

SPECIAL ARTICLES

THE MEDICAL CONSEQUENCES OF THERMONUCLEAR WAR

Editor's Note

A GROUP of physicians and physicists, intensely interested in the whole problem of thermonuclear war and its medical consequences, have collaborated in the preparation of the papers that compose this symposium.

The following introduction has been submitted by a committee representing the Special Study Section of the Physicians for Social Responsibility, an organi-

zation that originated in Boston several months ago. The committee consists of Drs. David G. Nathan, research associate in medicine, H. Jack Geiger, instructor in preventive medicine, and Victor W. Sidel, teaching fellow in medicine, all at the Harvard Medical School, and Bernard Lown, assistant professor of medicine, Department of Nutrition, Harvard School of Public Health.

Introduction

THE following articles are written to describe the biologic, physical and psychologic consequences of a thermonuclear attack. Much has appeared in the lay press and in scientific journals on these subjects. Why should physicians also be especially interested in the problem? The answers are clear. No single group is as deeply involved in and committed to the survival of mankind. No group is as accustomed to the labor of applying the practical solutions to life-threatening difficulties. Physicians are aware, however, that intelligent therapy depends on accurate diagnosis and a realistic appraisal of the problem. The object of these articles is therefore the presentation to physicians of some of the facts of thermonuclear warfare.

Descriptions of a thermonuclear attack and its sequelae are limited by the unavailability of all the pertinent data and by the need to rely upon a host of uncertain assumptions. The limitations of the data result in part from governmental classification and in part from the happy fact that few nuclear weapons (and no thermonuclear weapons) have been exploded over major cities. Information resulting from coral-reef blasts may not be applicable to cities of concrete, steel, glass and macadam. The major assumptions, however, lie in the political and military sphere. It is obvious that there is no certain way of predicting the nature of a thermonuclear attack on the United States. Since no single system of defense can meet all the possible conditions of attack, there is no sure way of predicting the efficacy or futility of a given civil-defense program. Numerous models of thermonuclear war have been presented to the public in recent years. The models range from massive single strikes against missile bases to repeated multimegaton saturation bombing of cities. In the former, significant protection might be provided for individuals in cities by adequate shelters against radioactive fallout. In the latter, no system of shelters would spare the people of the urban and industrial centers from blast and fire.

This is an age in which the scientific and technologic revolution has provided military forces with an

exponential growth in the power of weapons. The fission bombs dropped over Hiroshima and Nagasaki represented a thousandfold increase in destructiveness as compared to their chemical predecessors; the development of fusion bombs represents a further thousandfold multiplication. Guided missiles, antimissile missiles, neutron bombs and manned space platforms all influence the validity of plans for civilian protection. The rapid rate of arms development has been reflected in the changing and at times contradictory Civil Defense Program. The public seeks the facts and a coherent policy. Yet the magnitude of the spiraling arms race, the complexities of the cold war and the ever increasing size of the Government create a broadening gulf between citizen and decision-making process. It is essential that physicians, in their roles as protectors of the health of the community and advisors to their patients, become fully informed.

Any formulation of the subject of thermonuclear war must state its assumptions regarding the type of attack. The assumptions chosen by the authors of the following papers are those of the Joint Congressional Committee on Atomic Energy (the Hollifield Committee). The Committee heard testimony from many authoritative sources and arrived at a hypothetical attack, which its members, in 1959, considered a "realistic possibility." Of course, the attack may be less severe; on the other hand, in the light of recent thermonuclear-weapon development, the Committee report may be an underestimate. The 1446-megaton attack on missile bases and urban-industrial complexes of the United States envisaged by the Committee is probably an underestimate in the era of the 100-megaton high-altitude explosion, tidal-wave and fire-storm production and rapid advances in missile technology. Ervin and his associates describe the immediate sequelae for Boston and Southern New England of the attack outlined by the Committee. The authors assume a single strike, although it might be expected that an enemy would not be content with a single blow. The choice of Boston and Southern New England as the representative attack site is an inverse type

of chauvinism utilized merely for illustrative purposes. The charts and diagrams may be extrapolated to the conditions in other cities and areas.

The article of Sidel and his colleagues analyzes specific problems and explicit choices that will be faced by surviving physicians in the attempt to give medical care in the postattack period. This discussion, together with the article of Leiderman and Mendelson on the psychologic and social consequences of thermonuclear war, provides some basis for examining the utility of current disaster planning in the face of thermonuclear war. Aronow gives not only a useful glossary of terminology but also a physicist's description of the orders of magnitude involved in radiation and the fallout problem.

It is not the intent of the authors to provide a comprehensive plan for survival in the face of a thermonuclear Armageddon; it should be clear from the articles that there is no rational basis for such plans. It is their intent, rather, to demonstrate the magnitude of the threat that thermonuclear war presents, and to call attention to a conclusion familiar to physicians in other contexts: that there are some situations in which prevention is the only effective therapy. It is hoped that readers will carefully consider the implications of these articles for their roles as physicians in a nuclear age and will be stimulated to play a greater part in the search for peaceful alternatives to thermonuclear war.

I. Human and Ecologic Effects in Massachusetts of an Assumed Thermonuclear Attack on the United States*

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BOSTON

IN recent months public anxiety and confusion over the possibility and consequences of thermonuclear war have been increased and deepened by extensive (and often conflicting) publicity in newspapers and popular magazines, federal and local government announcements and commercial advertising concerning shelter programs. Many people, uncertain about what course to follow, have turned to physicians to provide expert information. These requests for evaluation and plans have ranged from consideration of immediate fallout effects to the optimal design of fallout shelters, the long-term prospects of blood dyscrasias and the suggestion of modification of medical-school curriculums to meet the needs of a postholocaust practice.

Many physicians, in turn, have had no opportunity to find and study the data on which any scientific and realistic appraisal of the medical consequences of thermonuclear attack must be based. Although numerous medical publications have dealt with one or another aspect of the problem with varying degrees of specificity, their conclusions have been conflicting; this reflects differences in the interpretation of data or — more often — differing but unstated underlying assumptions concerning the size, nature and characteristics of the hypothesized assault.

It appears to be useful, therefore, to review for the medical reader the nature of a clearly defined and specified thermonuclear attack on the United States and some of its short-term human and ecologic consequences in a given area, in particular, metropolitan Boston and other targets in Massachusetts. Careless extension of these observations to other areas of the

nation is not warranted, but the same methods of analysis will yield similar findings for other states and regions.

Although many pertinent facts are unknown or have been classified, enough information is available to permit such a review. Information has been presented in official governmental publications, including *Biological and Environmental Effects of Nuclear War*,¹ *The Effects of Nuclear Weapons*² and *Some Effects of Ionizing Radiation on Human Beings*.³ In addition, a recent monograph by Stonier⁴ has summarized this information within a broad context.

STATEMENT OF THE PROBLEM†

The hearings before the Radiation Subcommittee of the Joint Congressional Committee on Atomic Energy (the Holifield Committee) in 1959 were devoted in large part to an analysis of a "limited" attack of 1446 megatons on selected targets in the United States.¹ We have used this attack as the basis for our discussion. It should be noted that such an attack, considered realistic in 1959, could be greatly exceeded in the light of recent weapons developments.

The attack is assumed to occur in late fall after harvest, in fair weather, during the working day, and to provide twenty to thirty minutes' warning, equivalent to intercontinental-ballistic-missile flight time from the Soviet Union to the Eastern United States. The further assumption is made that there is only one strike, so that fallout, fire and other effects decay proportionately with time. The general availability of

*From the Special Studies Committee, Physicians for Social Responsibility.

†Reference to the accompanying article by Aronow for unfamiliar technical terms is suggested.

individual or community fallout shelters, meeting current Office of Civil Defense Mobilization recommendations, will be assumed. The attack pattern assigns 10 weapons, totaling 56 megatons, to Massachusetts.

Because of the complexities of overlapping effects from many target areas, we shall limit the detailed

DIRECT BLAST EFFECTS

The assumed 20-megaton ground blast (Fig. 1) would excavate a crater 250-300 feet deep and half a mile in diameter, heaping rubble over the surrounding area. (An air burst would produce no crater but would almost double the area destroyed.) The area

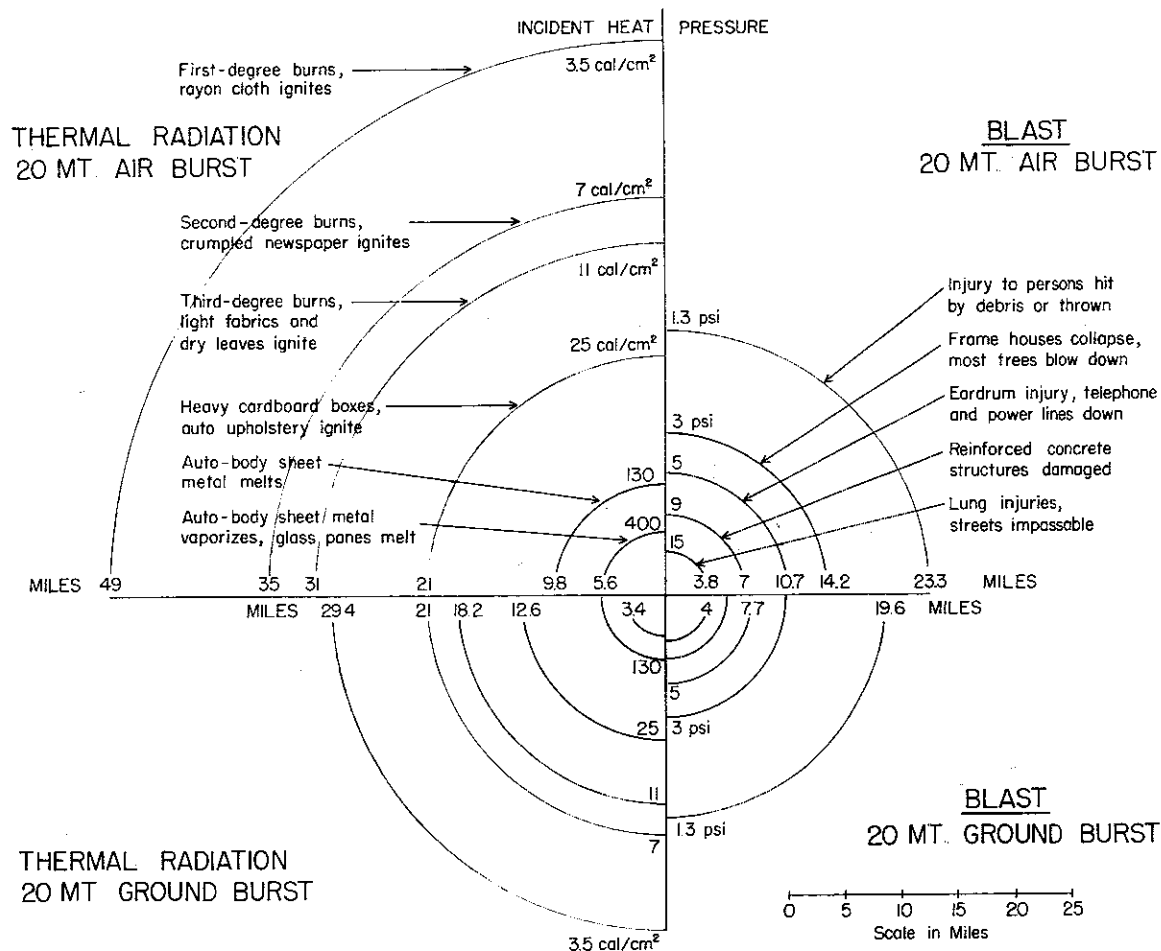


FIGURE 1 Effects of the Detonation of a 20-Megaton Fusion Bomb as a Function of Distance from Ground Zero. Upper right quadrant: blast effect at indicated distances for an air burst, in terms of pounds per square inch of overpressure and corresponding physical effects.

Lower right quadrant: similar relations, but at reduced distances for a ground burst.

Upper left quadrant: thermal effects at indicated distances for an air burst, in terms of calories per square centimeter of incident radiation and corresponding physical effects.

Lower left quadrant: similar relations, but at reduced distances for a ground burst.

examination to the results of ground-level explosions of 20 megatons on downtown Boston* and 8 megatons on nearby Bedford Air Base. In addition, we shall refer the total pattern of this attack on Southern New England to clarify the magnitude of the problems of planning in Massachusetts. The physical consequences of such an attack include damage from blast, heat and radioactive fallout; these will be treated separately.

*The pattern presented at the hearings before the Hollifield Committee includes two 10-megaton bombs on Boston, but it seems reasonable to assume a single 20-megaton burst.

of total destruction, in which even the most heavily reinforced-concrete structures and deep blast shelters would be demolished, would have a radius of 4 miles.² This would encompass the area from the ocean to Watertown, and from Everett to Dorchester (Fig. 2), thus including most of the medical facilities and personnel in the Boston area.

In a 6-mile radius, including Newton, Arlington, Melrose and Milton, all frame or brick buildings and any basement shelters would be totally destroyed. Lung damage from blast alone would produce total casualties of any exposed population.

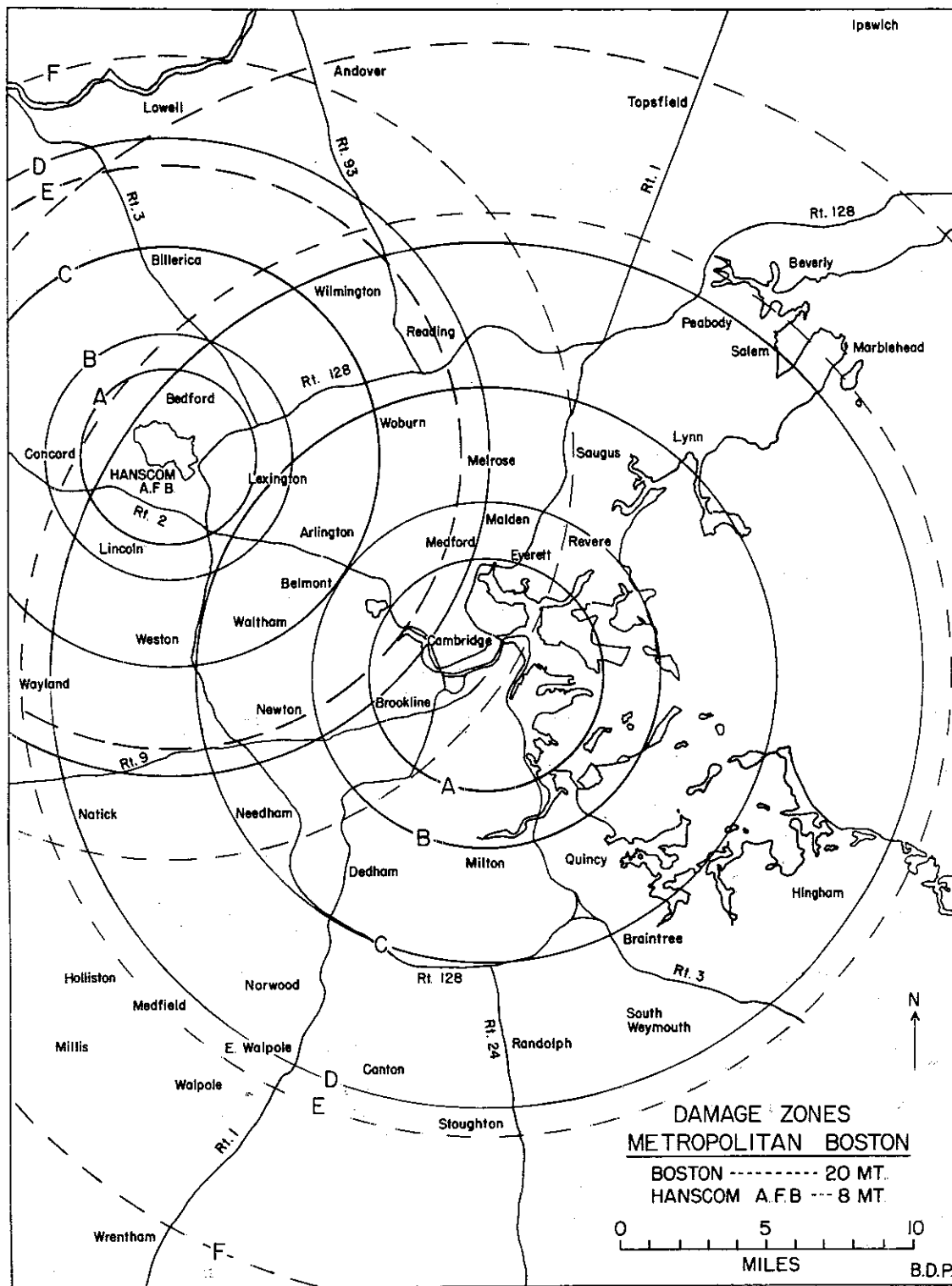


FIGURE 2. Detailed Map of the Overlapping Thermal and Blast Effects of the Boston and Bedford Explosions, as Detailed in the Text.

The concentric circles represent the blast effects, as described in the text for Boston and corresponding effects for Bedford at a 4-mile radius from the target (A), at a 6-mile radius from the target (B), at a 10-mile radius from the target (C) and at a 15-mile radius from the target (D), as well as the distance at which third-degree burns would be produced on exposed flesh (E) and that at which second-degree burns would be produced and fuel, leaves, cloth, paper and so forth would ignite (F) — this is therefore the extent of a possible fire storm.

At 10 miles, roughly to circumferential Route 128, reinforced-concrete buildings would be seriously damaged but partially repairable, whereas all other structures would be demolished. Deep blast shelters would be effective protection in this zone, but fallout shelters would be useless.

To a radius of 15 miles, including Saugus, Lexington, Weston, Natick and Quincy, all frame buildings would be damaged beyond repair and shelters under them compromised. Serious damage would be done in this area by flying objects carried by shock waves. Human bodies would be particularly hazardous mis-

The first of these, primary effects of blast-produced overpressures, include eardrum and lung rupture, although persons exposed to these pressures (20 to 50 pounds per square inch) are more likely to be killed by secondary or tertiary effects. The next type consists of secondary effects from damage after collapse of buildings and the impact of penetrating and non-penetrating missiles energized by blast pressures, winds and gravity. Many of these objects, including flying glass and masonry, which would be a hazard as far away as 18 miles, are traveling at the speed of sound. There is a risk for persons remaining outside build-

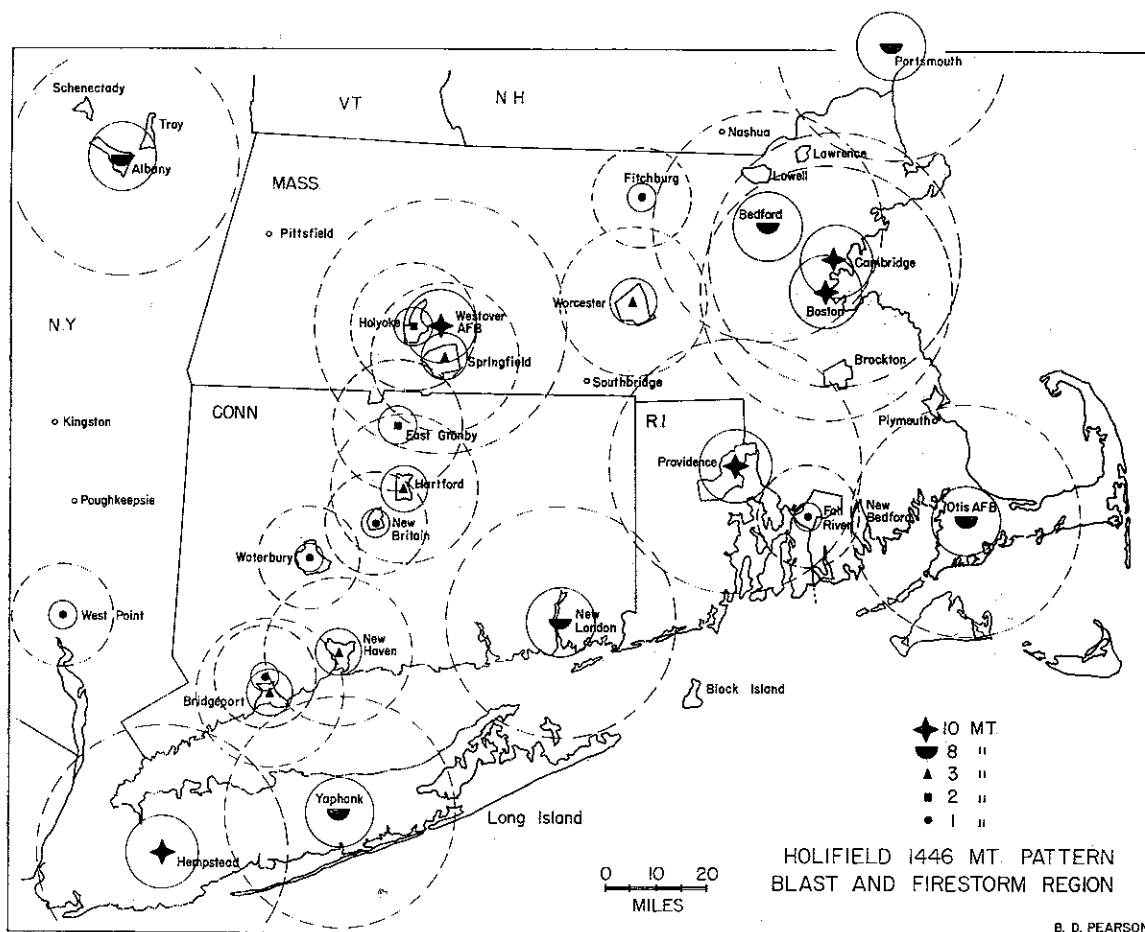


FIGURE 3 Southern New England Target Area of the Hypothetical Nuclear Attack, with Bomb Sizes Assumed at Specific Military and Industrial Targets Indicated in the Legend.

Circles indicate radiuses of possible destruction, not including additive effects of overlap. Inner solid circles are areas of severe blast damage to strong structures and complete collapse of frame houses. Outer dashed circles represent limits of some mechanical damage, ignition of fires in easily combustible materials and possible extent of fire storm.

siles, as would stones and glass. In an exposed population, casualties from this factor are estimated to run as high as 15 per cent.⁴

Some damage to construction would extend to much greater distances from the hypocenter, overlapping the effects of other explosions (Fig. 3). Medical facilities as far away from Boston as Emerson Hospital in Concord would be seriously jeopardized by blast alone.

Casualties from blast result from three hazards

ings, even if they lie flat in protected gullies. A forewarned population, however, may have taken cover inside buildings or in basement shelters. For these persons, the risk may be increased by structural collapse and falling debris. The final hazard comprises tertiary effects, involving injuries occurring as a consequence of displacement of human beings by blast, shock and wind. Such physical displacement could injure a 160-pound man at a distance of 20 miles from target, though — for persons caught in the open at

this distance — thermal damage would pose more of a threat than the blast hazards

THERMAL EFFECTS

Thermal energy is released by the bomb in two pulses. The first, a brief ultraviolet flash, is not a hazard, but the following infrared pulse, containing nearly 35 per cent of the bomb's energy, would produce burns on exposed persons and ignite inflammable material for many miles (Fig. 2). Up to 21 miles from the 20-megaton surface burst a person would have second-degree burns of all exposed skin, and his clothing and other easily inflammable material in the environment would ignite. As far as 40 miles away, a reflex glance at the fireball would produce blindness by retinal burning. (After the Marshall Island tests, small animals 345 miles distant were found with focal retinal burns²) The distances to which these thermal effects extend would be increased by explosion in the air rather than on the ground, or decreased by the presence of fog or smoke.

It has been estimated that typical American cities contain 5 to 25 potential ignition points per acre; a dry countryside might contain many more.² As the bomb explodes, a huge pressure wave initially traveling at a speed greater than that of sound spreads out from the center of the explosion, followed by wind at speeds transiently exceeding 1000 miles per hour. The wind creates a low-pressure area as it moves outward, and surrounding air rushes in, fanning the many fires started by the thermal radiation and initial blast damage. Thus, in a radius of 16 to 21 miles around the Boston target the immediate ignition of houses, foliage, oil tanks, gasoline and so forth would create a huge fire storm initially swept toward the center at 150 to 200 miles per hour and maintained by lower-velocity fire-produced winds. Such a fire storm developing after a series of conventional air raids on Hamburg in 1943 produced temperatures estimated at 800°C. (1472°F.).⁵ Days after the raid, as some shelters were opened, enough heat was found to have remained so that the influx of oxygen caused the entire shelter to burst into flames. Deaths inside shelters in Hamburg were described as due to heat stroke, dehydrating effects of intense heat and carbon monoxide poisoning.

The Hamburg (and Leipzig) experience is particularly germane in relation to the shelter problem, for as Caidin⁵ points out, only those who fled their shelters in the early stages of fire had any hope of reaching safety. Thus, huddling in a home shelter, particularly one without a self-contained air supply, might well be fatal if a fire storm developed overhead. Near the periphery of the fire storm, deep blast shelters would provide adequate thermal insulation, but only if supplied with sufficient oxygen to allow complete isolation from the external atmosphere for several days

From the foregoing data it is possible to make a numerical estimate of the casualties from blast and heat that would occur in the Boston area, assuming that every person would be in a shelter at the time of the attack and thus not subject to radiation. In the 4-mile radius of total destruction, the number of Boston residents killed outright would be at least 739,000 (*Census Handbook*, 1950), which does not include the commuter population. Within the 16-mile radius of the fire storm, assuming that no significant number of people is located in adequate deep blast shelters, an additional 1,501,000 persons would be killed, raising total deaths in the Boston area to 2,240,000. More distant persons who survived the instantaneous effects might need treatment for missile or blast injury, burns of second or third degree, including retinal damage, and conceivably for heat stroke or carbon monoxide poisoning. Similar estimates of casualties after the

TABLE 1. *Casualties and Property Damage in Three Massachusetts Cities Resulting from Blast and Fire Storms after a Thermonuclear Attack.*

AREA	EFFECTS OF BLAST ALONE		THERMAL & BLAST EFFECTS	
	TOTAL DESTRUCTION OF BUILDINGS, INCLUDING DEEP BLAST SHELTERS	FATALITIES	FIRE-STORM & BLAST CASUALTIES (ASSUMING NO SELF-CONTAINED BLAST SHELTERS)	FATALITIES
Boston	5.0-mi. radius	739,000	15.0-mi. radius	2,240,000
Springfield	3.15 mi.	174,000	5.6 mi.	250,000
Worcester	2.65 mi.	187,000	4.9 mi.	205,000
Totals		1,100,000		2,695,000

bomb drops shown in Figure 3 in the Springfield and Worcester areas are included in Table 1 and indicate that these three bursts alone are capable of destroying three fifths of the total population of Massachusetts.

RADIATION EFFECTS

The preceding analyses demonstrate that blast and fire damage, rather than radiation, constitute the major hazards for large areas surrounding the hypocenter. Radiation, however, would create a problem for persons beyond the range of immediate destruction. The initial burst (5 per cent of bomb energy) of neutrons and high-energy gamma rays is locally lethal but limited to the blast-destroyed area. Some materials, activated by this initial neutron flux, would contribute to later fallout. The 10 per cent of total bomb energy that goes into radioactive fission products is distributed in two parts. From a ground burst, some 20 per cent is made up of very fine particles, which are carried into the stratosphere with the mushroom cloud. These travel with upper-level winds and descend over months or years as global fallout of long-lived isotopes. The remaining 80 per cent of both short-lived and long-lived radionuclides begins to descend within minutes and continues for forty-

eight hours, the rate of descent depending on particle size. It should be emphasized that this pattern would not be true for an air burst, as at Hiroshima or Nagasaki, where there was little or no local fallout.

Physical Distribution of Fallout

For purposes of calculation an idealized fallout pattern has been assumed in official publications.² Our calculations are based upon the method outlined in this reference, but assume a wind of 40 miles per hour, as stated at the Holifield Committee hearings.¹ Winds of lesser velocity would produce more intense fallout over a smaller area.

One assumes a "ground-zero circle" of about 8 miles, which includes the fallout of heavier particles from the initial column and mushroom cloud. This material descends within the first hour after detonation, producing radiation that is unimportant since in this area there would be few survivors of blast and heat. The lighter particles require a longer time to come down and are displaced downwind, forming first an ellipse and ultimately a cigar-shaped figure. The best available estimate of the range of particle sizes in areas of hazardous fallout is 50 to 400 microns.² A 340-micron particle requires three quarters of an hour, and a 75-micron particle sixteen hours to descend from 80,000 feet. With a 40-mile-per-hour wind, the 340-micron particle would be blown about 22 miles from ground zero, and the 75-micron particle about 560 miles. Thus, they would arrive at angles of 5° and 0.1° from the horizontal respectively and could enter an open window.

It is generally assumed that 80 per cent of the total radiation due to local fallout would descend in the first forty-eight hours. From the idealized pattern, an area of contamination of 4000 square miles would follow a 20-megaton burst on Boston, such that an unshielded person at the edge of this area would receive 450 rem (an LD₅₀ dose) in forty-eight hours. However, the smooth contours described above are produced by idealized wind patterns, which do not exist in nature. For example, in the 1954 tests at one location 100 miles from the hypocenter, 2300 r were received in thirty-six hours. At another location, 25 miles from the first and 115 miles from the hypocenter, only 150 r were received.²

The assumption that 80 per cent of the radioactive material produced will return to earth as local fallout has also been questioned. It might be much less. On the other hand, all information on local fallout has been obtained from kiloton bursts on silicate, or from megaton bursts on coral sand. The fallout resulting from a surface burst in a city of concrete and steel might possess quite different properties.

Calculation of Radiation Levels

Various methods have been proposed for the determination of the pattern of radioactivity in the area surrounding a bomb burst. One must first esti-

mate the decay rates of the deposited radioactive material. Next, one must decide whether to assume a uniform field of radiation over the whole area, or to allow (as we have done in Figure 4) for wind effects, which would result in radiation contours. Ralph Lapp¹ examined the decay rates suggested in testimony before the Holifield Committee; these yielded various estimates of gamma radiation, ranging from 2400 r to 7000 r per hour at one hour after detonation. On the basis of actual field data, he proposed a 4000-r-per-hour rate, uniformly distributed over a 4000-square-mile area, as a model of the radiation levels. His assumptions include decay rates, which yield the dose schedule shown in Table 2 for a single 20-megaton ground-level explosion.

An individual shelter with 20 inches of concrete (giving a protection factor of 250, as usually suggested by the OCDM) would reduce the cumulative two-week dose from 10,955 r to 45 r (assuming that one remained continuously inside the shelter). One-half time outside the shelter during the next two weeks would add 215 r; three-quarter time during the remainder of the year would add 380 r. This total of 640 r in one year is probably compatible with individual human survival, but would have long-term genetic and somatic effects.

These figures, as we have indicated, are based on the assumption of a uniformly contaminated field. Contour maps allowing for wind effects make calculations more difficult but probably more realistic. For example, radiation levels near the hypocenter may be three to five times the average, whereas the peripheral areas may be much less contaminated. Figure 4 demonstrates this pattern for the Boston area. The hourly rates indicated are for one hour after detonation. The cumulative doses are proportional to the values shown in Table 2.

Medical Consequences of Radiation

Consideration of radiation problems in an exposed population must include initial exposure before shelter is reached, low-level accumulation in the shelter and later emergence into a radioactive environment (Fig. 5).

To estimate medical consequences one must first clarify the levels at which radiation damage occurs. Most official documents give estimates in terms of the LD₅₀. At this level, 400 to 500 r, given as a short-term dose, would permit the survival of 50 per cent of a healthy young adult population. From a medical point of view, however, even much lower levels (about 225 r) would take the lives of some persons, particularly the young, the old, those with pre-existing disease and those with blast or burn injuries. Furthermore, the choice of 400 to 500 r as the LD₅₀ ignores genetic and long-term somatic effects (for example, leukemia) of these high-level exposures. Levels of even 50 to 100 r would increase the late incidence of cancer and leukemia^{6,7} and double the spontaneous

gene mutation rate.^{8,8} Aronow, in the accompanying article, compares these dose rates with dose rates from by soft radiation (beta and low-energy gamma); and injury produced by deposition of radionuclides in

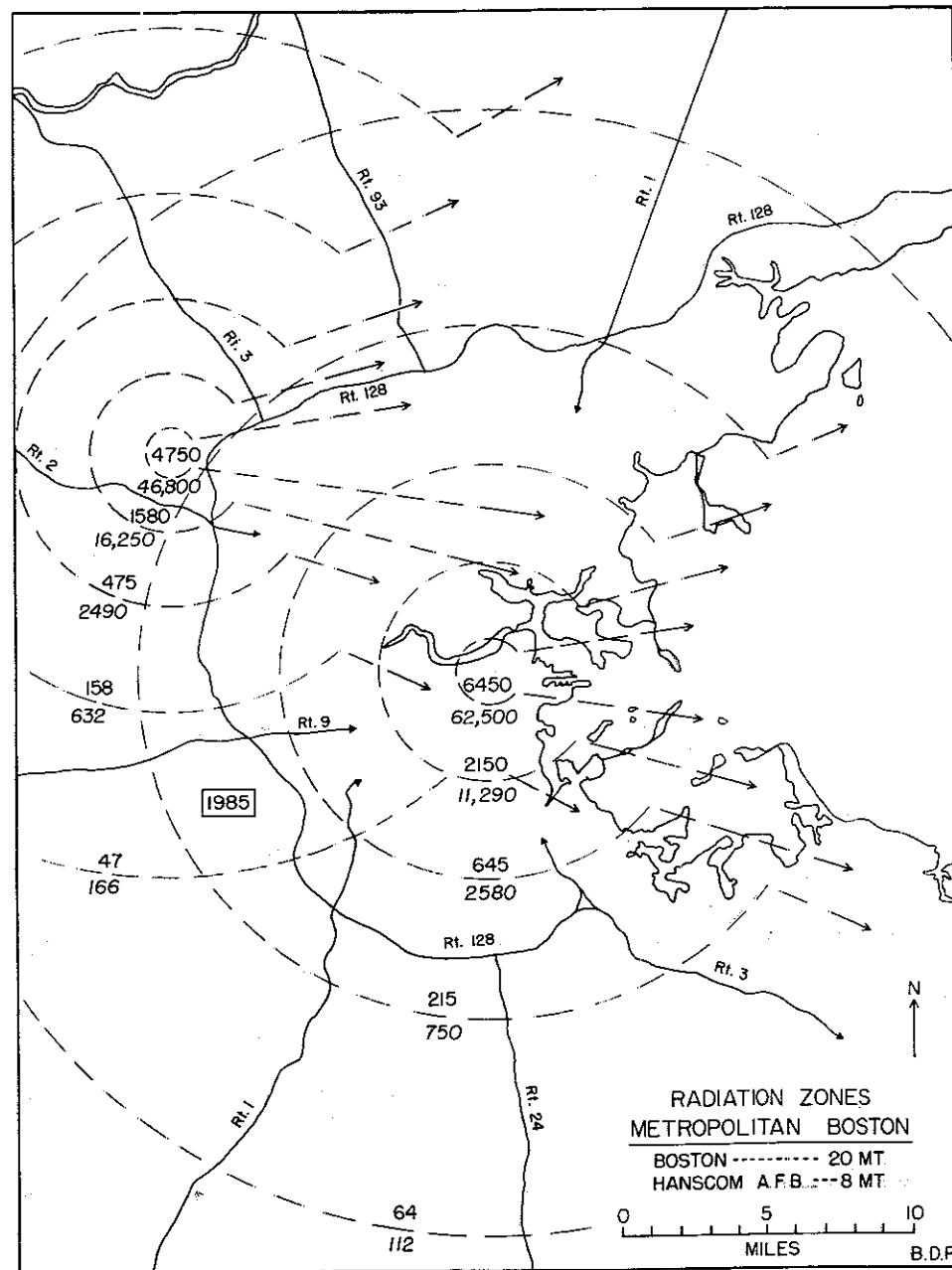


FIGURE 4. Idealized Map of Radiation Contours for the Boston and Bedford Explosions Alone, Indicating on Each Contour Line the Reference One-Hour Dose Rate in Roentgens per Hour at 3 Feet above Ground Level

The adjacent larger number represents the integrated dose for two weeks after the explosion, on the assumption that fallout begins in the outermost region at one hour and in the innermost immediately. The two indicated numbers represent averaged cumulative doses produced by the overlap of fallout fields. One can calculate such levels for any other region on the map by adding the indicated doses. This map emphasizes both the importance of the overlapping effects in assessing radiation and the possibility of extreme variations in levels in adjacent areas. Construction of such a map for New England (not shown) indicated initial levels of at least 10,000 to 12,000 per hour for most of Southern New England, the highest levels being present in Eastern Massachusetts, Rhode Island and Connecticut

more familiar sources, such as natural background, diagnostic x-rays and so forth.

Short-term effects of fallout may be divided into three classes: whole-body radiation injury produced by penetrating radiation; superficial burns produced

specific organs. Each of these types of radiation injury may produce both acute signs and later on chronic manifestations.

Table 3, adapted from Glasstone,² summarizes the short-term effects of acute whole-body irradiation

Whole-body doses of several thousand roentgens produce a "central-nervous-system syndrome" with in-

TABLE 2. Cumulative Gamma-Ray Dose at 3 Feet above Ground Level at Intervals after Detonation of a 20-Megaton Bomb, Assuming Uniform Fallout over 4,000 Square Miles.¹

INTERVAL	DOSE DURING INTERVAL	CUMULATIVE DOSE FROM 1 Hr AFTER DETONATION
	r	r
1-2 hr	2,500	2 500
2-3 hr	1,250	3 750
3-4 hr	800	4 550
4-5 hr	550	5,100
5-10 hr	1,500	6 600
10-24 hr	1,550	8 150
2d day	950	9,100
3d day	500	9 600
4th day	300	9,900
5th day	225	10,125
6th day	175	10 300
7th day	120	10,420
2d wk	535	10,955
3d wk	285	11 240
4th wk	140	11,380
2d mo	220	11,600
3d mo	100	11,700
4th mo	60	11,760
5th mo	40	11 800
6th mo	25	11,825
6th-12th mo	60	11 885
2d yr	20	11,905
3d yr.	6	11,911
4th yr.	3	11,914

evitable death in hours or days, preceded by hyper-

Doses of 1500 r may produce only a "gastrointestinal syndrome" before death, with nausea, vomiting, diarrhea and necrosis of intestinal mucosa. Although death usually occurs in the first week, these cases would contribute to the immediate medical-emergency problem. (The accompanying article by Sidel and his associates surveys this problem.)

Doses below 1500 r result in a gastrointestinal syndrome of decreasing severity, so that at levels of 200 r only mild radiation sickness occurs in most adults and is characterized by hair loss, nausea, diarrhea, malaise and weakness, delayed healing and lowered resistance to infection. Granulocytopenia, anemia and thrombocytopenia may produce hypoxia and purpura, and increase the possibility of infection. In Japan (where the air bursts produced little fallout) deaths from infection were most prevalent in the second and third weeks, and from hemorrhagic phenomena in the third to sixth weeks, although some radiation deaths occurred in the seventh week and later.

The overlap of responses and the similarity of presenting symptoms in persons who have been lethally irradiated and those who have received much smaller doses would create major diagnostic problems in the postattack period. Few, if any, survivors would know whether they have received 1000 r or 100 r. In attempting, for practical reasons, to

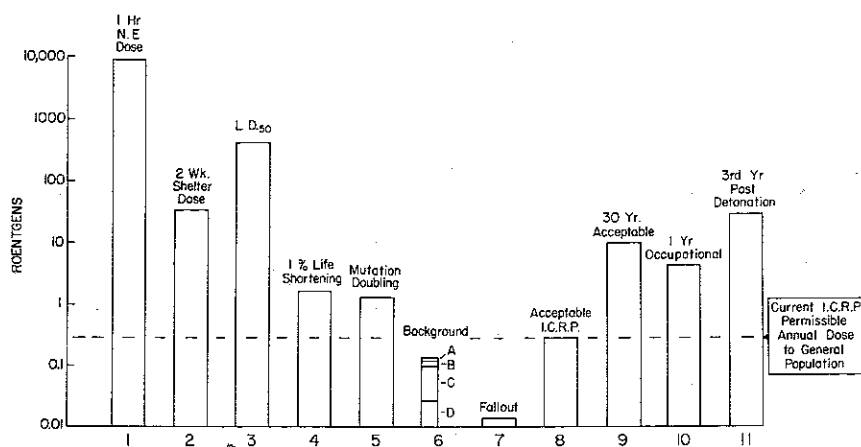


FIGURE 5. Comparison of Radiation Levels.

Note that the scale is logarithmic so that, for example, bar 1 is 100,000 times or 5 orders of magnitude greater than bar 6. (See glossary for discussion of this point.) The bars are identified as follows (note some differences in the time scales involved): initial (one-hour) dose rate for Southern New England (1), under the conditions specified in the text, corrected for additional fallout arriving from New York State alone; cumulative dose (2) received by a person continuously in a shelter with a 250 protection factor for two weeks after detonation of a single 20-megaton weapon (use of the data in bar 1 would increase this by 2.5 times); estimated lethal dose for half an exposed population (3); estimated level that shortens life expectancy by 1 per cent, based on animal experiments (4); estimated level that doubles mutation frequency in mammalian germ cells (5); natural background activity for American population (6), composed of man-made radiation, such as x-rays, luminous watch dials and television screens (A), internal emitters — K^{40} , C^{14} , Ra^{226} and so forth (B), gamma rays from granite — radium, thorium and so forth (C) and cosmic rays at sea level (D); estimated accumulated global fallout from testing through 1961 (7); annual dose suggested by the International Commission on Radiologic Protection as the "maximum permissible" for the general population from all sources (8); "maximum permissible" total cumulative dose (thirty years) suggested by the Commission for the general population (9); "maximum permissible" total cumulative dose (one year) suggested by the Commission for occupational exposure (10); and annual dose during the third-year post attack at the level indicated in bar 1 (11).

excitability, ataxia, respiratory distress and intermittent stupor.

classify irradiated persons into three groups whose survival is improbable, possible or probable, one

would have to rely on very broad symptomatic rules of thumb in the absence of adequate laboratory facilities, trained technicians and the opportunity to

TABLE 3. *Probable Short-Term Effects of Acute Whole-Body Irradiation*

ACUTE DOSE r	PROBABLE EFFECTS
0 to 50	No obvious effect, except possibly minor blood changes
80 to 120	Vomiting & nausea for about 1 day in 5-10% of exposed persons; fatigue but no serious disability.
130 to 170	Vomiting & nausea for about 1 day, followed by other symptoms of radiation sickness in about 25% of persons; no deaths anticipated
180 to 220	Vomiting & nausea for about 1 day, followed by other symptoms of radiation sickness in about 50% of persons; no deaths anticipated
270 to 330	Vomiting & nausea in nearly all persons on 1st day, followed by other symptoms of radiation sickness; about 20% deaths within 2-6 wk after exposure; survivors convalescent for about 3 mo
400 to 500	Vomiting & nausea in all persons on 1st day, followed by other symptoms of radiation sickness; about 50% of deaths within 1 mo.; survivors convalescent for about 6 mo.
550 to 750	Vomiting & nausea in all persons within 4 hr. after exposure, followed by other symptoms of radiation sickness; up to 100% deaths; few survivors convalescent for about 6 mo
1000	Vomiting & nausea in all persons within 1-2 hr.; probably no survivors
5000	Incapacitation almost immediately; all persons dead within 1 wk

follow survivors systematically for several weeks or more. The following general descriptions apply to the various categories of irradiated survivors:

Group 1 (survival improbable). If vomiting occurs promptly and continues, followed rapidly by prostration, diarrhea, anorexia and fever, the prognosis is grave. Even intensive therapy may be ineffectual.

Group 2 (survival possible). These patients show early vomiting of short duration, followed by a period of apparent well-being. Lymphocytes are depressed and remain so for months, neutrophils are depressed and drop to zero at seven to nine days, remaining below 1000 per cubic millimeter during the second week. Platelets may reach their lowest level after two weeks, with external evidence of bleeding in two to four weeks. In the most severely irradiated of this group the latent period may be one to three weeks, with little evidence of injury other than fatigue. At the end of this time epilation, purpura, diarrhea and infections will appear, followed, in the absence of vigorous treatment, by high mortality. If such persons enter shelters after their initial radiation exposure, a serious management problem would be created during the next several weeks.

Group 3 (survival probable). These persons may or may not have had fleeting nausea on the first day. If there are no further symptoms, hematopoietic changes are the best indicator of exposure. Lymphocytes reach low levels within forty-eight hours. The granulocytes may become depressed from the second to the seventh week or even later. Platelets reach the lowest count on about the

thirtieth day. Medical problems center around decreased immune mechanisms and impaired healing

Other Immediate Symptoms

Although superficial burns from beta radiation do not contribute to the hematologic depression they increase the possibility of infection and create other problems. From twenty-four to forty-eight hours after exposure, a fourth of the 64 exposed Marshall Islanders experienced itching and burning of the skin; a few had burning of the eyes and tearing. These symptoms subsided in two days but within two weeks after exposure epilation and skin lesions appeared. Early itching, burning and slight pain were associated with the lesions. Deeper lesions produced more severe pain, and foot lesions were particularly incapacitating. No constitutional symptoms accompanied these lesions, and they healed within seven to ten days.²

A more serious problem might well be the impaired healing of minor injuries in persons with sublethal radiation. The mean lethal dose for many cell types is 100 r; thus, not only hematopoietic defenses but also general healing processes are impaired at this dose level. As pointed out above, many, if not all, survivors would receive doses of this level in the hypothetical attack. Malnutrition, excessive fatigue and emotional stress would also contribute to recovery problems. Patients requiring regular insulin, digitalis, cortisone and so forth would have additional difficulties. It seems likely that major medical problems during the first few weeks would arise out of this combination of burns or injury and impaired healing and failure of immune mechanisms.

Internal absorption of fallout would not be a serious immediate hazard and will be considered a long-term problem. A possible exception might be the inhalation of fine particles by a population in shelters, with consequent pulmonary fibrosis and radiation pneumonitis.

The task of the medical profession in dealing with all these problems, and with such further complications as loss of medical facilities and personnel, is discussed in the following article.

Delayed Effects

It is difficult to quantitate the effects of residual radiation, since many of the short-lived fission products have decayed significantly by three to six months. The residual activity is the sum of these remaining levels plus those of longer lived nuclides that have decayed less. The pattern of fallout for much of Southern New England, including that deposited from distant detonations, would provide a residue of 0.5-1.0 r per hour at three months.¹ By the second year after detonation, levels would be slowly decaying from about 0.01 r per hour so that a constantly exposed person would get 90 r per year, which is compatible with individual survival. Much of this long-

term residue is beta emitting; furthermore, it weathers and is buried in soil, increasing the difficulty of making a realistic estimate. Many of the elements that comprise the long-term residue (as pointed out in the accompanying article by Aronow) are physiologically significant and tend to concentrate in selected body organs. Although this residual radioactivity is compatible with human survival, its effects would create an unpredictable hazard. The effects include: increased incidence of leukemia and other neoplasia; increased degenerative disease; accelerated aging and decreased life-span; increased incidence of congenital malformations; stillbirths, neonatal deaths and feeble-mindedness; decreased fertility; and increased incidence of cataracts.

A sensitive indicator of these biologic effects is the developing embryo. A striking aspect of this problem, considering the radiation resistance of mature nerve cells, is the susceptibility of developing neural tissue. Many cells become morphologically necrotic in less than four hours after 40 r to the whole body of mother or newborn infant.⁹ In Hiroshima many cases of microcephaly and an increased incidence of mental deficiency appeared in children who had been four months *in utero* at the time of the bombing.¹⁰ Furthermore, half the substantial number of mentally defective children born in the post-attack period were from mothers who had major immediate radiation exposure in the range of only 200 to 300 r. The history of abnormal termination of gestation in 45 of 177 pregnant Nagasaki survivors illustrates the dose dependency of embryo damage. The terminated pregnancies included all 19 within 1.8 miles of hypocenter, 15 of 20 between 1.8 and 11.2 miles and 11 of 138 beyond that.¹⁰

Effects such as these would reach important dimensions within months of the explosion. Other longer-range biologic effects will not be examined in detail, since there is little experimental information about the phenomena of delayed response.

The profoundly altered ecology of involved areas would also be of major importance, even after attack of only 1446 megatons. In many areas fire would consume the forest cover and result in severe flooding during spring thaws, lack of water retention in the drier areas and the creation of extensive dust bowls.¹ Flowering plants and young trees are extremely sensitive to radiation, and would be affected by radiation as well as by fire, flood and drought.

Moreover, short-term and long-term radiation effects of fallout might be expected to disrupt the balance normally maintained in the plant and animal world. Mammals and birds are highly sensitive to radiation; insects are extremely resistant (for example, cockroaches are not appreciably damaged by gamma radiation in the range of 40,000 r, which is one hundred times the LD₅₀ for man). Bacteria are similarly very resistant to radiation although mutation rates are increased — for example, only 10 per cent of

an *Escherichia coli* population is killed by 20,000 r of gamma radiation. Viruses and fungi are even more resistant.

The longer-term survival of human populations after this ecologic upheaval would be precarious. Even assuming an intact social structure and the maintenance of a functioning work force, agriculture, particularly domestic animals, would be all but destroyed. Before malnutrition became a major medical concern, however, the threat of epidemic infectious disease would be raised by the fact that bacteria, fungi, viruses and insects would survive the effects of radiation. The ultimate size of these populations in the absence of challenge by their natural enemies is difficult to estimate.

SUMMARY

This article examines the short-term human and ecologic consequences in Massachusetts, and in particular in metropolitan Boston, of the "limited" thermonuclear attack on the United States postulated by the Holifield Committee report of 1959. This assigns 10 weapons totaling 56 megatons to Massachusetts. Damage would result from blast, heat and radioactive fallout.

A 20-megaton ground burst on downtown Boston would seriously damage reinforced-concrete buildings to a distance of 10 miles, roughly to circumferential Route 128, and demolish all other structures.

Within a circle of a radius of 16 to 21 miles second-degree burns would be produced, and clothing, houses, foliage, gasoline and so forth would ignite, producing a fire storm. Human survival in this area would be practically impossible, and an estimated 2,250,000 deaths would occur in metropolitan Boston from blast and heat alone.

Beyond the area consumed by fire, many persons would be exposed to lethal doses of radiation from local fallout. For some of these persons, fallout shelters could reduce the cumulative dose of radioactivity to levels compatible with survival, provided immediate entry into shelters was achieved and occupancy of the shelters maintained for the necessary several weeks. For many persons access to shelters would be made more difficult by blindness produced instantly by retinal burning. Many sheltered survivors would be subject to acute radiation sickness and to the long-term somatic and genetic effects of radiation.

Acute whole-body irradiation produces a variety of clinical syndromes, largely dependent on the dose of radiation absorbed. The similarity of presenting symptoms in persons who have been lethally irradiated and those who have received much smaller doses would create major diagnostic problems in the postattack period. Sublethal irradiation would increase the morbidity and mortality from pre-existing disease and from blast injuries, burns and infections.

Long-term effects of radiation due to fallout would

include increased incidence of neoplasia, stillbirths, congenital malformations and cataracts.

Serious ecologic problems would result from thermal destruction of forests and widespread lethal irradiation of mammals and birds, accompanied by relative sparing of bacteria, fungi, viruses and insects, all of which are highly resistant to radiation.

The authors are indebted for the painstaking and thoughtful art work of Mr. Bradford Pearson, as well as for his critical commentary.

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II. The Physician's Role in the Postattack Period*

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BOSTON

MANY monographs and articles¹⁻⁸ have been written to acquaint physicians with the medical problems that might follow a thermonuclear attack on this nation. Often, these articles rely on experience with previous disasters — for example, the New England hurricane of 1938, the Cocoanut Grove fire of 1942, the Texas City explosion of 1947, the fire bombing of Hamburg in 1943 and especially the nuclear bombing of Hiroshima and Nagasaki in August, 1945.⁹

To reason from these models to thermonuclear war, however, is to make the assumption that the problems of H-bomb warfare will be quantitatively greater, but qualitatively similar to those of these earlier disasters. This usually unstated assumption implies that since we have survived other catastrophes we will survive now — under any circumstances — if only we plan carefully enough. An illustrative example is the recent report by the Official Committee on Disaster Medical Care,¹⁰ which calls on physicians to promote sound planning for handling of mass casualties, to encourage the population to engage in survival training and to “lend assurance that a successful recovery from mass attack is possible.”

The present article examines some of the medical effects of a thermonuclear attack for a defined geographic area, the state of Massachusetts. It demonstrates that thermonuclear war will differ in size and nature from anything in previous experience (and parallels with past disasters are therefore often

inapplicable) and considers the implications for disaster planning

A thermonuclear attack poses a series of questions for physicians. How many persons will be killed outright? How many will be fatally injured? How many will be injured, but survive? Similarly, how many physicians will be killed or injured? How many hospital beds will be destroyed, and how many will remain intact? Will any necessary medical supplies — drugs, plasma, blood, dressings, instruments and the like — be left? And where will physicians, patients, beds and supplies be in relation to one another? The answers depend, however, on still other questions. What will be the type, timing, magnitude and distribution of the attack — or, more bluntly, how many bombs will there be? Will they be fission or fusion or both? Where will they fall? Will the attack occur in daylight or at night? Will the weather be clear or hazy, moist or dry, windy or calm? Will there be warning time? How accurate will delivery be? Will there be one strike or more? These are not rhetorical questions; each has a quantitatively measurable effect on the results of thermonuclear attack, and the total pattern of medical consequences is a function of the answers to all the questions.

Thus, there are so many variables and so many imponderables in the complex equation of thermonuclear war that one can reach almost any conclusion by choosing appropriate assumptions. The primary responsibility of the physician to the medical community and to the public, therefore, is neither to offer sweeping and uncritical reassurances nor to cry doom, but rather to define and study the consequences of a specific and possible pattern of attack.

We have based our report on the findings of the

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Joint Committee on Atomic Energy of the United States Congress (the Holifield Committee).¹¹ This scientifically detailed study has become the standard reference for those writing on the subject. In the course of official hearings in 1959 on the biologic and environmental effects of nuclear war, the Committee hypothesized an enemy attack on the United States totaling 1446 megatons. It was assumed that 263 weapons would be employed, directed at 224 targets, of which 71 were cities and industrial centers. Ten weapons of 56 megatons were "assigned" to Massachusetts.

In view of the development of over 50-megaton weapons and rapid improvements in missile capacities since 1959, there is reason to believe that this estimate is, by now, conservative.

CASUALTIES

On the basis of the postulated attack, the specific conditions of which Ervin et al. have described in the previous article, and on the testimony of expert witnesses, the Holifield Committee compiled an estimate of the number of casualties for each area attacked. The estimates for the Boston metropolitan area and for Massachusetts as a whole, taken directly from the Committee Summary Analysis,¹² are given in Table 1. In the Boston area (hit by 10

TABLE 1 *Casualties in Metropolitan Boston and Massachusetts after a 56-Megaton Attack*

TARGET AREA	NO. OF PEOPLE IN ATTACKED AREA*	NO. KILLED ON 1ST DAY	NO. FATALLY INJURED	NO. SURVIVING INJURED	NO. UNINJURED
Boston metropolitan area	2,875,000	1,052,000	1,084,000	467,000	272,000
Massachusetts (including Boston)	4,691,000	1,347,000	1,501,000	878,000	965,000

*Based on 1950 population figures

megatons each on Boston and Cambridge and 8 megatons on Bedford), about 1,000,000 people will be killed on the first day and about 1,250,000 will be injured. Of the injured, approximately 1,000,000 die, making a total of more than 2,000,000 dead in the Boston area. Over the entire State, including the Boston area, over 1,300,000 persons will die immediately, over 2,300,000 will be injured, and of these about two thirds will die.* The number of injured immediately after the attack is thus about 1,500,000 for Boston and over 2,000,000 for the entire Commonwealth.

Estimation of the number of physicians who will remain uninjured is more difficult. Data on the number of physicians within a given large target area are available.^{13, 14} Since the physicians of a state tend to be concentrated in the large cities and those within a metropolitan area are usually concentrated

*These figures differ slightly from those in the previous article because the Holifield calculations assume an unsheltered population and include the effects of radiation and blast, but attribute no casualties specifically to fire storms.

near its center, physicians face a higher risk from thermonuclear bombardment than the general population. For example, 70 per cent of the physicians of the Commonwealth live within the Boston metropolitan area¹³ whereas only 50 per cent of the total population of the Commonwealth live in this area.¹⁵ Furthermore, some 85 per cent of the physicians of the Commonwealth live within the metropolitan areas of Boston, Worcester, Springfield-Holyoke, Fitchburg-Leominster and Fall River,¹³ each of which is scheduled for thermonuclear bombardment in the Joint Congressional Committee's estimate.¹¹ Although the risk for physicians is clearly higher than that for the general population, we have made the assumption that physicians are at the same risk as the population as a whole. Table 2 is based on this assumption and thus represents an *overestimate* of the number of physicians remaining uninjured. Even so, some 4800

TABLE 2 *Casualties among Physicians in Metropolitan Boston and Massachusetts after a 56-Megaton Attack*

TARGET AREA	NO. OF PHYSICIANS IN ATTACKED AREA	NO. KILLED ON 1ST DAY	NO. FATALLY INJURED	NO. SURVIVING INJURED	NO. UNINJURED
Boston metropolitan area	6,560 ¹³	2,380	2,470	1,070	640
Massachusetts (including Boston)	9,440 ¹⁴	2,710	3,020	1,730	1,980

physicians would be killed or fatally injured, 1000 would be injured, and only about 650 would remain uninjured in the Boston area. In the entire Commonwealth, including Boston, some 5700 physicians would be killed, 1700 would be injured, and only 2000 would remain uninjured. If we assume further that 25 per cent of the physicians who are nonfatally injured will be able to carry on medical duties in the postattack period despite their injuries, the number of physicians available for medical service will be about 900 in the Boston area and about 2400 in the Commonwealth as a whole.

When this calculation is examined, it is clear that it rests on still other assumptions. For example, it includes physicians of all ages, and many in at least partial retirement. This calculation also counts, as physicians available for postattack service, many whose work has centered on administration, laboratory research or preclinical teaching rather than on clinical care of patients. Additionally, it must be remembered that this count of functioning physicians includes pathologists, psychiatrists and other specialists who have had little recent training or experience in the treatment of burns, trauma or radiation injury.

The data in Tables 1 and 2 yield a ratio of approximately 1700 acutely injured persons to each functioning physician in the Boston area, and about 1000 injured to 1 physician in Massachusetts as a whole. These are minimum estimates of the number of injured per physician. It must also be remembered

that the total population-to-physician ratio, which includes the uninjured survivors, both healthy and ill, will be still higher.

These calculations of death and injury have been made without reference to the provision of fallout shelters. As the preceding article by Ervin and his associates and a recent editorial in this journal¹⁶ clearly demonstrate, radiation shelters will be useless in the extensive area of blast and fire storm surrounding each hypocenter.

Nevertheless, it has been stated that the provision of radiation shelters will markedly reduce the number of casualties. There is little doubt that of the people fortunate enough to be outside the range of blast and fire, some who would have otherwise have been irradiated would escape such injury by reaching and remaining in an adequate fallout shelter. The magnitude and relative importance of this protective effect varies, however, with the type and distribution of thermonuclear attack.¹⁷ In the presently postulated attack on targets in Massachusetts, some 721,000 radiation deaths and 557,000 radiation injuries would be averted *if* fallout shelters were provided for the entire population, *if* the shelters were 100 per cent effective against fallout, *if* every shelter were adequately provided with food, water, an independent oxygen supply and other necessities for inhabitation for several weeks or more, *if* warning time were adequate and *if* transportation and the maintenance of order in a threatened population were sufficient to enable most of the population to reach shelters. Assuming that all these conditions are met, however, the presently postulated attack will still result in 1,347,000 deaths on the first day, 780,000 fatal injuries and 321,000 nonfatal injuries in Massachusetts.

The continuing radioactivity described by Ervin et al in the preceding article will make it necessary for any survivors inside shelters to remain there for a period of weeks and then to leave only for brief periods. The same restrictions will apply to surviving physicians. Therefore, any increase in the number of uninjured physicians achieved by the provision of radiation shelters would be balanced by the fact that these physicians could not safely venture outside the shelter to aid the injured. Thus, the net effect of preserving physicians by having them remain inside radiation shelters is to reduce the number of physicians available at the time of greatest medical need — that is, for the care of the acutely injured in the immediate postattack period — though increasing the number of physicians available in subsequent weeks.

The consequences of a ratio of 1000 or 1700 acutely injured persons to 1 physician are made clear when one examines the immediate postattack situation in greater detail. If the physician were to spend only ten minutes on diagnosis and treatment of each injured patient, and if he worked twenty hours every day, it would require eight to fourteen days before

every injured person could be seen for the first time. Even this estimate, however, is unreasonably optimistic, for it assumes that every physician will be willing to expose himself to high or lethal levels of radiation and will be able to identify the areas in which he is most needed, transport himself to those areas and find every one of the 1000 or 1700 survivors with *no* expenditure of time. If, on the other hand, the complete availability and effectiveness of fallout shelters is assumed, and all surviving physicians are sheltered, the situation changes. Under these circumstances, there will be *no* functioning physicians outside shelters in the immediate postattack period, but the injured-to-physician ratio will be considerably improved two weeks or more later, when physicians emerge from their shelters, since large numbers of the injured will have died in the interim.

The ratio of total patients to physicians in both the immediate and later postattack periods will be affected by the number of persons not physically injured in the attack who would demand the physician's time. This includes those with pre-existing illness requiring continuing medical attention and those with acute illness secondarily related or unrelated to the attack; it also includes those who merely believe they are injured. That this will be a considerable problem is indicated by past experience in much lesser catastrophes¹⁸ in which patients not at all involved presented themselves with the appropriate symptoms. The symptoms of radiation sickness, in particular, are such that many persons exposed only minimally are likely to confront the physician with weakness, nausea, vomiting and diarrhea. These patients, too, will require diagnosis and treatment, further reducing physician availability to the acutely injured.

It follows that most of the fatally injured persons will never see a physician, even for the simple administration of narcotics, before they die. Many of those injured who might survive with adequate care will also die, and many other injured persons will have to accomplish their survival without medical aid.

MEDICAL FACILITIES

What of the injured persons who are fortunate enough to find an available physician? What facilities and equipment will remain intact for the physician to use?

A fairly accurate estimate can be made of the number of hospital beds remaining in Massachusetts after a 56-megaton attack of the distribution envisioned by the testimony before the Holifield Committee.¹⁹ The extent of blast and fire damage is shown on the map in the preceding article by Ervin and his associates. Table 3 summarizes the hospital destruction to be expected; this is a deliberate underestimate since it ignores damage to Massachusetts facilities caused by bomb explosions in Providence, Rhode Is-

land, and Portsmouth, New Hampshire. Thus, even if radiation is not considered, less than 10,000 of the existing 65,000 hospital beds in the Commonwealth

the needs of millions of casualties in addition to the normal medical needs of the population. As of 1956²⁰ the Federal Civil Defense Administration's plan was

TABLE 3 *Massachusetts Hospitals Surviving Blast and Fire in a 56-Megaton Attack*

TYPE	No OF HOSPITALS			No OF BEDS		
	PRESENT TOTAL	OUTSIDE BLAST AREA*	OUTSIDE BLAST & FIRE-STORM AREA†	PRESENT TOTAL	OUTSIDE BLAST AREA*	OUTSIDE BLAST & FIRE-STORM AREA†
General	128	68	24	21,796	7,483	2,104
Psychiatric	31	19	7	33,937	22,963	5,899
Tuberculosis	12	8	2	2,139	1,712	195
Chronic	9	4	2	2,449	530	120
Pediatric	3	1	0	546	43	0
Maternity	3	0	0	357	0	0
Miscellaneous	23	11	3	4,491	3,501	1,238
Totals	209	111	38	65,715	36,232	9,546

*Following radiuses of blast area assumed: for 10-megaton attack, 7.0 mi.; for 8.0-megaton attack, 6.5 mi.; for 3-megaton attack, 4.7 mi.; for 2-megaton attack, 4.0 mi.; & for 1-megaton attack, 3.2 mi. These are radiuses at which blast pressure will be 5 pounds/square inch & within which brick buildings will collapse.

†Following radiuses of fire-storm area assumed: for 10-megaton attack, 23.0 mi.; for 8-megaton attack, 21.0 mi.; for 3-megaton attack, 14.0 mi.; for 2-megaton attack, 12.0 mi.; & for 1-megaton attack, 9.0 mi. These are radiuses at which thermal radiation will be 8 calories/cm² & within which easily combustible materials will ignite.

will remain to accommodate their present occupants in addition to 2,000,000 injured. It must be noted that over half these remaining beds are in psychiatric hospitals. Although these hospitals are poorly equipped to deal with traumatic injury and radiation sickness, the beds will be needed. Psychiatric beds now have a high occupancy rate. To make them available for victims of thermonuclear attack it will be necessary to displace their current occupants. If large numbers of psychiatric patients — many of them unable to care for themselves under normal social circumstances — are released, the consequences will be difficult to predict. It must be noted, furthermore, that there is no medical or scientific basis for reaching a decision about whether a patient with schizophrenia or the victim of a third-degree burn "deserves" or should be assigned an available bed. Problems of this kind are considered further in a later section of this article.

In an attempt to meet the problem of hospital destruction the Federal Civil Defense Administration planned to provide 6000 200-bed improvised hospitals for the nation as a whole.²⁰ At the time of writing of this article 60 of these hospitals actually have been stored in warehouses in Massachusetts.²¹ A description of the use of 1 of these improvised hospitals has been published.²² If none of these were destroyed by the attack, if roads remained intact and if manpower were available to activate all of them, they would still provide beds for less than 1 per cent of the acutely injured in the Commonwealth.

Estimation of medical supplies remaining is extremely difficult. At the present time most large concentrations of drugs and equipment are in the hospitals and the wholesale-drug warehouses of the large metropolitan areas and would be destroyed. If the investment were large enough, it would be possible to cache sufficient supplies in outlying areas to meet

to disperse almost \$500,000,000 worth of medical supplies in some 100 warehouses in "fringe" areas around major cities throughout the nation. The further cost of maintaining these supplies was not stated, but the magnitude of the problem is considerable:

Penicillin G tablets carry a five-year dating and the parenteral preparations are not intended for use more than three or four years after formulation. Streptomycin in dry form has a four year dating; tetracycline, two years; and erythromycin, three years. Tetanus Antitoxin has an expiration date of three years.²²

If these supply stockpiles are completed and kept up to date, if they escape blast and fire-storm damage, if transportation facilities remain intact and roads stay open and if manpower is available to distribute them in an organized manner, they will be sufficient to treat 5,000,000 casualties in the United States for three weeks.²⁰ Since the Holifield estimate for the nation as a whole is 40,000,000 injured (as well as 20,000,000 killed in the first day), this large national investment will provide for less than 15 per cent of the anticipated injured. Furthermore, narcotics, one of the most essential groups of drugs in the care of seriously injured casualties, have not been stockpiled at all in Massachusetts because of difficulties in storage and handling.²¹

The absolute number of physicians, beds and supplies is only one aspect of the problem. Their distribution, in relation to the geographic distribution of the injured, is an equally critical consideration. To move physicians, ancillary personnel and beds into attacked areas presupposes good communications and transport. Furthermore, the reluctance of physicians to leave their shelters and their own patient populations to enter areas of higher radiation danger may be supported by national policy. Any surviving physician who leaves a fallout shelter for more than a few hours in the immediate postattack period may himself suffer radiation injury.

On the other hand, the attempt of injured persons

to make their way to relatively undamaged areas may precipitate grave social conflict. As Leiderman and Mendelson point out in their accompanying article, psychologic disorganization is likely under post-attack conditions. In Nagasaki a surviving physician observed that " . . . those who survived the bomb were, if not merely lucky, in greater or lesser degree selfish, self-centered, guided by instinct and not civilization."²⁴

That similar problems to those in Nagasaki may be anticipated in the United States is demonstrated by the statements of local civil-defense officials. For example, the *Los Angeles Times* of August 5, 1961, reported a speech by the Civil Defense Coordinator of Riverside County, California, warning the citizens to arm themselves to repel the hundreds of thousands of refugees who would flee that way if Los Angeles were bombed. The *San Francisco Chronicle* of September 23, 1961, reported a speech by the Civil Defense Coordinator of Kern County, California, suggesting that people fleeing from Los Angeles be diverted into the desert by armed policemen.

The question of immediate concern to physicians, given the almost inevitable acute shortage of medical care after a 1446-megaton attack, is whether or not reactions of panic and violence will develop in the competition for access to remaining medical facilities.

The considerations reviewed thus far, serious as they are, represent only one aspect of the problems of medical planning for thermonuclear attack. Physician-to-population ratios and the survival and distribution of beds and drugs are essentially quantitative and logistic questions. But there are substantive questions as well, bearing not so much on the quantity of medical care as on its content. Given the survival of some physicians and facilities, in short, what will the doctors have to do?

NEW MEDICAL PROBLEMS

In the attempt to develop methods of clinical practice and medical care in the postattack period, the experience of the armed forces in combat zones has guided planning. This involves establishment of an organization providing for an orderly process of medical management, sorting or triage of the sick and wounded according to the presenting type and urgency of the problem, deciding on priority of treatment and evacuating those requiring extensive care to better equipped installations. The applicability of this military model, however, is limited. In a thermonuclear attack there is no clear-cut front line and safe rear area, for blast and fire effects are widespread and radiation is almost ubiquitous.

In any case, as every physician knows, clinical practice is profoundly affected by its setting. In the postattack period the physician will encounter many major disruptions of the human environment. These include destruction of transportation, communication

and electricity, contamination and depletion of food supplies, destruction of housing and fuel, destruction and pollution of public water supplies and disruption of garbage and sewage disposal as well as other sanitary facilities.

These circumstances will, at the same time, create new medical problems and alter the management of such familiar entities as burns, fractures and blood loss. In some ways the situation will resemble those in underdeveloped areas in which too few physicians lacking essential resources must handle large populations. The problems peculiar to nuclear attack will be superimposed.

Care of the Individual Patient

The specific medical problems facing the surviving physician will include large numbers of patients with the following injuries: blast injuries, lacerations of soft tissues and fractures; thermal injuries, with surface burns, retinal burns and respiratory-tract damage; and radiation injuries, including acute radiation syndrome and delayed effects. Substantial numbers of patients will present infectious disease owing to lowered resistance and epidemic outbreaks²⁵; others will suffer psychologic breakdowns consequent to fear, grief and trauma.²⁶ In addition, the physician must deal with such pre-existing medical conditions as diabetes mellitus, hypertension and cancer.

Many medical articles have outlined optimal treatment for the types of injury most likely to be encountered after a nuclear attack: blast injuries²⁷⁻²⁹; thermal injuries³⁰⁻³²; radiation syndromes^{33,34}; and psychiatric problems.²⁶ The interested physician is referred to these sources. The *feasibility* of optimal treatment for these and other conditions under post-attack circumstances is germane to any analysis of nuclear-disaster planning by physicians.

The problems of trauma provide a good example. Major public concern has been with radiation injury; however, thermal and mechanical trauma will be of much greater importance. It has been estimated³² that the radius at which the initial ionizing radiation is at the 300-rem level (sublethal) increases only by a factor of 5 from a 1-kiloton to a 20-megaton airburst. The same increase from 1 kiloton to 20 megatons increases by a factor of 27 the radius of blast-induced pressures of 2.5 pounds per square inch. Thermal energy sufficient to cause second-degree burns increases by a factor of 64, from a radius of 0.5 mile to a radius of 3.2 miles. It has been concluded, on this basis, that burn injury is likely to cause the greatest number of casualties in any nuclear explosion.

Optimal therapy for serious burns requires sedation, oxygen administration and large intravenous infusions of fluids, electrolytes and plasma expanders. For example, a patient weighing 70 kg and having a burn of over 30 per cent of his body surface may require fluid replacement in excess of 6000 ml in

the first twenty-four hours after injury to combat hypovolemic shock. Antibiotics, tetanus prophylaxis and local wound care will also be necessary. Even if the individual physician is well instructed in the modern care of serious burns, it is difficult to see how he will cope with hundreds of such patients at once when he is lacking the most essential diagnostic and therapeutic facilities.

In the patients with thermal injuries, diagnosis and triage may be difficult and preclude prompt judgment and decision. But thousands of patients will also present fractures, ruptures of internal organs, penetrating wounds of the skull or thorax and infections; many, in fact, will suffer all these and burns as well. How are these problems to be identified and treated rationally in the absence of adequate x-ray and other diagnostic facilities? The question is important since decisions will have to be made to abandon the care of many. Patients with fatal or nearly fatal injuries may be neglected to make care available to more salvageable ones, and primary attention may be assigned to those who have the greatest possibility of survival. Triage for this or any other purpose is made even more difficult by the presence of radiation injury. The early clinical pictures of psychogenic nausea and diarrhea and of moderate, sublethal and lethal radiation injury overlap, and the medical history will be of little use since few patients will be able to report their exposure accurately. The necessity of making quick judgments involving life-and-death decisions for individual patients after only cursory examination, and the possible decision to ignore the critically ill and the near dying, would represent a profound and difficult reversal in the attitudes and performance of the physician.

In the face of these difficulties, many civil-defense plans place considerable reliance on nurses and on the training of large numbers of laymen in self-care and first aid. Once again, this attempt is drawn from military models and requires critical examination for the postulated postattack situation. There is no doubt that many minor injuries can be treated satisfactorily by first-aid measures and that some more seriously injured persons — for example, those with active hemorrhage — will be saved. Complicated problems involving a mixture of thermal, blast and other traumatic injuries will be beyond the competence of most nurses and laymen, however, and unfortunately will be of frequent occurrence. Careful consideration makes it clear that first aid is essentially a "holding" operation, effective only on the assumption that adequate medical care will be provided later. Yet the simple logistics of physicians, beds and supplies make it extremely unlikely that any subsequent and more skilled medical care will be available within a reasonable time.

Public-Health Problems

The medical problems of the postattack period will

require more of a public-health orientation than many practicing physicians have hitherto utilized^{25,35}. In a society struggling for survival adequate sanitation and the provision of food and water may save more lives than the most skilled specialist care. For example, Beckjord discusses the problem of water supply²⁵:

The military and civilians are accustomed to having anywhere from 50 to 150 gal. of water per person per day for all purposes, including bathing. After an enemy attack on our large cities, the individual will be very fortunate to have even a quart of water per day. The importance of having an adequate water supply, regardless of its potability, has not been sufficiently stressed if we are to keep people alive and to suppress dysentery through personal hygiene.

The control of epidemic disease will constitute an ever present challenge. As Ervin et al. have shown in the preceding paper, it is likely that the vectors of epidemic disease would survive radiation injury better than the human population. Eastern equine encephalitis, hepatitis, poliomyelitis and other endemic disease could easily reach epidemic proportions under these circumstances. The radiation might also cause new mutant forms of bacteria and viruses, some of which could be highly infective in the absence of immune defenses. Furthermore, the lessening of host resistance by radiation exposure, malnutrition, excessive fatigue and severe emotional stress would render human beings susceptible to bacteria or fungi that are not normally invasive. Poor hygienic conditions and inadequate medical facilities would contribute to the epidemic potential³⁶.

Among the new public-health problems will be disposal of the dead. Although this problem has not received extensive discussion in most articles dealing with the medical consequences of thermonuclear attack, the fact that there will be almost 3,000,000 bodies in Massachusetts alone suggests that a serious hazard to the health of the remaining public will exist. Documented experience with certain past disasters provides some comparative data; this will be examined in greater detail as an example of the gap between current planning and the actual problems to be faced.

As the Joint Congressional Committee on Atomic Energy has estimated, there will be approximately 2,800,000 dead in Massachusetts, including 2,100,000 in the Boston metropolitan area alone. These deaths will occur in two peaks; a calculation of the United States Army Mortuary Service suggests that, "due to the latent period of radio-injury, an upward curve in the death rate should be evident at two weeks post-attack, reach a maximum at four to six weeks and gradually subside during the following six months."³⁷

Prompt disposal of corpses will be essential for many reasons. Some of the public-health problems are obvious — for example, the need for control of epidemic disease and its vectors, flies and rodents. An equally important, though less apparent, reason is psychologic. There is evidence³⁸ that profound emo-

tional disorders and somatic manifestations follow the sight and smell of decomposing bodies

Explicit consideration has been given to this problem by health officers of the Office of Civil Defense Mobilization, and it is instructive to review their comments³⁷ In an attack in which the maximum weapon size is 20 megatons, they make the following observation:

it is logical to assume that most combustibles as well as the dead on the surface within a 10 to 11 mile radius of such a weapon burst will either be vaporized or incinerated through the resultant firestorm . . . intense radiation [will prevent] little more than heroic rescue in the 10 to 20 mile zone for several weeks. What cadavers might be recovered are those on the fringe of the blast area and upwind . . . The city is lost and rehabilitation is unthinkable until residual radioactivity has effaced itself. It may be far simpler to build new cities elsewhere and allow the dead to sleep in their memorial

The Boston area may thus become a mausoleum. The same authors note that "for obvious public health reasons, the demolished city must be fenced in or cordoned and placed under quarantine . . . there is little need to consider large-scale removal and disposal of the dead for the blast area."

In fringe areas, however, the problems and plans differ. Here, the same source suggests, "regular procedures of the peacetime mortuary service can be preserved, including collection, identification, record-keeping, religious rites and burial. Little need be changed from normal routine except adjustment to greater quantities of dead."

When the assumptions implied in this account are examined, however, it is difficult to accept it as a realistic prospect for Massachusetts. The description of highly efficient, mobile, smoothly operating burial services assumes the maintenance of transportation, the survival of adequate medical facilities at which the dying might congregate and the existence of a high degree of motivation and social organization. Residual levels of radioactivity will sharply limit the safe working time of mortuary teams. Finally, it must be noted that bodies exposed to the atmosphere will be covered with radioactive particles; disposal thus becomes a problem akin to the disposal of radioactive waste, which, even in peacetime, has required extensive technical equipment and special skills.

Data from official military sources on an earlier attempt to dispose of the bodies of wartime casualties may illuminate the magnitude of the postnuclear task. When the United States Army entered Manila in 1944, it faced the problem of burying 39,000 bodies of Japanese and Filipinos killed during the preceding week.³⁹ It was soon found that American troops were unable to withstand the psychologic aspects of this work, and "with a few exceptions, nausea, vomiting, and loss of appetite occurred after a few days." Local laborers were recruited at double pay to place the dead in large pits; nevertheless, the burial of these 39,000 dead, unhampered by such complications as radioactivity, required eight weeks

It is difficult to comprehend such consequences of the postulated attack as the existence of more than 2,000,000 dead, and it is distasteful to dwell at length on the technics of disposal.

The difficulties exemplify the unprecedented problems physicians and the public may face, and emphasize the fact that planning based primarily on previous disasters is inadequate to deal with the scope and magnitude of a thermonuclear attack.

ETHICAL PROBLEMS FOR THE PHYSICIAN

The postattack medical responsibilities that we have described will challenge the physician with alternatives that have profound ethical implications. There has been little discussion, however, of the specific ethical problems likely to occur.

For example, what is the physician's relative responsibility to himself, to his family, to his preattack patients, to acutely injured casualties and to any society that may remain? The individual questions that these conflicting demands raise are numerous. Does the physician remain at his post and neglect his family? Dr. Takashi Nagai,⁴⁰ a physician of Nagasaki, states in an autobiography:

I was an officer of the College First Aid and Rescue Committee, and I was so conscious of my position, so concerned about doing what I felt was expected of me as an officer of the Rescue Committee, that it was over two full days before I got to my home where my wife lay dead. I discharged my responsibility. What will be my reward in the eyes of [my children] when they are grown?

Does the physician seek shelter? The following recent examples illustrate the intensity of feeling on this issue. Dr. J. C. Cain,⁴¹ of the Mayo Clinic, states: "We must first protect ourselves . . . Remember that a sick or dead doctor is of no value to his country . . ." An article by Dr. G. C. Chalmers⁴² (a pseudonym) in *Medical Economics* asserts:

If my community is hit, my obligation as a doctor will be greater than ever. And if I'm to go on functioning as I should, not only must I survive, but my family as well. So I've built a blast shelter beneath my front yard . . . There are two precautions I've taken in case a nuclear catastrophe interrupts the normal enforcement of law and order. I've taught my family a special knock code as a signal for opening the shelter's thick, steel-plated door. And I've stocked the shelter with firearms and ammunition.

Dr. Eugene V. Parsonnett,⁴³ in a commentary on this article, strongly disagrees:

I suppose Dr. Chalmers plans to remain in his secure little shelter, having morally protected himself and his immediate family, having probably had to shoot to death some stray friends and acquaintances who may have wished to invade his sanctuary . . . I find it inconceivable that people who proudly bear the name of doctor can isolate themselves from family, friends, and society in this immoral kind of seclusion.

If the physician finds himself in an area high in radiation, does he leave the injured to secure his own safety? Is the neglect of his patients under these circumstances justifiable because many patients will profit from his help in other areas?

Other ethical problems are raised by the necessity for allocation of the inadequate supply of physicians and resources. When faced with hundreds of severely injured patients, how does the physician select those to be treated first? How does he choose between saving the lives of the few and easing the pain of the many? How does he allocate limited supplies of narcotics and analgesics?

In Hiroshima and Nagasaki, embryos exposed to radiation *in utero* were born with a great number of malformations.⁴⁴ If there is a place for therapeutic abortion after rubella in the first trimester, as seems widely accepted,⁴⁵ is there a place for mass abortion in the postattack period?

Finally, when analgesics are limited or unavailable, what is the physician's responsibility to the fatally injured or those with incurable disease? Which of his duties — the prolongation of life or the relief of pain — takes precedence? Regardless of his own professional training and convictions, the physician will daily face demands from patients for euthanasia on a scale and with an intensity unparalleled in his past experience.

Neither the Hippocratic Oath, the published codes of ethics of the American Medical Association nor the personal morality on which every physician relies provides an easy answer to these questions. In fact, a review of these trusted and cherished guides in the light of the problems of thermonuclear war makes them seem curiously and sadly obsolete, as if they reflected the human innocence of an earlier era.

DISCUSSION

The thermonuclear attack on the United States postulated by the Holifield Committee has been shown to lead to medical problems quantitatively greater and qualitatively different from any ever faced before. Although it might be feasible through sufficient economic investment and at the cost of public and physician regimentation to prepare a disaster plan to meet this postulated attack, such a plan would neither prevent the loss of millions of lives nor be effective against other types of attack. A change in any of the relevant variables such as the addition of a second strike or more bombs in a different distribution could nullify defenses prepared against the type of attack postulated by the Holifield Committee. There is, to our knowledge, no scientific basis for accurate prediction of the pattern of an enemy attack — except, perhaps, to note that the most unlikely pattern is the one against which an enemy knows that elaborate disaster plans have been prepared.

It is deeply misleading, therefore, to speak of any single disaster plan as a secure answer to the hazards of thermonuclear war. It is deeply misleading to focus on radiation shelters while ignoring the problems of blast and fire storm. And it is deeply misleading to propose patterns of medical treatment without examining the magnitude of the task or the availability of

resources in sufficient detail to reveal the nature of the anticipated problems.

To select a disaster plan is to make an uncertain prediction — in plainer words, to gamble on the nature of the attack. Physicians interested in rational consideration of any given medical plan for nuclear attack must recognize the nature of the vast gamble with human lives that selection of this plan would represent. Since it is impossible to prepare adequately for every possible type of nuclear attack the physician's responsibility goes beyond mere disaster planning. Physicians, charged with the responsibility for the lives of their patients and the health of their communities, must also explore a new area of preventive medicine, the prevention of thermonuclear war.

SUMMARY

The medical consequences in Massachusetts of a 1446-megaton thermonuclear attack on the United States are analyzed. Of 6560 physicians in the Boston metropolitan area, approximately 900 functioning physicians would remain; of the 9440 in the Commonwealth as a whole, 2400 would still be available. The resultant *injured-to-physician* ratio would be over 1000 to 1; the total patient-to-physician ratio would be much greater. Of 65,000 hospital beds in the Commonwealth, 10,000 would remain to serve their present occupants in addition to 2,000,000 injured. Medical supplies would be inadequate. Competition by survivors for the remaining facilities and supplies would be likely to raise new problems.

These quantitative increases in medical needs would lead inexorably to qualitative changes in the type of medicine practiced. Some of the problems to be expected in the care of the individual patient, in public-health measures and in decisions of an ethical nature are examined in detail. The implications for disaster planning are discussed.

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III. A Glossary of Radiation Terminology*

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THIS article consists of two parts. The first is a short glossary of three sets of terms concerned with the physics of radiation. The second discusses the concept of the range of numerical magnitudes that enter into an analysis of the nuclear-bomb problem.

The first set of definitions refers primarily to the source of the radiation, the second is related to the target of the radiation, and the third applies to problems of nuclear warfare and protection.

RADIATION TERMINOLOGY

Source of the Radiation

Isotope — one of the several masses that atoms of a particular chemical element may assume. The mass is determined by the sum of neutrons and protons in the nucleus. Some of these combinations are stable; others are unstable, and on a random basis change to a stable combination by splitting apart or emitting pieces of matter or bursts of energy. These unstable isotopes are called *radioisotopes*. A more precise designation is *radionuclide*, which emphasizes the point that the properties of the nucleus are critical.

Curie — the unit of the amount of radioactivity. Originally, it referred to 1 gm of radium, but it is now defined as an amount of a radioisotope in which 2.2×10^{12} atoms are disintegrating each minute.

Half-life — the time it takes a radioisotope to decrease to half its initial radioactivity. Although the disintegration is a random process, the half-life, as an average value, is fixed for each particular radioisotope. Half-lives range from millionths of a second to thousands of years.

Biologic half-life — the time required for half an element or chemical compound in the body to be excreted. Many biologic processes follow an exponential excretion curve similar to the decay of radioactivity. For a radioisotope, the *effective half-life* is the time for the radioactivity in the body to decrease to half its original value. It is a combination of biologic and physical half-lives, stressing the shorter.

Radioactive decay products — the "radiation" that results from a nuclear disintegration may be a combination of several types, each having a characteristic mass and electrical charge. *Gamma rays* are photons of electromagnetic energy, like light or x-rays, but of higher energy; they have neither mass nor charge. *Beta rays* are electrons, with positive or negative charge, moving at very high speeds. *Alpha rays* are positively charged helium nuclei, again moving at high speeds. Excess *neutrons* may be ejected from a nucleus. They are called *thermal neutrons* at low speeds and *fast neutrons* at high speeds. Neutrons have mass but no charge. When heavy nuclei break apart, as in fission, the pieces may be nuclei of other atoms. If these have high speeds they are also considered to be radiation. These *fission products* are

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themselves radioisotopes and undergo further radioactive decay.

Energy levels — radiation particles are also characterized by their energy content. The energy is usually expressed in terms of *electron volts*, *ev*, or *million electron volts*, *mev*. The latter is the energy an electron would acquire if, starting from rest, it were attracted to a positive electrode at a potential of a million volts. With gamma rays, the high energy is associated with high frequency. With particles, it is associated with high velocity.

Neutron activation — neutrons interact with matter by being absorbed in the nucleus of an atom. This changes the structure of the nucleus and usually results in an unstable configuration. For example, copper⁶³ absorbs a thermal neutron and becomes radioactive copper⁶⁴. In the process, the total mass will decrease slightly, the difference appearing as a high-energy gamma ray. Neutron activation may be used for trace-metal analysis or for bomb detonation.

Mass-energy relation — the basic physical principle from which the enormous energy of nuclear explosions derives is the Einstein relation $E = mc^2$, which equates changes in energy with changes in mass. The magnitudes and significance are discussed in a later section.

Target of Radiation

Roentgen — the fundamental unit of the quantity of gamma radiation or x-radiation. It is measured by the ionization, as a quantity of electricity, produced in a standard volume of air by the flux of radiation. It depends on the product of the number of photons in the flux and their energy.

Rad — this is the unit of absorbed energy, or *dose*, applicable to all types of radiations. It is defined as the absorption of 100 ergs of energy per gram of absorbing matter. For gamma rays of moderate energy the rad and roentgen are approximately equal, and the two terms are often loosely interchanged.

REM — the *roentgen-equivalent (man)* is the quantity of a particular type and energy of radiation that, when absorbed in man, produces the same effect as the absorption of 1 roentgen of gamma rays. The expression may also be used in terms of rads rather than roentgens. In a mixed radiation flux the total REM is the sum of the value for each species.

Relative biologic efficiency or **RBE**, for a given type and energy of radiation, is the dose of gamma rays necessary for the same biologic effect as a unit dose of the energy in question. Thus, $REM = RBE \times RAD$, if REM is in rads. The RBE is a function not only of the type of radiation and its energy but also of the biologic test that is used as a criterion. Thus, a value of RBE calculated from viability tests on dry yeast may be greatly different from the values obtained for leukemia induction in man. The RBE is roughly 1 for beta rays, 5 for thermal neutrons, 10 for fast neutrons, and 20 for alpha particles.

Linear energy transfer, or **LET**, is a property of radiation that is closely related to RBE. It is the space rate at which the particle loses energy as it moves through the absorbing medium. A large charged particle, such as an alpha particle, interacts much more vigorously with the atoms of the absorber than a highly penetrating gamma ray of the same energy. The alpha moves only a short distance before its energy is all absorbed and it stops, so that there is a high rate of energy transfer per unit length of travel. Since the biologic effects depend on energy absorption, the higher the LET, the greater the RBE in the particular region of the absorption.

Dose rate — the units discussed above were for total, or integrated dose, independent of the time over which the energy was absorbed. It is frequently important to observe the dose rate or the energy received per unit of time — for example, rads per hour. Such numbers must be examined carefully, for any units of time or of dose may be used. Electronic instruments usually measure dose rate. Dosimeters and film badges usually measure the total accumulated dose.

Nuclear Warfare and Protection

Fission weapon — this is a type of bomb in which the active element is at the heavy end of the periodic table — for example, uranium or plutonium. When the nucleus of one of these elements absorbs an extra neutron, it becomes drastically unbalanced and splits in half, yielding two atoms of elements in the middle of the periodic table. Several neutrons, other radiation and great thermal energy are also produced in the process.

Fusion — in this type of bomb, isotopes of hydrogen, deuterium (H^2) or tritium (H^3) combine to form helium, again with the release of enormous energy, and neutrons. This process is not self-starting and must be triggered by a fission bomb.

Surface burst — an explosion of a bomb at the surface of the earth. This produces maximum fallout at the expense of blast and thermal damage. An *air burst* above the surface, so that the fireball barely touches the earth, has minimum fallout but increased blast and thermal effect.

Yield — the explosive power of a bomb is expressed in terms of the number of tons of TNT that would have the same explosive effect. This is of the order of thousands of tons, KT, or millions, MT. Fission bombs are physically limited in size and hence in yield, but fusion bombs can, in principle, be made as large as desired. A ton of TNT is equivalent to 10^9 calories.

Fallout — the radioactive debris that results from a bomb explosion distinguishes nuclear weapons from an equivalent amount of conventional explosives. The amount of fallout depends upon the design of the weapon and the position of the explosion. The fission process itself produces radioisotopes in the middle of

the periodic table as an end product (listed in Table 1), whereas the fusion process does not. In either case the energetic particles released, in particular the neutrons, can activate the atoms of the bomb material as well as earth, air and other matter near the explosion. A burst near the earth vaporizes this matter,

TABLE 1 Some of the Principal Radioisotopes Produced by the Fission Process

NUCLIDE	HALF-LIFE	EMISSION	CRITICAL ORGAN
Lanthanum ¹⁴⁰	1.7 days	Beta; gamma	Gastrointestinal tract; liver
Molybdenum ⁹⁹	2.8 days	Beta; gamma	Kidney
Iodine ¹³¹	8.1 days	Beta; gamma	Thyroid gland
Barium ¹⁴⁰	12.8 days	Beta; gamma	Total body
Praseodymium ¹⁴³	13.7 days	Beta	Bone
Cerium ¹⁴¹	33.0 days	Beta; gamma	Liver
Niobium ⁹⁵	53.0 days	Beta	Bone
Strontium ⁸⁹	35.0 days	Beta; gamma	Total body
Ytterbium ⁹¹	61.0 days	Beta	Bone
Zirconium ⁹⁵	65.0 days	Beta; gamma	Total body
Cerium ¹⁴⁴	282.0 days	Beta; gamma	Bone
Ruthenium ¹⁰⁶	1.0 yr	Beta	Kidney
Strontium ⁹⁰	28.0 yr	Beta	Bone
Caesium ¹³⁷	30.0 yr	Beta; gamma	Muscle
Carbon ¹⁴	5568.0 yr	Beta	Total body
Technetium ⁹⁹	2×10^6 yr.	Beta	Kidney
Caesium ¹³⁵	3×10^8 yr.	Beta	Muscle
Iodine ¹²⁹	1.7×10^7 yr	Beta; gamma	Thyroid gland

which on condensing collects and carries down the radioactivity. There are three parts to the radiation from a bomb. The first, *immediate radiation*, is not fallout, but radiation generated in the bomb explosion process. The second, *immediate fallout*, is the heavier particles that descend to earth near the explosion within minutes or hours. The third, *long-term fallout*, consists of fine particles that are carried into the upper atmosphere and may take days to years to descend.

Blast — this is the mechanical effect in which the sudden thermal expansion of the air around the bomb builds up an enormous pressure, which spreads out as a shock-wave front at velocities greater than that of sound. The *overpressure* or excess of pressure above atmospheric in the wave front, usually tabulated in pounds per square inch (PSI), is a measure of the destructiveness of the blast. The high-pressure wave front is followed by a wave of partial vacuum, which is also destructive.

Absorption coefficient — the measure of the ability of a given material to absorb or stop radiation. The linear absorption coefficient is the stopping power per unit of thickness; dividing by the density gives the mass absorption coefficient, or stopping power per unit of mass. The numerical value is a function of the type and energy of the radiation as well as the atomic number and density of the absorber. As a rough rule the stopping power is proportional to the total mass (thickness \times density) of the shield and inversely proportional to the energy of the ray.

Half-thickness — this applies primarily to gamma radiation absorbed exponentially and is the thickness of shielding that reduces the intensity of the radiation

to half its initial value. Some typical values for shelter materials are given in Table 2. To reduce the intensity by a factor of 1000 requires 10 half-thicknesses of shield ($2^{10} = 1024$).

TABLE 2 Thickness of Materials Required to Reduce Radiation from Fallout by Half

MATERIAL	HALF-THICKNESS in
Wood	8.8
Water	4.8
Earth	3.3
Concrete	2.2
Steel	0.7
Lead	0.3

Inverse-square law — the intensity of ionizing radiation, like that of any other radiation, decreases inversely as the square of the distance from a point source. This use of distance is one of the most effective means of radiation protection, from an isolated source. It should be noted that radiation from a large, uniform plane source falls off with distance with a more complicated formula, more slowly than the inverse square.

Protection factor — this composite factor, including distance, shielding materials and type of radiation, describes how much a given shelter will reduce the dose rate from that existing outside. The range of values is about 2 for the first floor, 10 for the basement of a frame house, 250 for a basement shelter of the type recommended by the Office of Civilian Defense Mobilization to 1000 for an elaborate earth-concrete shelter.

LD₅₀ — this is the level of radiation dose at which half the exposed population will die. It is used as a criterion of dangerous dose levels. Other values, LD₂₀ or LD₈₀, at which 20 and 80 per cent respectively would die, are also used. Since this is a statistical value dependent on the type of organism, state of health of the population, type of radiation, exposure pattern and so forth, it should be used only as an order of magnitude, not as a certain number. Table 3 lists the biologic significance of a number of radiation levels. These are largely approximate values, or estimates based on scanty knowledge.

More complete glossaries and further discussions are contained in other publications.¹⁻⁶

ORDERS OF MAGNITUDE

It is difficult to comprehend the range of numerical magnitudes involved in the phenomena of radioactivity. This conceptual problem is the root of much confusion in evaluating the hazards of nuclear radiation. In ordinary life a range of numbers of 1 to 1,000,000, whether this is dollars in a budget, people in a community or cells in an organ, is readily appreciated, but somewhere above this range an intuitive grasp of magnitude is lost. For scientific work, however, larger numbers are needed, and the compact mathematical

notation of powers of 10 — for example, 1,000,000 = 10^6 — is used. Numbers such as 10^{100} , a number larger than all the particles in the entire universe, are easily written but have little comprehensibility.

In nuclear phenomena just such numbers are dealt

few powers of 10 up or down. This may be illustrated by specific numbers.

Certain isotopes emit positrons, or positive electrons. A positron interacts with a negative electron so that they both disappear as matter and are transformed into energy in the form of two gamma rays. The amount of this energy may be calculated by means of the mass-energy relation $E = mc^2$. The velocity of light, $c = 3 \times 10^{10}$ cm. per second, and the mass, m , of the single electron is 9×10^{-28} gm., so that the corresponding energy is 8×10^{-7} ergs, or, expressed in electron volts, 500,000 ev. A single such interaction can be detected with great certainty because these high-energy gamma rays may be considered to have a large information content per photon. That is to say, if the energy is absorbed by ionizing the molecules of a suitable detector, about 20,000 ion pairs are formed. This large number of ions appearing at the same time in a small space may be observed by a variety of instruments. Although in this sense, information-carrying capacity, the energy per gamma ray is large, it is very small in terms of ordinary energy levels. It would require 10^{15} of these per second, or the equivalent of 30,000 curies of radioactivity to light a 100-watt electric bulb.

This low total energy but high energy density is of particular significance in biologic effects because biologic materials are very highly organized chemical systems, many of which are primarily designed for information transmission. Ten thousand ion pairs may, through the mediation of free radicals, cause an appreciable destruction in such information centers as a cell nucleus.

The hazard of radiation derives from this high specific destructiveness of individual particles of radiation to biologic materials. Again, as part of the ambivalence of these numbers, it must be appreciated that there is an extremely low probability that if a ray is absorbed in the body it would affect a critical molecule. Even if it does destroy some critical molecules, the organism usually has many to spare. Unfortunately, although the probability is low, it is not known exactly how low. Human beings exist in a sea of background radiation that apparently does them little harm, but how much above background the radiation need go to have more effect is not known with any degree of certainty.

The probability that lung cancer will develop in a person smoking 20 cigarettes a day is much greater than the probability that leukemia will develop from exposure to 20 mr a day, and yet the latter causes much more public concern. Two reasons for this are the mysterious qualities of radiation and the fact that the low numbers of background radiation are mentally associated with the high numbers of bomb levels. The unfortunate fact that official statements have seemed to reverse the process, belittling the effects of bombs by identifying them with background levels,

TABLE 3. *Biologic Effects of Radiation **

DOSE RATE r/wk	TOTAL DOSE REM	DESCRIPTION	EFFECT
0.001		Cosmic rays at sea level	None detectable
0.002-0.005		Natural background	None detectable
0.001		Fallout from bomb tests	None detectable
0.01		Entire population — whole body	Maximum permissible for general population
0.1		Whole body after age of 18	Maximum permissible for radiation workers
0.02	50	Entire population — whole body	Statistical life-span shortening
0.04	60	Entire population — gonadal — to age of 30	Estimated doubling of mutation rate
0.3		Whole body	None detectable
1.5		Hands	None detectable
5.0	5000	Radium in bone (0.5 microcurie); 20 yr.	Marginal bone-tumor induction
7.0		Whole body — long term	Leukopenia
50.0		Whole body — long term	Carcinogenesis
	0.02-0.2	Chest examination — local	None detectable
	10-30	Gastrointestinal series — local	None detectable
	1.5-100	Teeth — local	None detectable
	5-250	Fluoroscopy — local	None detectable
	2-4	Whole body — <i>in utero</i>	Doubling of childhood cancer
	200	Single dose — to thyroid gland — in children	Marginal cancer induction
	300	Single dose — skin	Hair loss
	300-1000	Single dose — skin	Erythema
	1500	Single dose — eyes	Cataracts
	2000	Single dose — skin	Marginal cancer induction
	6000	Single dose — tumor	Lethal to tumor
	25	Single dose — whole body	Blood-cell changes
	50	Single dose — whole body	Marginal radiation sickness
	150	Single dose — whole body	Recoverable radiation sickness
	200	Single dose — whole body	Marginal radiation death
	450	Single dose — whole body	\approx LD ₅₀ in man
	900	Single dose — whole body	LD ₁₀₀ in man
	300	Single dose — ovaries	Sterility
	500	Single dose — testes	Sterility
	10^3 to 10^4	Single dose	Lethal to insects
	10^4 to 5×10^6	Single dose	Lethal to bacteria
	10^6 to 5×10^7	Single dose	Lethal to viruses
	2×10^8	Single dose	Radiation polymerization of plastics

*It should be noted that these values are largely approximate or estimates based on scanty information.

with. Events occurring in a single electron may be measured, or, at the other extreme, forces of sizes previously observed only in cosmic events may be generated. In this enormous gamut of numbers it is easy vastly to overrate or underrate hazards by sliding a

has only added to the public misunderstanding and uneasiness

What happens to the numbers when related to bombs? The mass of an electron is equivalent in energy to 8×10^{-14} watt seconds, but 1 gm. of mass would contain 1.1×10^{27} electrons, or 9×10^{13} watt seconds. This is an incomprehensibly large amount of energy, equivalent to exploding 20,000 tons of TNT.

Thus, in discussing energy levels between background radiation and 10-megaton bombs, a ratio of about $1:10^{30}$ must be examined. With the very delicate balance of physical and chemical conditions under which life exists, it is not surprising that there is anxiety in the minds of the public and the scientific community about how sure supposedly safe levels are.

Actually, of course, numbers can be assigned with a fair degree of precision to many levels of this energy range. The physical properties of matter, in particular, may be accurately measured. Unfortunately, the biologic effects of radiation are poorly understood and imperfectly measured. Is a level of 100 rads a hazard? Not in military terms, since it is not immediately lethal. Yet by peacetime standards, 0.1 rad is considered a high dose for a radiation worker.

The long-range ecologic and social significance of nuclear warfare is even more poorly understood and evaluated. Effects can be estimated only in terms of orders of magnitude.

An evaluation of the medical problems of nuclear warfare must therefore be made with this unfamiliar and approximate frame of reference in mind. There are two extreme views. Those who stress the long-term effects of low levels of radiation may rightly be criticized as worrying about dangers that are real but minor in the face of national security. On the other hand, those who are employed in civil defense and optimistically claim to be able to save X per cent of the population should know that the military potential exists, even at present, to destroy completely civilization if not all human existence.

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IV. Some Psychiatric and Social Aspects of the Defense-Shelter Program*

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DURING the past year a great deal of attention has been given to problems concerning the design, construction and utilization of shelters for protection against radioactive fallout. Although many opinions have been volunteered by both Government officials and laymen the overall effect has been to raise many new questions rather than to provide definitive answers for existing ones.

In this paper we shall attempt to bring our clinical and research experience to bear on some of the psychologic and social aspects of the current defense-shelter program to help our colleagues to advise their patients and plan for their own and their communities' well-being and perhaps to maintain survival of the human race.

This paper will be addressed to two major issues: the psychologic impact on the individual and community in planning for a defense-shelter program;

and the psychologic and social problems related to shelter utilization in the event of a nuclear holocaust.

We have purposely limited ourselves to a consideration of the shelter program. Although broader and more important social and psychologic considerations are involved in the stress of living in the nuclear age¹ many of the issues and tensions related to these problems have become focused upon a shelter program. Therefore, consideration of the psychology of shelter issues has relevance to the total problem of the behavior of man faced with major crisis situations.

SOME ISSUES IN SHELTER PLANNING

Although man has had experience with limited disasters such as war, tornadoes, earthquakes, floods and epidemics he has never been confronted with *planning* for a potential disaster on a global scale. Expert and near expert persons have suggested, however, that the current situation is similar to events experienced in the past, at least so far as the threat of war is concerned. To the extent that this point

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of view is applicable, we shall use data from studies of relatively limited disasters to help physicians understand present reactions and perhaps to predict future behavior. In particular we should like to emphasize the nature of the differences between acute, relatively short-term stress and chronic, prolonged stress. In medicine especially management and therapy of chronic illness, as contrasted to acute illness, has become a major problem. The nature of the cold war and even the hot war, for the survivors, demands that one take cognizance of the *chronic* as well as of the *acute* psychologic issues. Famine, slavery and plague might be more relevant historical social experiences to draw on rather than military conflicts of relatively limited duration.^{2,3}

Another aspect of the current situation, differentiating it from the past, is the marked urbanization of American society. There is a greater degree of interdependence than ever before. The social fabric has become more tightly woven, and one might question whether it can sustain *tears* as in the past. A consequence of this increased interdependence is that the needs and expectancies of man have become progressively dependent upon organized social activities. The era of the isolated frontiersman, caring for himself in a hostile environment, has been relegated to other continents. Thus, it is not surprising that the introduction of an *individual* shelter-building program evoked many hostile responses, ranging from "We won't build one" to "We'll build it and arm it." Others expressed fear, apathy and confusion when faced with a novel, ambiguous situation in which they alone were asked to be responsible for themselves. The data on individual and group responses that we present from relatively simple societies should be considered against the background of the highly organized urban society now prevalent in the United States.

The assessment of public response to the shelter-building program is important in the attempt to predict the behavior of people who eventually might use shelters. Since this assessment is not yet complete, it might be well to examine the views of two distinguished commentators on public affairs, Hanson Baldwin, military analyst of the *New York Times*, and Arthur Krock, political writer, of the same paper. Hanson Baldwin⁴ writes:

At the same time, a national shelter program could have two other seemingly disparate but concurrent effects of considerable political, psychological and military importance.

It could induce a mistaken sense of security in the American people, a Maginot-line psychology. It would at the same time emphasize in the American mind even more than in the past the dangers of radioactivity with a consequent hobbling and hampering effect upon any resumption of atmospheric nuclear testing by the United States and on our diplomacy in general.

In psychologic terms this mistaken sense of security at the *extreme* can lead either to undue apathy or

to unwarranted, impulsive behavior. A situation could develop that, at a time when appropriate and legitimate demands are made upon the individual to respond to danger, he may not be prepared to respond appropriately. The boy crying, "Wolf," is a well known tale.

Arthur Krock raises another issue. In discussing the Office of Civil and Defense Mobilization pamphlet,⁵ he states⁶:

The appeal of the pamphlet, despite the President's shift from his original encouragement of private shelter-building to constructions for community protection, nevertheless is principally a guide for the more fortunate — "fortunate" in having the money to build the private shelters so elaborately described, or in being sufficiently remote from a blast area to survive. But, hopefully, there seem to be numerous Americans who reject as immoral and degrading the booklet blueprints — for \$150 and up — of the cellars and the backyards their superior resources permit. And hopefully, too, there seem to be numerous Americans who get the opposite of comfort from the thought of survival because of a chance location.

The divisive aspects of the program, raising such issues as urban vs. rural, rich vs. poor, West vs. East and North vs. South, will undoubtedly demand major consideration. The emphasis on the selection of individuals and groups to be saved is particularly troublesome, whether the choice is made by self-selection or Government fiat. Margaret Mead,⁷ at a recent AAAS symposium in Denver, in 1961, suggested that an international program be developed through which certain recently married couples would be provided their honeymoon underground in a blast-proof shelter. By this scheme she argues that, at any given point in time, a reasonable breeding population would be protected from annihilation in the event of a nuclear attack. The effects on children of the shelter program can only be guessed at. Suggestions that, at the minimum, shelters be constructed for the school-age population, separating children from their families in the event of disaster, points up how deeply the program penetrates to the very foundations of society.

Physicians in particular, because of their special role in society, have to face the pressure of community-health responsibility, as well as personal responsibility to their families. The question whether special provision should be made for them and for other groups in similar roles has not been discussed openly. That a shelter program might include only persons with specified talents, but not all of them, emphasizes, at the very least, the importance of discussing the moral and ethical considerations included in a shelter program.

PROBLEMS RELATED TO SHELTER UTILIZATION

The two atomic bombs dropped on Hiroshima and Nagasaki represent the only actual experience that man has had with nuclear war. Since these cases are the only ones available, they deserve close clinical

scrutiny. These attacks were followed by massive psychologic and social consequences. Hachiya,⁸ a Japanese physician at Hiroshima, writes of events after the blast:

Parents, half crazy with grief, searched for their children. Husbands looked for their wives, and children for their parents. One poor woman, insane with anxiety, walked aimlessly here and there through the hospital calling her child's name.

What a weak fragile thing man is before the forces of destruction. After the flash the entire population had been reduced to a common level of physical and mental weakness. Those who were able walked silently towards the suburbs and distant hills, their spirits broken, their initiative gone. When asked whence they had come, they pointed to the city and said "that way"; and when asked where they were going, pointed away from the city and said "this way." They were so broken and confused that they moved and behaved like automatons.

Their reactions had astonished outsiders who reported with amazement the spectacle of long files of people holding stolidly to a narrow rough path, where close by was a smooth easy road going in the same direction. The outsiders could not grasp the fact that they were witnessing the exodus of a people who walked in the realm of dreams.

About Nagasaki, Nagai⁹ writes:

From that time . . . everybody seemed to be going crazy.

In general then, those who survived . . . were the people who ignored their friends crying out in extremis selfish, self-centered, guided by instinct and not civilization . . . and we know it, we who have survived.

Neither of the populations involved anticipated, nor were in any way prepared for, the havoc produced by nuclear weapons, although there were some preparations for and experience with conventional bombing. It is not only the accounts of stress and physical suffering resulting from these nuclear attacks that have impressed students of behavioral science, but the enormous impact of these events upon an entire nation, the majority of whose citizens were not directly exposed to the physical hazards of the attack itself.^{10,11}

What other sources of data are available by which to assess the psychologic and social response patterns of American communities following a nuclear attack? Though the data are not directly related to wartime conditions, we shall attempt to draw on the material available, recognizing the limitations involved.

Assuming that a period of warning would exist before a nuclear attack, what behavior might be anticipated during this period of threat of impending disaster? Ideally, where shelters existed, one would hope there would be an orderly procession to places of maximum security even though the interval before the attack was relatively short. The following account, quoted from a symposium on stress,¹² reveals the degree of variation of response during a fifteen-minute interval of warning before the destruction of a small town by a tornado.

Behavior during the 10 to 15 minutes under the threat varied in interesting ways. From the sample of our interviews one would judge that most of the men went home

for their wives, and most of the women tended to go home to their mothers. . . . The duration of the warning and threat periods determines in part how much survival action is possible. Many survivors in discussing these periods felt guilty that they had not done more or assumed more responsibility when something could have been done to help. Two people who showed depressive reactions during the remedial phases revealed that they had acted helplessly during the threat and impact phases. This behavior had mobilized guilt feelings — and also defenses against guilt.

An excellent appraisal of some of the factors involved in both individual and group response to disaster is given in a summary by Demerath¹³ of a symposium on adaptation to disaster. On the basis of study of a variety of disasters he concluded that the individual responses depend upon the destructive forces involved, particularly as they impinge on the social situation and cohesiveness of the society, the initial perception and behavior of the persons affected, the organizational structure and situations in the postdisaster phase.

Of particular interest, Demerath points out that social disorganization is greater as the disastrous force is more rapid, the period of forewarning briefer, the disaster agent less well known and less clearly perceived, the physical destructiveness greater and the length of time in which the force acts is greater. These are the probable conditions of nuclear attack.

In the design and construction of shelters primary attention has been given to radiation hazards. The problem of family and community shelters against blast and thermal effects of megaton bombs has yet to be worked out. Radiation hazards are unique when compared with the dangers sustained by civilian populations during World War II air raids. The dangers encountered during conventional bombings were, for the most part, associated with information that anyone could obtain through his sensory modalities during the actual period of impact. The usual air-raid warning systems informed the public when the attack was imminent and, in addition, announced when the threat of danger had passed. Even if no air-raid warning device was available, a person could judge the magnitude of danger via his auditory, visual and tactile modalities. One can neither hear, feel, touch, smell nor see radiation. Radiation-detection equipment, of course, would provide some information to help a person make reliable judgments of the degree and duration of fallout dangers, if he had the technical skills to use the equipment.

It has been shown in previous studies of disaster that threats or dangers that cannot be perceived by the senses can have tremendous psychologic impact. An example of such a situation was the mass poisoning by bootleg whisky (containing methyl alcohol) resulting in the death or blindness of nearly 50 people in Atlanta, Georgia.¹⁴ A large number of persons drank the contaminated whisky, but were, of course, unable to detect the presence of toxic substances by taste, color or odor; furthermore, there was a period

of latency between ingestion and the appearance of toxic effects. As the number of deaths and the incidence of blindness increased in the community, mounting publicity and official warnings were issued to the population. A report on the consequent behavior states:

From the 433 clinic sheets examined, of every ten who were treated in the Emergency Clinic of Grady Hospital, four were negative to the test which the hospital was using. Two frankly said, "Doctor, I do not know whether I had it or not. Please check me over." And only four apparently justified treatment in the eyes of the medical staff

It seems reasonable to conclude that many individuals in a population exposed to a danger undetectable by sight, sound, touch or taste will respond with symptoms even though they are not actually injured, or even exposed to danger. Even if shelters do, in fact, provide protection against fallout, many individuals may emerge with "symptoms" that may hamper or cripple their effectiveness

Another type of situation that may be employed to help predict the behavior of individuals and groups subjected to prolonged involuntary isolation in a physically hostile environment is that of nuclear-powered submarines. The crews of these submarines are confined for long periods in restricted quarters and are in danger of potential exposure to a radiation hazard during the course of their cruise. Psychologic studies have been made on the responses of such crews.¹⁵ Although these studies are not generally available, published statements emphasize the fact that major efforts have been made to provide the crews of nuclear vessels with a maximum degree of comfort and security

The problems of isolation for long periods, a condition that would exist in a fallout-shelter environment, may be better understood from studies concerned with the effects of sensory deprivation, isolation and confinement on man.¹⁶ Anecdotal reports by explorers and shipwrecked sailors suggest that a variety of aberrant behavior may be evoked by sustained isolation in an environment that is potentially physically hazardous.¹⁷ The reports of Admiral Byrd¹⁸ during his isolation in a shelter designed to protect him against the forces of the Antarctic climate attest to the fact that prolonged isolation may lead to symptoms of oppression and depression, as well as difficulties in cognition and perception. Studies from hospitals¹⁹ have shown that isolation superimposed on illness, even though physical care is adequate, can result in severe abnormalities of behavior. Experimental studies²⁰ have shown that both short-term and long-term isolation and confinement can have a variety of behavioral consequences ranging from anxiety and the appearance of somatic complaints to symptoms of hallucinations and delusional thinking. It should be pointed out that the isolation imposed in experimental studies is a relatively mild stress because the subject may escape from his iso-

lated environment at any time by merely requesting release. This possibility of escape from a bomb shelter would not exist, and the degree of psychologic decompensation can be expected to be more pronounced than in experimental studies. On the other hand, in the actual life situation, appropriate adaptive responses ensuring survival would also be called forth. Thus, the assessment of any individual response is extremely difficult to predict purely from laboratory study.

If the shelter-building program is predicated on individual family shelters, information on the confinement of small family groups becomes relevant. It should be obvious that only under the most fortuitous circumstances would an entire urban family be expected to be in the shelter together during and after an attack. Families in small towns and rural areas might be expected to be together. Systematic studies of families forced to live under conditions of isolation have been few in number and generally without pretense of scientific rigor. Vernon²¹ studied one family, consisting of parents and 3 children, 2 of preschool and 1 of grammar-school age. They remained in a shelter for two weeks. The psychologic effects, he reports, were minimal, though there were behavioral problems related to the high heat and humidity within the shelter. It seems apparent that for self-selected volunteers, under conditions where they know relief from confinement is possible at any time, and no disaster has occurred, short-term stays of up to fourteen days are feasible. Other anecdotal reports of families living in shelters have been less optimistic. Obviously, there are wide differences in behavior, depending on the type of family constellation and adaptability to stress. Enforced social contact will tend to heighten whatever adaptive and maladaptive mechanisms are usually employed. Perhaps one of the most beneficial by-products of the defense-shelter problem could be more imaginative, intensive studies of family interaction under conditions of isolation.

Other sources of information on the response of urban family groups to enforced isolation are the reports of Jews in hiding in Nazi Europe. The documentation regarding the plight of these Jews, some of whom remained in hiding for years, is usually in the form of diaries, or reconstruction of events after rescue. The prototype of many such accounts is the *Diary of Anne Frank*,²² which reveals some of the potential for adaptive and maladaptive behavior in the setting of family and relatively close friends. Another book deals with the problem of the few survivors of the Warsaw Ghetto,²³ where individuals of separated families, including children and elderly people, remained underground for several months. This book is revealing for the generation of despair, depression, homicide and suicide attendant upon massive threat. However, in these

groups the danger was one that was available to the senses, devastating but corporeal. The problem, related to unseen, unfelt radiation, would undoubtedly be somewhat different.

Although there have been several well documented studies concerned with the effects of isolation on the individual in confined circumstances, there have been only a few laboratory studies concerned with group behavior under conditions of confinement. One study, designed specifically to test the effects of shelter living on a self-selected group of men, women and children, members of several families ranging in age from seven to seventy-two years, was conducted by the American Institute for Research.²⁴ The study consisted of 4 groups of 30 individuals each. Three groups remained in a simulated shelter for one week, and 1 group remained for two weeks. The major experimental variables were temperature and the presence or absence of a designated and trained shelter manager.

The chief findings were that the presence of a manager increased overall adjustment to shelter living and that there was reasonable tolerance of shelter temperatures up to 85°F. The absence of adequate leadership led to a breakdown in established standards of conduct, with such behavior as teen-age petting, gambling and use of vulgar language, all of which were particularly disturbing to the older members of the group. According to the findings, adequate leadership was able to cope with such problems as sleeping difficulties, sexual tensions, hostility to other shelter occupants, claustrophobic reactions and depression. It is not unexpected that such psychologic reactions should occur; however, it would have been desirable for the authors to have cited in greater detail the frequency and severity of such reactions.

The maximum tolerated temperature appeared to be 85°F. Regarding the type of discomfort reported, humidity combined with temperature rated second, being exceeded only by complaints of lack of water. Other elements that made for discomfort, in order of frequency of mention, were lack of exercise, crowding, dirt, sleeping difficulties, noise, physical symptoms, food and the behavior of others. Agitation and tension were greatest immediately after shelter entry and before release. The desire to leave mounted steadily throughout the confinement period. Only 1 subject, a self-designated leader of a group, had to be removed from the shelter on the sixth day at the request of several mothers who "feared for the safety of their children." It is evident from the description of his behavior that he suffered a paranoid reaction. He appeared to recover his preshelter level of adjustment within hours after being removed from the shelter. The remainder of the group completed the experimental confinement period.

The authors of this study conclude that the major problem areas in an adequate shelter program are

competent management, provision for sleep and minimization of conflict of social, moral and ethical values. They recognize the following limitations in presenting their findings: all the subjects in the study were sympathetic to the shelter program; it was a *simulated* shelter situation; and the termination date of the stay was known to all members of the group before shelter entry.

Other studies of groups, conducted by the West German Government,²⁵ the Swedish Government²⁶ and the United States Navy²⁷ on group living have less relevance because either military men or prison volunteers were used as subjects. One finding that is important for this discussion was as follows:

During the first 3 days, about three-fourths of the testees stated that they felt well-balanced or cheerful; during the remaining 2 days, only half of them made that statement. The remaining testees stated that they were quite depressed or restless, cross or edgy. Two of them complained of agoraphobia and felt that the constant co-existence amid the group was unbearable.

The performance of meaningful tasks appeared to alleviate some of the feelings of anxiety evidenced in this study, a finding corroborated by polar studies.²⁸

The major finding in this survey of studies in the problem of shelter habitation is the remarkable lack of well controlled hypothesis-testing research. The physician recognizes that before any therapeutic regimen or public-health program is instituted, a series of investigative procedures that utilize the best available scientific methods are necessary. Although the available solutions to the problems of nuclear attack are dwarfed by the magnitude of the problems posed, it is apparent that a minimum amount of systematic research in the area of human behavior is essential before the solution of shelter construction is embarked upon.

DISCUSSION

Although we have outlined some of the psychologic and social problems of shelter utilization, we are aware that we have only peeked into a Pandora's Box of psychologic difficulties involved with the atavistic return of man and his tribe to the recesses of the earth. It is one matter for man to have evolved from living deep in a Paleolithic cave to the city apartment or the garden home in the suburb, but an entirely different matter to consider whether he can successfully return to the cave. The question of whether an abrupt return along this evolutionary path is psychologically possible will hopefully remain a meta-physical issue.

Up to this point we have raised many questions, and it is appropriate that we suggest approaches to their solution that may have reasonable opportunity for success. It should be apparent that *prevention* of the need for a shelter program would be the best single approach to the social and psychologic issues accompanying such a program. Like our public-health

colleagues, who focus their attention on the malaria-producing swamp rather than on treatment of the individual patient, we should attempt to define the sources of the nuclear epidemic that we are now experiencing and thus to control it. The physician can accomplish this in part by fully assuming his professional responsibility for the preservation of human life. This emphasis on the biologic approach may be effective in bringing into proper perspective the implications of such strategic concepts as "over-kill" and the "toleration of 120,000,000 deaths" in a first-strike nuclear raid.

Assuming that the nuclear epidemic will continue and that a workable shelter program is physically and economically possible, the question arises of how it can function if the psychologic needs of the individual and the group are considered. The evidence that we have presented indicates that for an untrained, unselected urban population, a shelter permitting the group to carry on some of its usual activities would probably maximize adaptive behavior. It would permit some of the same type of differentiation of function that exists in preshelter society. Physical and psychologic illnesses, which would almost certainly exist in some members of the group, would not appreciably interfere with the survival of the group. In family shelters dysfunction or death of a single important member might mean disaster for the entire family. However, in either type of shelter situation, dissolution of the family unit would unquestionably have severe psychologic consequences. Since some disruption of the family unit in a nuclear disaster is almost certain, community shelters that permit some family members to remain together would probably be the most desirable alternative.

One of the necessities in planning for a shelter program is reasonably adequate information about the magnitude of nuclear danger that confronts society. It appears that responsible Government officials have been most cautious in communicating this information to the public for fear of arousing anxiety or apathy. Thus, the Office of Civil Defense booklet⁶ circulated recently gives survival information based on fallout effects of 5-megaton bombs, whereas blast, thermal and fallout effects of 20-megaton bomb attacks are more generally discussed in the official Holifield Committee hearings.²⁹ As physicians we may sympathize with this problem, since similar problems arise, for example, in deciding how much information a physician should communicate to a patient with a terminal cancer. As is well known, physicians take different views, which embrace a spectrum of positions ranging from that of telling the patient as little as possible to those who say that the patient must be told all. As psychiatrists we recognize that such communication must be tailored to meet the needs of a given patient. Although this analogy has obvious limitations there are many who

see the present nuclear arms race as a type of malignant lesion encroaching upon the body politic, with the ever present possibility of metastatic dissemination of nuclear weapons.

Although the question of how much information should be communicated to the public is a difficult one, there is no question that the communication of misinformation or the lack of information is frequently more dangerous. As physicians we know that misinformation frequently leads to impairment of reality testing and results in maladaptive responses. Patients utilize diagnostic information according to their individual needs. Thus, some patients with cancer will deny its presence even when told of it and, by this denial, may bring about a situation where no corrective therapy is possible. On the other hand, there are patients who insist upon drastic and potentially life-shortening therapies. Still others turn to various forms of quackery. A very small proportion, through hopelessness and despondency, yield to self-destructive tendencies. Analogous to the last group are those who seek therapy for the cancer of nuclear threat through massive doses of radiation. As physicians we attempt to use judgment in adapting the type of therapy to the individual patient. We know that many can face the knowledge of life-threatening situations with a high degree of adaptive behavior, courage and hope. Most people do seek out knowledge, make reasonable judgments and take action that is beneficial to themselves, their families and their community.

SUMMARY AND CONCLUSIONS

We have attempted in this paper to delineate the nature of the situation that confronts man today in planning for his psychologic and social survival under the threat of and in the event of a nuclear holocaust. We have quoted opinion and cited some anecdotal and laboratory observations that may be relevant to an understanding of these problems. We have suggested possible approaches physicians can make to some of these problems.

It is obvious that we have raised many more questions than we have answered. It should be apparent that the psychologic and social problems raised in planning a defense-shelter program are of a magnitude and complexity that make it advisable to concentrate massive efforts on *eliminating the need* for such a program. Physicians, as one group of professionals concerned with the alleviation of suffering and the preservation of human life, are urged to examine the issues and take specific actions that will enable them most effectively to help in the achievement of these fundamental aims.

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