; (5) distortion of cellular structures; (6) cytolysis; (7) pyknosis and other visible microscopic changes. (5)

The clinical picture of "atombombendisease", or radiation sickness, has been attributed principally to effects on the blood and

blood-forming tissues (14) and on the liver by some, (19) but the latter is a moot point.

The effect on the blood can readily be followed by the clinical manifestations as well as from the laboratory standpoint. There were three chief groups of symptom complexes due to damage to hematopoietic tissue;-

1. Symptoms due to leukopenia.
2. Symptoms due to thrombocytopenia.
3. Symptoms due to anemia.

In the leukopenic group infection, particularly Ludwig's, angina, was the outstanding manifestation and the great bulk of these deaths occurred during the first three weeks following the bombing. It is felt that this process differed in no way from agranulocytic angina from any cause. Judging from the studies of Japanese investigators, the leukocytes in the circulating blood were destroyed at the same time the hematopoietic tissue was damaged, so that white blood counts as low as 200 per cubic millimeter were found in the first few days. (2)

Thrombocytopenia induced by radiation damage to magakaryocytes of the bone marrow contributed to a number of deaths three to six weeks after the bombing. Manifestations of the blood dyscrasia ranged from small petechiae under the skin to massive ecchymoses and hemorrhages from various body orifices. This also increased the bleeding from burns and other wounds so that healing of wounds was prolonged coincident with the appearance of radiation sickness, and these patients did poorly. (19,20)

Even in the most heavily irradiated individuals there was some evidence of proliferation of the reticulo-endothelium and the hematopoietic system. In some patients it appeared that regeneration proceeded from normal hematopoietic elements which had survived irradiation. In others, proliferation of the reticulo-endothelial system with evolution of functional marrow from the products was observed. (2)

The clinical significance of the latter in relation to the value of therapy in these victims is apparent, for if the victim can be carried safely through the critical period of depressed marrow function by supportive measures such as blood transfusions and antibiotics, he may recover from an otherwise fatal malady.

LeRoy (21) observed unusual numbers of mast cells in pathologic specimens taken from Bikini test animals and from victims of the Hiroshima-Nagasaki explosions. In view of the relation between mast cells and heparin it seems possible that the bleeding tendency in these people may have been due, in part, to the presence of increased amounts of a heparin-like substance in the peripheral blood. Allen and Jacobson (22) found that hyperheparinemia and hemorrhagic manifestations occurred in animals after acute exposure of the whole body to high ionizing radiations and that the anticoagulant could be neutralized by appropriate means. Investigations being conducted at the present time to find a more reliable means of neutralizing this substance may open up a new therapeutic approach to the hemorrhagic diathesis as observed in the atomic bomb victims.

The importance of liver lesions is equivocal, but Keller, (19) in his studies, attributes the albuminuria, tyrosinuria, hypoproteinemia, positive indirect van den Bergh reaction, jaundice and fever observed in his series of cases to disturbed liver functions. He also attaches great diagnostic and prognostic significance to the elevated sedimentation rates in victims which went as high as 150 millimeters per hour.

Effects on Other Body Tissues (summarized (10))

Skin:- Epilation was frequently observed in persons who had been close to the bomb and who had survived more than two weeks. On about the thirteenth of fourteenth day the hair suddenly began to fall out, but complete epilation was not necessarily correlated with a bad prognosis. Of all the individuals who died of radiation effects at about the fourth week, fourteen percent had no epilation. It is assumed that they had received some shielding to filter out the softer rays, which cause the epilation effect on the skin, but death resulted from the hard penetrating rays which have little effect on the skin.

Gastrointestinal tract:- The pathology in the gastrointestinal tract varied somewhat but included marked swelling and edema of the mucosa followed by submucosal hemorrhage, ulceration and the formation of a pseudomembrane similar to that seen in bacillary dysentery. Much of the process apparently was not only an irradiation effect on the sensitive intestine, but also a result of lowered local ability to cope with intestinal microorganisms plus superimposed lowered antibiotic capabilities of the blood. The intense vomiting and bloody diarrhea secondary to the lesions mentioned caused severe

dehydration and acidosis, which in itself, undoubtedly caused a large number of deaths.

Testes:- Histologic changes were profound in the majority of men who received enough gamma radiation to cause symptoms. Of 23 patients studied who had been within 1,500 meters only three had a sperm count above 40,000. Of 39 who had been within 2,000 meters, 13 had counts below 40,000. (It is unusual for fertilization to occur if the sperm count is below 40,000). Several patients complained of loss of libido or even loss of potency following the bombing. According to Japanese physicians the return to normal has been slower in the male than in the female.

Ovaries:- Histologically, the ovaries showed less striking changes than the testes. There was a high incidence of menstrual disorders among Japanese women in relation to the bombing. According to Japanese physicians most of this was due not so much to the radiation effects on the ovaries themselves as it was to malnutrition, overwork, and anxiety associated with the bombing. A year later no patients were found complaining of menstrual disorders attributable to the bombing.

III. THERAPEUTIC PROBLEMS AND OBJECTIVES.

The type of injury present or the combination of injuries following an atomic explosion will determine the type of problems encountered by medical personnel. Traumatic wounds from blast effects and burn cases would be handled by conventional methods and will not be discussed here except to mention that wound healing may be complicated

by the presence of radiation sickness with its leukopenia, anemia, and bleeding tendencies making the treatment of these injuries much more difficult.

The therapeutic problems presented by patients with gamma radiation sickness are related mainly to the gastrointestinal disturbance and the destruction of hematopoietic tissue. (2) Dehydration and acidosis secondary to vomiting and diarrhea no doubt killed many people at Hiroshima and Nagasaki. The severe leukopenia which persisted from one to three weeks was certain to facilitate the development of overwhelming infections and septicemia. The hemorrhagic state which accompanied the thrombocytopenia was capable of causing exsanguination from the ulcerated mucous membranes or from wounds as well as fatal hemorrhages into the central nervous system, the myocardium, or the adrenal gland.

As stated before, it would probably be impossible to evacuate and treat all casualties during the period immediately following an atomic explosion. One of the big problems facing medical personnel would be the proper selection of cases for intensive therapy based on the severity of the radiation disease, trying insofar as humanely possible to use the necessarily limited medical supplies on cases which might ultimately respond to therapy and not "waste" it on hopeless ones.

King (23) points out that persons who received over 500 roentgens will probably die, and should not be evaculated as it would uselessly increase the load of the rescue parties. Also, those near

the center of the blast who survive, and who have been exposed to the residual contamination of radioactive materials for some time would have received a lethal dose. The distance of the victim from the center of the blast, the approximate amount of shielding between the casualty and the blast, the clinical picture which the patient presents i.e., nausea, vomiting, diarrhea, etc. in relation to time after the explosion, all would contribute to an evaluation of the dosage of radiation received and disposition of the casualty made accordingly.

As for the treatment of radiation sickness per se, not much is known up to the present time. The proper objectives in the treatment of patients who have been exposed to the amount of radiation emitted by an exploding atomic bomb have been stated by LeRoy, (1) however, as follows:

1. Maintain fluid and acid-base balance.
2. Control infectious processes.
3. Combat hemorrhagic tendency.
4. Correct the anemia.

Blood transfusions, intravenous plasma and electrolytes, and the forcing of fluids by mouth would facilitate maintenance of fluid and acid-base balance. Infectious processes would require huge amounts of antibiotics and blood transfusions. The hemorrhagic tendency would be treated by massive transfusions for want of a better method. The anemia would require large amounts of whole blood until the time the bone marrow had regenerated sufficiently to take over the function of supplying erythrocytes to the peripheral blood.

Much work is being done at the present time on the use of certain materials for their specific action in radiation sickness. Of these, vitamin B-6, methionine, and adrenal cortical homone seem the most promising according to King. (23) Many recent investigators (Hodges and Kaplan, (24) Wells and Popps; (25) Maxfield et al (26)) feel that pyridoxine hydrochloride (vitamin B-6) is the best single adjunct to therapy of radiation sickness at the present time.

In event of an atomic disaster it does not seem unreasonable to believe that in the hospitals of the western world where plasma, electrolyte solutions, whole blood and penicillin are available in more adequate amounts, a much lower mortality rate could be achieved than was observed in Japan. How satisfactory the thoroughly modern treatment of the syndrome of radiation injury would be is difficult to predict, but if it requires 37,500,000 units of penicillin and 150 gallons of whole blood to keep one goat alive for two and one-half months as it did following the Bikini test explosion, (12) how much will it require to extend reasonably humane medical care to a military and civilian population devastated by atomic weapons? It is obvious that no nation can afford unpreparedness in the face of such an emergency.

IV. PLAN FOR AN ATOMIC DISASTER.

A large contribution to the reduction of mortality in event of an atomic explosion would be the organization and execution of a well-formulated atomic disaster plan. At Hiroshima and Nagasaki such a plan was extremely inadequate and even that which did exist

failed to function. (3) In an attack on a modern city it is believed that about 50,000 deaths would result from a single bomb. It is felt that, if the individual civilian and soldier in such a city were adequately trained as to what he could do for himself and others in case of an atomic detonation, perhaps 10,000 lives could be saved. (10)

King (23) has summarized the whole problem of the medical aspects of an atomic catastrophe very well. He feels that the following points are the most pertinent;-

"1. An organizational plan for an atomic disaster should be set up, with full cooperation of the medical profession and military and civilian organizations.

2. Training of medical and lay personnel in the effects of ionizing radiation, and preparations for a possible atomic disaster are of immediate importance. Training of special technicians in both the civilian and the military organizations is also important.

3. Proper handling of an emergency by the doctor can best be performed if channels of communication and transportation remain open between the devasted areas and relief stations.

4. Each city and large military base should have a number of potential blood banks, fully equipped, in its suburban areas or periphery.

5. Dressing stations and decontamination stations should be established in the outlying areas of locations of a potential explosion.

6. A program of decentralization of industry, government and military establishments should be instigated, with despersion of housing and hospital facilities some distance from these locations.

7. The problem of maintaining a water supply, not dependent upon lakes and rivers which are easily contaminated with radioactive materials, should be studied.

8. Storage sites of non-perishable foods and medicinal supplies, with adequate protection from radiation, and within easy reach of abovementioned blood banks, dressing stations, and decontamination centers should be planned and established.

9. An adequate supply of special clothing for rescue workers, and of specially adapted masks for all workers and possible exposed personnel should be procured, and available for instantaneous use.

10. Urban areas and military bases should practice organized drills in use of above equipment, and in evacuating a city, or an exposed military base. These drills should employ the use of masks, detection instruments, protective clothing, and simulate rescue and decontamination measures.

11. The civilian personnel of the country, and civilian workers at military bases, should have an adequate background so that they may relieve the military in a large number of these tasks, if the military are called upon for active defense against an enemy.

12. Further investigations should be carried out in the problem of atomic defense, shielding of radiation, protective clothing, and treatment of radiation sickness."

V. PROTECTION AGAINST THE BOMB - - SUMMARIZED (10)

Protection must be developed against:-

1. The blast or shock wave.

2. Visible light, ultraviolet and infrared radiations.

3. Nuclear radiations.

4. Psychological effects.

An individual's best protection against the blast is to be in an underground shelter, or, if in the open, or in a building, to lie flat, thereby avoiding flying debris and glass.

The light and infrared radiations causing flash burns can be avoided (when in direct line of sight with the detonation) by the wearing of any type of loose-fitting, light-colored material. Dark clothing will not reflect this radiation but will catch fire and produce flame burns on the skin beneath the clothing.

In shielding against external radiation (gamma rays and neutrons) some substance must be interposed between the individual and the source. Gamma radiation is stopped in proportion to the weight of the material between the body and the source, therefore, lead is a good shield because of its great mass.

Neutrons are not as effective at greater distances as gamma rays, but are difficult to shield. The type of material, not the weight, is the important factor here. The best substances are those of low atomic weight such as hydrogen, water or paraffin. Earth, concrete, wood or water are all good substances to use and should be considered when construction of defences against the bomb are undertaken.

Protection against internal radiation resolves itself into the development of decontamination techniques, avoidance of eating or drinking contaminated foods, of eating with contaminated hands, breathing contaminated air (use of gas masks) or of being injected with contaminated medicinals.

Education of the civilian and military populace regarding the effects of the bomb, what it will and will not do, and instructions on what to do for self-preservation in case of an atomic bombing, should do much to dispel much of the devastating psychological effect of the bomb.

VI. SUMMARY AND CONCLUSIONS.

The general effects of the casualty-producing aspects of the atomic bomb have been discussed. It was pointed out that in case

of an atomic disaster the mortality rate could be considerably reduced over that seen at Hiroshima and Nagasaki if adequate steps were to be taken in anticipation of, or in case of, such an event.

Such steps include (1) building of adequate defences against the bomb; (2) education of the military and lay public as to a plan for an atomic disaster; (3) education of medical personnel in the treatment of this particular type casualty.

One of the big problems confronting medical personnel would be proper selection of cases to be treated. Medical supplies and personnel would necessarily be limited immediately following an atomic explosion, so they should be applied to those cases most likely to recover under therapy and not "wasted" on hopeless cases. Criteria for selection of such cases and current ideas for their treatment are discussed.

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